Oral Health in America

Advances and **Challenges**

Oral Health in America:

Advances and Challenges

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Introductory Message

Two decades ago, Surgeon General David Satcher released a major report examining the nation's oral health. This first-time report was considered a public health milestone, emphatic in its assertion that oral health was inextricably linked to overall health and well-being. It also took great care to illuminate the stark disparities and inequities that exist with regard to disease burden and accessing and affording oral health care in this country.

Seventeen years after its publication, Dr. Satcher, along with Dr. Joyce H. Nottingham, partially assessed the progress made since the 2000 report, publishing a paper in the American Journal of Public Health. Based on emerging data, they offered the American people some early perspective in the form of good and bad news. The good, they proffered, was that "our understanding of oral diseases continues to grow." And the bad? Too many Americans still suffered from diseases of the mouth, the majority of which were related to oral health disparities.

That piece, it turns out, was a fitting, if unintended, prologue to this report, which is a sweeping, comprehensive effort to tell the whole story of the state of oral health in America. And, as the title suggests, in the last 20 years, there has been progress in some areas, and in others, a collective realization that far more work needs to be done.

It is our hope and intent that this report will serve as the foundation for that work. Work that—in light of a global pandemic that so plainly shows that the mouth is the gateway to the rest of the body and that those individuals and communities most affected in the pandemic are the same as those who so badly need oral health care—is perhaps more important than it has ever been. As this report describes, there is already promising research completed and underway to better understand the role the oral cavity plays with regard to SARS-CoV-2 transmission and infection. Research, innovation, and new technologies must continue to shine light into the dark corners of this global public health crisis.

This report also sheds new light on how people in the United States experience oral health differently, based on their age, economic status, and a number of other social and commercial determinants. And, while good oral health is vitally important to the health and well-being of everyone, the report shows that oral health care has not been, and is not, equitably available across America.

Undoubtedly, you will see parallels to the 2000 report. As that document did, NIH, with the support of the Surgeon General, is also putting forth "calls to action" and specific recommendations on how to improve the oral health of our nation. In the following pages, we at the National Institute of Dental and Craniofacial Research, in concert with a vast array of editors and contributors, have painstakingly connected the dots that make up the constellation of amazing oral health research that has occurred since release of the first report at the turn of the century. With the utmost humility, the research team asked: "What have we learned?"

This report is their answer.

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Oral Health in America: Advances and Challenges
Introduction

Introduction

This report, facilitated by the National Institutes of Health, and titled *Oral Health in America: Advances and Challenges*, is only the second comprehensive document on this topic and the first in more than 20 years. Since the publication in 2000 of *Oral Health in America: A Report of the Surgeon General* under the auspices of Surgeon General David Satcher (U.S. Department of Health and Human Services 2000), our knowledge of oral health and our understanding of both the etiology and epidemiology of oral diseases has increased more dramatically than at any comparable time period. Today, most of us understand that oral health is important to overall health, and we have begun to grapple with the challenge of improving the oral health of the nation. We now know that achieving this goal requires understanding the deep disparities in the experience of disease by different population groups and the systemic inequities in access to care that inevitably accompany those disparities. Still, the job is far from finished.

In 2018, the National Institute of Dental and Craniofacial Research (NIDCR) was asked by then Surgeon General Jerome Adams to lead the development of a new report on oral health in America (U.S. Department of Health and Human Services 2018). In requesting this report, the Surgeon General called for an update on the status of oral health and its relationship to overall health. He asked that attention be given to differences across the lifespan and to the impact of a broad range of social influences, addressing both challenges and progress in achieving oral health for all. This report began with that structure, and subsequently was both impeded and stimulated in new ways by the challenges that emerged in the form of the COVID-19 pandemic. The ongoing global health crisis has impacted both oral health and the practice of dentistry in ways we are still working to assess, and those changes have required a recasting of some of the work that was completed in the early stages of preparing this report. Realizing the urgency of making this vast trove of new information and synthesized knowledge available to the scientific and professional communities, as well as to the general public, the NIDCR elected to adopt the report and move it as quickly as possible to publication.

Although this report reviews many of the same topics that were discussed in the 2000 Surgeon General's report and assesses our progress since that time, it also describes areas where previously identified problems persist and where new challenges have arisen. The report highlights the most promising new approaches for improving oral health and for ensuring that all Americans enjoy its benefits. Finally, this work describes the many ways in which we have come to understand that oral health adds value to our lives; supports our general physical health; and contributes to the public well-being, security, and prosperity of our nation.

A Look Back on Oral Health

A look back at the 2000 Surgeon General's report provides an important framework for understanding both the progress that has been made and the challenges that remain in seeking oral health for all. That report comprehensively assessed the status of oral health in the United States, with attention to the burden of specific oral and craniofacial diseases and disorders across population groups, as well as to opportunities and challenges related to the prevention of those health problems. In doing this, it brought new levels of awareness regarding the impact of oral disease in the United States and increased scientific focus on this vital area of our public health.

The single most important message of the 2000 report was its strong statement that oral health means more than healthy teeth; rather, the report concluded, “the mouth is the center of vital tissues and functions that are critical to total health and well-being across the lifespan.” In 2000, this was a relatively new idea, and many people—even health professionals—knew little of the relationships between oral health and general health; consequently, the importance of oral health had long been misunderstood.

The report also spelled out the many safe and effective measures that can be taken to improve oral health and prevent disease, again linking oral health to overall health. It made clear that many well-known risk factors for chronic disease, including tobacco use and unhealthy dietary practices, such as high sugar consumption, also affect oral health. Finally, it showed that addressing oral health can help to mitigate the total impact of some other health issues.

Major Findings of the 2000 Report. As is the case here, the 2000 Surgeon General’s Report on Oral Health was based on the available objective evidence as reflected in the scientific literature, including reviews of published research and the full range of investigations—from randomized controlled trials to clinical reports and case studies. In addition to relevant laboratory research, both clinical and community-based research informed the work, as did information gleaned from carefully developed and maintained national and state databases. The following important points were made in the 2000 report:

1. A healthy mouth is essential to general health and well-being, providing through the mucosal immune system a main line of defense against pathogens and toxins, and through salivary components, protection and maintenance of oral tissues.
2. Microbial infections are the primary cause of the most prevalent oral diseases, and the etiology and pathogenesis of these diseases and disorders are complex. Both inherited and congenital conditions of the craniofacial complex affect millions, often causing pain that reduces quality of life. The very young and very old are especially vulnerable, and use of various substances also can contribute to susceptibility to diseases and disorders. Although major improvements in oral health have occurred in the U.S. population over the last 50 years, profound disparities, defined on the basis of race/ethnicity, sex, and income, persist.
3. Many systemic diseases and conditions, as well as treatments for such conditions, have important oral manifestations, and conversely, oral infections may place many individuals at greater risk for morbidity from a variety of causes. Oral and craniofacial diseases and their treatments can compromise function, as well as self-esteem and other aspects of mental health; these manifestations create a burden on society in terms of lost productivity, as well as direct cost.
4. Many effective approaches to disease prevention and oral health promotion are available, and these may require community action as well as individual self-care behaviors and professional care. The limited availability of insurance for dental care is a major barrier to oral health, and the maldistribution of dental professionals, as reflected in the number of geographic areas lacking adequate oral health services, contributes to this access problem.
5. The complex interplay of biology, physical and socioeconomic environment, personal behaviors and lifestyle, and the organization of health care work together to determine the level of oral health.

The 2000 report provided detailed descriptions of challenges related to these aspects of oral health and identified the research that is needed to point us to solutions. A framework for action that would use this information to improve population oral health was described, utilizing strategies for changing the perceptions of three critical audiences: the public, policymakers, and health care providers.

2003 Call to Action. After publication of the 2000 report, the Office of the Surgeon General issued an open invitation to public- and private-sector organizations to participate in a meeting with the goal of creating a strategic plan to address critical issues that had been raised in the report. The resulting National Call to Action to Promote Oral Health (U.S. Department of Health and Human Services 2003) was issued by then Surgeon General Richard A. Carmona and drew on input from stakeholders across the country.

The vision of that Call to Action was "to advance the general health and well-being of Americans by creating critical partnerships at all levels of society to engage in programs to promote oral health and prevent disease." The goals were straightforward: to promote oral health, to improve quality of life, and to eliminate oral health disparities. Finally, five actions within the Call to Action spelled out more specific objectives and clarified the problems and barriers that have stood in the way of achieving better oral health. These were: (1) change perceptions of oral health; (2) overcome barriers by replicating effective programs and proven efforts; (3) build the science base and accelerate science transfer; (4) increase oral health workforce diversity, capacity, and flexibility; and (5) increase collaborations. For each of these action steps, there were more detailed descriptions of innovative approaches or strategies that could be used to accelerate their accomplishment. These strategies and approaches were broadly shared and resulted in the development of new programs and policies supporting oral health.

The impact of the 2000 report on the advancement and application of knowledge has been prodigious. For many basic and clinical researchers, the report stood as an important guide to the most critical questions that needed to be addressed in relation to oral health. Consequently, it served as an important stimulus for expanding the scientific evidence base. It encouraged new directions in research and new methods, often involving the use of multidisciplinary approaches and innovative strategies for understanding the newly articulated complexity of oral health within the context of overall health.

The 2000 Surgeon General's Report on Oral Health in America stimulated consideration of collaborations in the context of health services delivery as well as scientific research, and it called our attention to the diversity of social contexts within which we experience and address oral health. This led to new attention on the increased need for diversity, capacity, and flexibility in the oral health workplace and across the workforce. These changes in knowledge, practice, and perspectives ushered in a new era for oral health, but in the intervening years, the world has changed. We know more, and we are doing a better job of achieving the benefits of oral health, but we also are confronting new challenges and opportunities.

Need for a New Report

Although the importance of the 2000 Surgeon General's Report on Oral Health in America has been indisputable, in recent years it has been noted that not all of the challenges outlined in that report have been met. The need for a reassessment of the status of oral health in this country has emerged as a priority. We know that there have been changes in the experience of dental disease. For example, while the overall rates of dental caries (tooth decay) have decreased in young children, this improvement has not been achieved equally for all groups of these children. When we examine the dental caries experience across the lifespan and our efforts at controlling it, such as the progress in reducing caries prevalence or addressing untreated tooth decay, any benefit gained has generally been uneven across key demographic indicators. It is time to directly assess the causes of these disparities and take action to address the inequities.

Since 2000, our knowledge of the impact of poor oral health from a global perspective also has changed. We now know that oral diseases and related conditions are highly prevalent worldwide, with dental caries the most prevalent health condition globally. More specifically, the 2016 Global Burden of Disease Study reported that among the 328 health-related conditions assessed, 4 among the top 30 prevalent diseases are related to oral health: untreated dental caries in adult teeth (#1), severe periodontitis (#11), untreated dental caries in baby teeth (#17), and severe or complete tooth loss (#29) (GBD 2016 Disease and Injury Incidence and Prevalence Collaborators 2017). These rankings reflect the oral disease experiences of about 3.5 billion people worldwide.

The economic costs of oral health care continue to be substantial. The direct and indirect costs of dental diseases globally (excluding oral and pharyngeal cancers) accounted for approximately $545 billion (USD) in 2015 (Righolt et al. 2018). In 2019, dental expenditures in the U.S. totaled $143.2 billion (Centers for Medicare & Medicaid Services 2020), representing 4% of the total health care spending in the nation (Hartman et al. 2020). In 2000, total U.S. health care spending was approaching $1.4 trillion, with 4.5% accounted for by dental care expenditures. Over the last 20 years, as total health care spending has increased to nearly $3.8 trillion, the proportion attributed to total dental expenditures has declined from 4.5% to 3.7%, and out-of-pocket dental expenditures have remained more than 40% of all dental care spending during this period (Centers for Medicare & Medicaid Services 2020).

There is no question that our world has changed since 2000, and the context for oral health also has changed. The landscape for oral health in our country has been affected by rapidly increasing changes in the demographic profile of the United States and by such extreme health-impacting problems as the epidemic of opioid addiction, as well as the more recent threats of COVID-19 and the potential for other such pandemics. Oral health also has been affected by advances in technology and scientific knowledge, and by greater recognition of both cultural and social determinants of health and the structural barriers that create inequities in access to health care. While these advances suggest new possibilities in treatment and prevention, they also challenge our ability to deliver on those promises. From the perspective of individuals needing care, changes reflected by the sharply rising costs of dental care and the lack of affordable insurance—particularly among adults—have become obstacles that lead only to hard choices. Clearly, finding ways to meet the health care needs of a nation requires attention both to costs and to policies that can address those costs.

Population Considerations. Among the most striking changes noted and addressed in the current report are those related to our changing population. The 2000 report on oral health identified a number of disparities, especially among socioeconomic groups, and unfortunately, these have persisted. Many Americans living in chronic poverty and those from certain racial and ethnic minority groups not only experience poorer oral health than the general population, but they also continue to live with poorer oral health as they grow older. Consequently, although many oral diseases are highly preventable, or treatment is generally available, the related oral health disparities have become intransigent. The U.S. population now is more diverse than ever in terms of racial, ethnic, religious, and other differences that describe us socially and culturally, and this diversity is further expanded by newly arriving immigrant groups in our communities. Issues of acculturation and health literacy that represent different perspectives and orientations to health care are becoming more complex, requiring new approaches to meeting oral health care needs. All such aspects of the growing diversity in our population, along with the recent recognition of systemic racism within an array of public services, has prompted an acknowledgment that such biases are embedded in health care, too. This realization no doubt will lead to new efforts to address the more subtle, but insidious, negative impact of these phenomena on oral health.

Demographic data demonstrate clearly that the United States is an aging nation. By 2035, there will be more adults over 65 than there will be youth in our country (U.S. Census Bureau 2018). The health care requirements of older adults, including their needs for oral health care services, are different from those of younger people. Older Americans are keeping more of their teeth and are benefiting from advances in treatment that help to replace teeth lost to oral diseases. Nonetheless, accessing oral health services can be challenging for many older Americans, in part because most dental insurance is employer-based and because dental care has not been deemed an essential benefit within Medicare.

The aging of America is an important concern that will affect all of us. Over the next 2 decades, as the number of older adults surpasses that of young people in the United States, the proportion of working-age adults will decline. This shift, in turn, increases what demographers refer to as the "dependency ratio," or the number of those receiving services in relation to those actively paying for them through various taxes and withholding procedures. As a result, the existing mechanisms used to fund our health care system, including oral health services, will be severely stressed and will touch most Americans, regardless of age.

Social determinant considerations. Over the past 20 years, we have learned the importance of societal factors now recognized as influencing health and well-being. In 2003, the Institute of Medicine reported that even among individuals with access to care, there were significant racial/ethnic disparities in health resulting from social and economic inequality, structural discrimination, and a fragmented health care system (Institute of Medicine 2003). Today, we understand more about the many societal factors that influence oral disease, and how they affect some groups of people more than others, often converting these health disparities into what can only be described as health and social inequities.

Research also is exploring how both unconscious biases and overt racism affect health and health care in the context of complex societal relationships. Systemic racism, which has been embedded in our social structures historically, differentially harms people of color and limits their opportunities. As our country becomes more diverse, the success with which we struggle to overcome biases, discrimination, and social isolation will largely determine our ability to overcome oral health inequities. A recent Surgeon General's Report on Community Health and Economic Prosperity acknowledged this influence "of structural, cultural, and interpersonal racism and bias on health, wealth, and well-being" (U.S. Department of Health and Human Services 2021). These racial concerns that permeate U.S. society broadly and unmistakably contribute to oral health disparities and inequities as well.

The lives and health care needs of our changing population suggest that we may need to consider new ways of delivering services. The training of health professionals, too, must change in order to accommodate these needs. While we have seen some increases in the diversity of those entering oral health professions, the social and demographic profile of the workforce still does not reflect the profile of the population as a whole. The structure of the workforce, too, is changing. Providers of oral health care now include new professional groups, such as dental therapists and community oral health coordinators, who increasingly represent essential health care resources for underserved populations. Traditional medical care providers are taking a greater interest in oral health and are contributing in important ways. As we see new providers entering the arena, we also are seeing oral health care move out of the dentist's office and into more frequently visited locations, such as schools and medical clinics. Although teledentistry was slowly being recognized as a useful tool for some oral health needs, especially in rural communities, it has been given a substantial boost with the social distancing restrictions imposed on us by the recent COVID-19 pandemic.

Finally, the pandemic has reminded us that the burden of disease is global. Clearly, the health concerns of one country do not exist in isolation from those of other countries, and the problems of disease and the responses to those problems are not experienced or addressed in isolation. In discussing the impact of a changing population on oral health, therefore, it is important to acknowledge global population health, as well as the global economy and the global scientific community, because all of these can affect our own experiences with oral health.

Emerging Public Health Threats. Oral health in the United States today is affected in several ways that were not so visible on the public health landscape 20 years ago. In addition to the impact of COVID-19 on the ability of individuals to receive what has been considered routine oral health care, we cannot ignore that the group disparities so painfully highlighted by the COVID-19 pandemic mirror those identified in oral health. The urgency of addressing the root causes of these inequities becomes more salient with the observation of these overlapping patterns.

We are acutely aware, too, of other health threats that are inextricably related to oral health. More Americans than ever before are reporting mental illness, and millions also experience dependence on or abuse of illicit drugs. These experiences can and do affect oral health—both directly, in terms of impact on oral tissues, and behaviorally, when oral health is neglected or there is difficulty accessing professional care. Dentistry has been implicated in the opioid epidemic because the use of these medications for alleviation of dental pain was common practice for many years. These evolving situations have led both to changes in approaches for treatment of dental pain and to a realization of the need for oral health professionals to be well educated about the implications of mental illness and substance use.

We have long known that tobacco affects oral tissues and is directly implicated in oral cancer as well as periodontal disease. The use of e-cigarettes for tobacco products and marijuana, especially among youth and young adults, represents a new threat to oral health that scientists are working to fully understand. Another newer public health threat has emerged in the form of cancers associated with the human papillomavirus (HPV), with oropharyngeal cancers now the most common form of such malignancies. The ongoing public health threats of dramatically increased numbers of Americans affected by diabetes or obesity also have required new levels of attention to oral manifestations and interactions. The roles of oral health care providers are changing as a result of these and other new or evolving health patterns and challenges.

Development of the Report

Early in the development of this report, decisions were made to ensure that it would reflect the perspectives of all who would be affected by it. Rather than simply charging a small group of scholars with planning and preparing the report, the decision was made to seek input from large numbers of scientists, practitioners, public health experts, educators, community representatives, and others from across the country in a way that would bring to this task the multiple experiences and perspectives related to the oral health needs of all segments of the population.

That process of seeking input began with a Listening Session convened by then–Surgeon General Adams and organized by the Centers for Disease Control and Prevention's Division of Oral Health in November 2018. The event was attended by more than 150 health professionals, researchers, educators, profession and community leaders, and other experts. That group spent two days considering data and programmatic reports related to oral health and sharing their experiences and perspectives related to the challenges, as well as the opportunities, that would be involved in meeting the goal of optimal oral health for all. Shortly thereafter, in January 2019, the project directors of this report conducted a webinar inviting public comment on the planned report. More than 1,700 individuals viewed the webinar, which also elicited hundreds of written comments. The webinar included a call for ideas for addressing oral health challenges that generated more than 40 descriptions of innovative programs from around the country. Those submissions addressed a variety of oral health needs in new ways or described services for previously underserved population groups. Professional and scientific associations also were directly solicited for ideas, and they shared information that elicited a diversity of views from health care, academic, research, and public health perspectives. An open call was made for descriptions of exemplary private-public partnerships for improving oral health. At a variety of meetings across the country, sessions were well attended and important advice and information were offered.

To further ensure that the report represents oral health needs in our country, the expertise of a broad array of volunteers was sought for assistance in writing the report. Ultimately, more than 350 individuals directly contributed content for this report—a number that was unprecedented for any similar report. The organization and ultimate preparation of the report, moreover, has been completed by an editorial team of 28 editors, section editors, and section associate editors. Sixty-five scientists and health professionals with expertise in the areas of each section of the report provided first-level scientific review and critique that further shaped the content and ensured its accuracy. An additional review of the full report was undertaken by 9 recognized experts from across the health fields whose task was to ensure that the report addresses all its goals and that it is responsive to the many and diverse perspectives of those whose interests it serves. Finally, scientists at NIDCR also reviewed the report and made suggestions related to its content, and federal review processes were conducted for ensuring that the standards of the National Institutes of Health and the U.S. Department of Health and Human Services have been met.

Considering all the forms of participation described above, the preparation of this report benefited from the input of nearly a thousand individuals qualified in a wide array of professional and scientific specialties and practices, or who brought relevant background experiences. Although constructing a comprehensive and evidence-based document in this manner may not have been the easiest way to complete the task, it was believed to be essential to the ultimate veracity of the report, as well as to its credibility. With the goal of inclusiveness in mind, the NIDCR and its federal partners also endeavored to ensure participation that reflects the diversity not only of those involved in oral health but also of those who make up our nation as a whole. Given the changes in our country and our society that have served to shape this new look at oral health, addressing diversity in this way was an essential part of the task.

Organization and Content of the Report

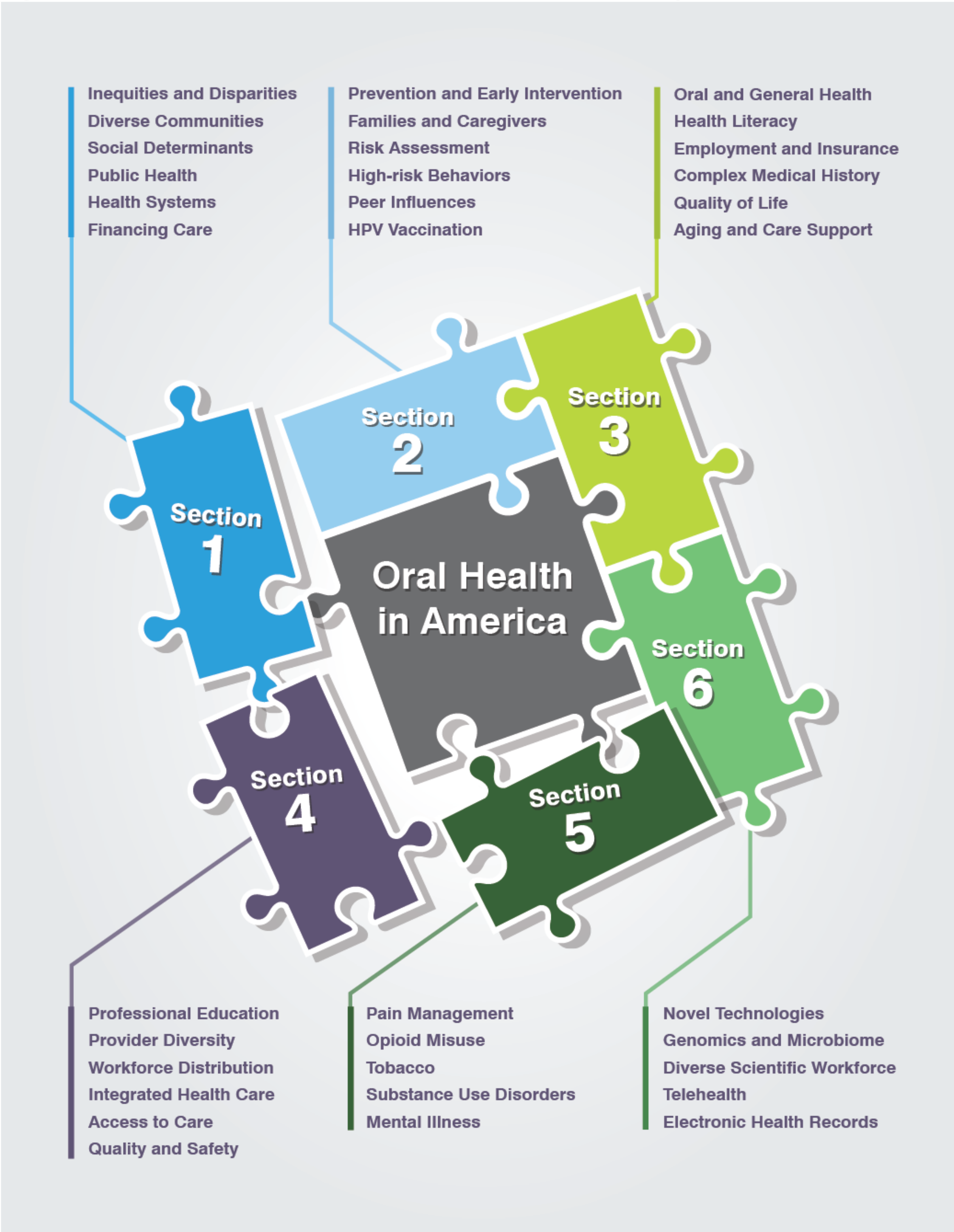
Acknowledging the need to address oral health in today's context, this *Report on Oral Health in America: Advances and Challenges*, was organized somewhat differently than the 2000 report. Rather than focusing on various diseases, this report takes a population perspective in terms of the impact of oral health, and in terms of responses to that impact. It emphasizes the need to improve the oral health of a nation and does this by taking into account the aspects of society that affect our health, learning from new challenges as well as old ones, and identifying promising ideas and strategies wherever they may occur. When the COVID-19 pandemic emerged, disrupting progress on the report, those involved received considerable and sometimes conflicting advice about whether and how to incorporate content related to the pandemic's impact on oral health. Ultimately, the decision was made to address both the impact and the implications of the COVID-19 pandemic throughout the report, whenever there was relevance to issues of oral health and wherever the topic served to raise important questions for the future. The COVID-19 story is unfinished, of course, and although the report cannot include the many studies currently underway, it attempts to address what we have learned to date, and what we may still need to learn, about the effects of SARS-CoV-2 and potentially of other novel disease outbreaks on oral health.

Section Content. In addition to this brief introduction and a summary at the end of the monograph, the report comprises six sections that address important factors influencing the oral health experience of Americans today (Figure). Many of these factors can easily be organized within a series of well-established topics, whereas others may be less well understood. The process of organizing these topics into the six main sections was much like building a puzzle with the goal of trying to present the most comprehensive and accurate view of Oral Health in America. These sections are described briefly below.

Section 1 is titled "Effect of Oral Health on the Community, Overall Well-Being, and the Economy." This section considers how oral health and disease affect all aspects of our society, from our financial well-being to our health care systems, as well as our ability to respond to a variety of social changes and threats. This includes the many ways in which financial interests, demographic factors, and social and cultural changes influence the oral health of the population. The current COVID-19 pandemic has reminded us of the ongoing challenges our country faces with persistent health disparities and inequities. Section 1 provides a big-picture perspective on social determinants of health as crucial underlying factors that contribute to oral health disparities and inequities in the United States. These topics also raise questions about how the interpretation of social differences can create systemic racism that may, in turn, shape health care in ways that result in the inequities that have been documented both in oral health and in access to care. Specific topics, such as the expensive overuse of emergency department services for dental care, are among the examined phenomena that reflect the importance of fully exploring the implications of social determinants of health. Section 1 also delves into policy issues, including recommendations for restricting the sale of products that are detrimental to oral health, and the need for public-private partnerships that can ensure the delivery of essential oral health care in times of crisis.

Section 2 is called "Oral Health in Children and Adolescents" and is divided into two parts, respectively covering oral issues for these two groups within the younger segment of our population. The section acknowledges the advances that have been made in reducing dental caries (tooth decay) prevalence in young children. It clarifies the patterns whereby children of some minority racial groups and those affected by poverty continue to experience more disease, especially as they reach school age. This section discusses the importance of risk assessment, early prevention and intervention, as well as the roles of families and caregivers in preventing and controlling dental caries. In addition, it describes some novel ways in which dental care is being provided to children to address unmet needs. The second part of Section 2 reports on oral health in adolescents and describes the common patterns of oral disease in this group, noting that caries experience has not declined for adolescents as it has for younger children. New issues for this group related to HPV infections, the availability of HPV vaccines, and the roles of oral health professionals in encouraging and administering these vaccines are discussed, as are a range of other reasons for giving greater attention to the oral health of adolescents. This section also reminds us of the challenges this age group confronts with peer influences that sometimes encourage engaging in high-risk behaviors that have an adverse effect on their oral health, as well as on their general health, both now and in the future.

Figure. Overview of select content within *Oral Health in America: Advances and Challenges*



Section 3, “Oral Health in Working-Age and Older Adults,” looks at the oral health of this largest segment of the population and also comprises two parts. Not only are the oral diseases and problems affecting adults generally different from those that are most common in childhood, but they also differ over the life course of adults. Issues related to accessing oral health care often are salient for working-age adults, yet public insurance programs are not made available for adults to the extent they have been for children. Recommendations related to oral health care in pregnancy are discussed, as well as adult needs related to dental fear and anxiety. This section also reinforces the important interconnections between oral health and general health, brought to our attention more than 20 years ago in the 2000 report on oral health (U.S. Department of Health and Human Services 2000). Although fewer older adults lose all their teeth than was the case 20 years ago, it also is true that new materials and techniques now offer more satisfactory solutions for the replacement of natural dentition. Living longer also means living with chronic diseases and with a variety of other health conditions that often have oral manifestations. These problems for the older population are discussed, as well as specific issues such as difficulties related to obtaining oral health services for those living in group care settings.

Section 4 covers the topics reflected in the title, “Oral Health Workforce, Education, Practice and Integration,” highlighting patterns and changes related to who delivers oral health care and where they deliver that care, rather than simply what treatments are provided. The maldistribution of oral health care professionals and its stimulation of new workforce models and new professional categories are explored. Other topics in this section include new settings for delivering oral health care, new financial models for providing care, and changes that are taking place in professional education related to oral health. Issues pertaining to the affordability of professional education and the regulation of services provided by oral health professionals are discussed. Finally, dramatic changes in approaches to facilitating the quality and safety of dental care that have been stimulated by COVID-19 and other disease threats are discussed, with attention to potential future needs.

Section 5, “Pain, Mental Illness, Substance Use, and Oral Health,” examines the title topics as they are related to oral health. Pain has long been studied by scientists interested in oral health, but new interest and new approaches have been stimulated by the urgency with which mental health issues, and especially the opioid use pandemic, have mandated the attention of oral health providers and other medical care specialists. The publication, *Facing Addiction in America: The Surgeon General’s Report on Alcohol, Drugs and Health*, called for addiction to be recognized as “a chronic neurological disorder” that is treatable and that requires our health care system to appropriately address it with ongoing and supportive care (U.S. Department of Health and Human Services 2016). The problems of mental illness and substance use raise important issues for both oral health status and the treatment of dental disease, underscoring a need for more attention to these topics among oral health professionals. The competencies that will prepare dental professionals for addressing these problems also are described. Finally, the ongoing opioid epidemic is discussed, along with the ways in which dental practice has been evolving to help reduce the devastating impact of this epidemic—an impact that escalated to unprecedented numbers of overdose deaths and economic costs of billions of dollars per year in health care costs and lost productivity (U.S. Department of Health and Human Services 2021).

Section 6 looks at “Emerging Technologies and Promising Science to Transform Oral Health.” This section explores catalytic research advances, for example, the possibilities inherent in today’s growing understanding of the human microbiome, or the community of microscopic organisms within our bodies. Study of the oral microbiome is leading to new ways of understanding and treating oral diseases and has paved the way for a more effective focus on actually preventing, rather than treating, problems of oral and craniofacial health. New approaches include regenerative techniques that can provide more natural replacements for diseased or lost bone and other tissues. Salivary research, including studies related to disease diagnostics, represents another continuing strong focus for investigation, and it has recently produced new information related to the ability of the COVID-19 virus to directly infect cells in the salivary glands and gingival tissue, with important potential implications for the course of illness and for non-invasive rapid diagnostic techniques.

Paired with the science emerging from a greater understanding of the human genome, the application of new analytic and computing techniques that draw on data from integrated electronic health records can move us toward an era of personalized dentistry in which treatments can be designed that meet the specific health profiles and needs of each individual. These technical advances highlight the promise of integrated electronic health records not only to facilitate research but also to inform clinical decision making and support public health policy initiatives. Another important topic, given its recent emergence as a practical tool to help facilitate oral health care during the COVID-19 pandemic, is telehealth as it applies to dentistry.

Organization Within Sections. In addition to the organization of subjects by section, the same four chapters are included in each section of the report. These are:

1. **Current Knowledge, Practices, and Perspectives,** which describes what we now know about the topics included, the extent to which that knowledge is being used, and the range of perspectives influencing the topic;
2. **Advances and Challenges,** which tracks progress made since the publication of the 2000 Surgeon General's Report on Oral Health and describes persisting challenges and threats, as well as new or emerging obstacles to achieving oral health goals;
3. **Promising New Directions,** which indicates where we see emerging solutions to problems, and new ideas for meeting challenges and reaching the goal of optimal oral health; and
4. **Summary,** which recaps the most important points of the section.

In addition to these sections, other supporting data and content are provided. This content comprises a collection of data tables and figures supporting the text of the report for each section, as well as a set of callout boxes to describe some of the programs that exemplify best practices in oral health promotion. As part of the broad review of advances made, and challenges remaining, over the 2 decades since the release of the 2000 report, a number of analyses were conducted to examine changes in oral health status, dental expenditures, and insurance coverage. Data for these analyses were obtained from the National Health and Nutrition Examination Survey (NHANES) and the Medical Panel Expenditure Survey (MEPS).

Because the 2000 report on oral health used NHANES data from the 1988–1994 survey period, the current report uses the same data to serve as the base period (period 1). Two additional survey periods of data have been used to assess change over a two-decade period: 1999–2004 (period 2) and 2011–2014 (period 3). These data periods represent the most currently available oral health data that align best with the type and scope of oral health information that was collected in NHANES 1988–1994, thereby maximizing validity for assessing changes over time. In addition, these two data periods represent excellent collection periods with appropriate spacing over nearly three decades to assess changes in oral health status at the national level.

Finally, oral health data collected during these three survey periods have been evaluated for quality assurance and reliability with assessments previously reported (Drury et al. 1996; Dye et al. 2007; Dye et al. 2008; Dye et al. 2019). To assess changes in individual dental expenditures and insurance coverage, MEPS data from the same time periods (1999–2004 and 2011–2014) were used. Unfortunately, dental-related MEPS data from 1988–1994 are not available. The majority of estimates resulting from the NHANES and MEPS analyses are used to support figures presented in Chapter 2 ("Advances and Challenges") within most sections. All statistical analyses were conducted using SAS v9.4 survey procedures (SAS Institute Inc.). Population estimates and standard errors using Taylor Series Linearization were calculated. Differences between groups were evaluated using a t-statistic at the $p < 0.05$ significance level. Tests were conducted without adjustment for other socio-demographic factors, except for age adjustment (2010 US Census). All differences discussed are statistically significant unless otherwise indicated in the text.

The consistency of structure across the six sections is intended to sustain the report's public health focus on achieving the benefits of good oral health for every individual. In addition, an important element of the work has been to address a broader array of critical health issues in relationship to oral health—issues such as substance use, vaccination rates, and of course, the challenges of COVID-19, which emerged during the course of writing this report. The report also describes the essential role of partnerships to improve health. Early calls for participation reached out to the broad oral health community asking for nominations of successful private-public partnerships that are showing promise in improving the oral health through efforts that address a broad range of health issues. Some of these partnerships are showcased across the sections in the chapters titled "Promising New Directions."

The logic of the report's structure supports a comprehensive evaluation of the current context for oral health and the progress that has been made, the identification of challenges, and the search for solutions that will create a better future. Only by understanding fully where we are, where we have been, and where we want to go, can we create a realistic plan and amass the tools and the resources needed to fulfill that plan. This report provides a guide for that journey toward our ultimate goal of ensuring that the benefits of oral health are equally experienced by every person in every community across this country.

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Community
Individual
Person
Private
Race/Ethnicity
Higher
Institute
Surveillance
Status
Provide
Inequity
Model
Patient
Population
Time
Wellness
Benefit
Visit
Integral
Primary
Federal
Emerge
Related
Important
Live
Group
Improve
Income
Year
Literacy
Develop
Clinic
Equity
Level
Rural
Educate
American
Prevent
Study
Quality
Disease
Commercial
Public Health
Social
Service
Economy
Promote
Risk
Center
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Poverty
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Public
Age
Care
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State
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Treatment
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Challenge
Family
Poor
Policy
Severe
Epidemiology
Tobacco
Continue
Understand
Low
Health Systems
Diverse
Cost
Report
Financing Care
Practice

Oral Health in America: Advances and Challenges

Section 1: Effect of Oral Health on the Community, Overall Well-Being, and the Economy

Chapter 1: Status of Knowledge, Practice, and Perspectives

Oral health plays a vital role in the physical, mental, social, and economic well-being of individuals and populations (Peres et al. 2019). The oral cavity and its surrounding structures are essential parts of the human body, integral to its daily functioning and contributing substantially to the overall well-being of individuals. The oral cavity also is the main conduit of human interaction with society. Humans use it to verbally communicate with others, to take in nutrients and participate in communal eating, and to convey emotion. The appearance of an individual's teeth and surrounding structures greatly influences how others perceive them and how they perceive themselves. This perception has an impact on an individual's ability to work, contributes to one's social status, and can affect a person's socioeconomic position in society.

Although there is much to celebrate about ongoing improvements in oral health, many people still suffer from chronic oral conditions and lack of access to the dental care they need. Moreover, the incidence of oral diseases, like many chronic disease conditions, is socially patterned, with the largest burden of disease occurring among children living in poverty, racial and ethnic minorities, frail elderly, and other socially marginalized groups, such as immigrant populations. Marginalized groups include groups defined by race, religion, age, financial status, politics, and culture (Given 2008; Li et al. 2018; Hung et al. 2019). Others not defined by sociodemographic characteristics, but who have special health care needs (SHCNs), also can be marginalized. Not only do these groups suffer the highest burden of oral disease, they also face the greatest barriers to accessing routine preventive and other dental services (Parish et al. 2015; Velez et al. 2017; Lebrun-Harris 2021). The major barriers to accessing dental treatment include high cost, lack of accessible dental services in the community, geographic isolation, fear and anxiety, and other social and economic factors (National Advisory Committee on Rural Health and Human Services 2004; Nasseh and Vujicic 2014; Davis and Reisine 2015; Vujicic et al. 2016a; Gupta et al. 2019).

Beyond individual benefits, maintaining good oral health brings social and economic benefits to families and communities. As Listl and colleagues (2019) note, the effects of oral diseases are significant in economic terms. There are direct, indirect, and intangible costs, such as treatment expenditures, missed days from school and work, and lessening of the quality of life (Listl et al. 2015). In 2015, dental diseases around the world (with the exclusion of oral and pharyngeal cancers) accounted for approximately $545 billion (USD) in total costs, which included $357 billion in direct costs and $188 billion in indirect costs (Righolt et al. 2018). In high-income countries, such as the United States, significant numbers of days are lost every year from school, work, and daily activities, with productivity losses being similar to those associated with musculoskeletal injuries and disorders (Australian Research Centre for Population Oral Health 2012; Guarnizo-Herreño and Wehby 2012a; Hayes et al. 2013; Singhal et al. 2013). The academic performance of children, employment in adults, and productivity in the workplace are also affected (Mobius and Rosenblat 2006; Seirawan et al. 2012; Bóo et al. 2013; Singhal et al. 2013). In fact, securing employment and what one can earn is influenced by the appearance of the mouth and teeth (Hamermesh and Biddle 1994; Glied and Neidell 2010;

Bóo et al. 2013). Oral diseases worsen the impacts of other diseases, too, such as diabetes. Importantly, research demonstrates that periodontal treatment can reduce total and diabetes-related health care costs (Nasseh et al. 2017). The out-of-pocket costs that dental care can impose are also of concern, as they can put economically insecure families at risk of poverty (Bernabé et al. 2017). Finally, poor access to dental care also affects the health care system, resulting in inappropriate use of physician offices and hospital emergency departments (Allareddy et al. 2014; Vujicic and Nasseh 2014; Singh et al. 2019). As can be seen from the above, the economic benefits of improved oral health and access to dental care are substantial.

There are three broad-ranging factors that contribute to oral health and oral disease as they manifest at the community or population level. The first theme explores the important concept that oral health is integral to overall health and should be embedded in the broad framework of the whole body's health (Peres et al. 2019).

It has been more than 25 years since Surgeon General C. Everett Koop (Koop 1993) brought this notion to national attention when he said, "You're not healthy without good oral health." Having good oral health means, at a minimum, that an individual is free of oral infection and pain and has acceptable oral function and facial aesthetics. The FDI (French: Fédération Dentaire Internationale) World Dental Federation General Assembly recently updated its definition of oral health (Box 1) to emphasize that oral health must be thought of broadly and that it has numerous implications for an individual's physiological, social, and psychological well-being (Figure 1) (FDI World Dental Federation).

The second theme emphasizes that the benefits of good oral health extend beyond the individual to families and communities. When considering oral health from a population perspective, it becomes clear that the burden of oral disease falls most heavily on the most vulnerable groups in U.S. society. Oral diseases disproportionately affect population subgroups that have limited economic resources, low levels of educational attainment, poor access to dental care, and lower levels of social influence or political capital. This leads to recognizable oral health disparities and inequities.

Identifying the factors that contribute to poor oral health among vulnerable groups can provide guidance for developing and targeting oral health promotion strategies and reducing inequities. To that end, models of oral disease development have been created that bring attention to the multilevel factors now known to contribute to oral health status. Peres and colleagues' recent model (Figure 2) (Peres et al. 2019; World Health Organization 2020) shows that the determinants of oral health arise from the level of the individual, the family, the community, and the nation. Factors known to influence oral health status are classified into three levels, labeled as the structural, intermediate, and proximal determinants of oral health. Proximal determinants are related to an individual's biology and behavior, and the relationship of these determinants to health status often is readily apparent. For example, an individual's choices around diet, tobacco use, and oral hygiene all have clear links to oral health.

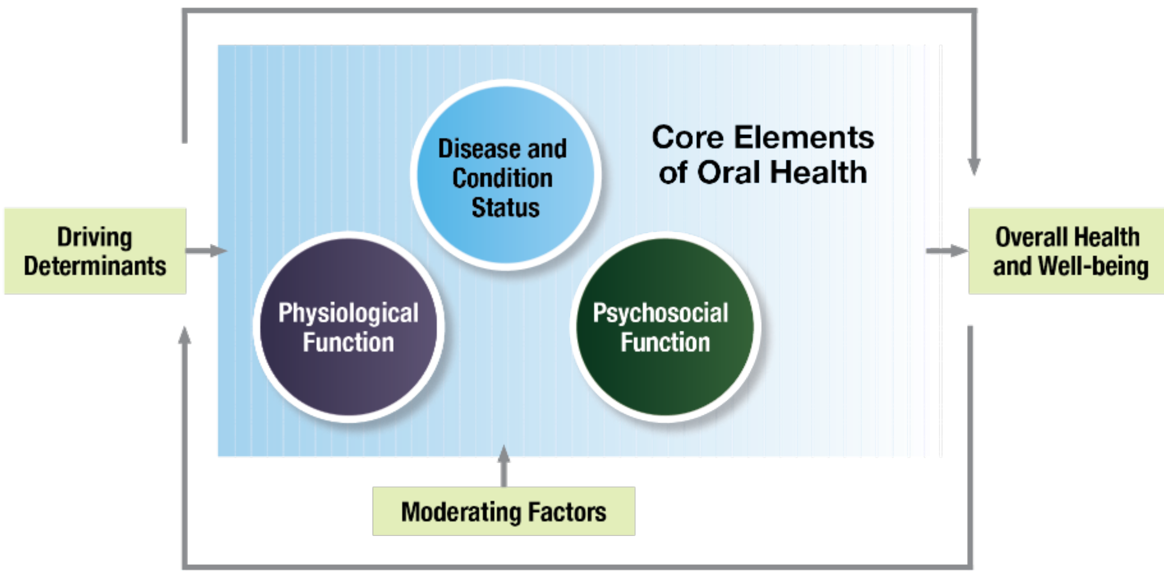
Box 1. FDI World Dental Federation definition of oral health

Oral health is multifaceted and includes the ability to speak, smile, smell, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex. Further attributes of oral health:

- It is a fundamental component of health and physical and mental well-being. It exists along a continuum influenced by the values and attitudes of people and communities.
- It reflects the physiological, social, and psychological attributes that are essential to the quality of life.
- It is influenced by the person's changing experiences, perceptions, expectations, and ability to adapt to circumstances.

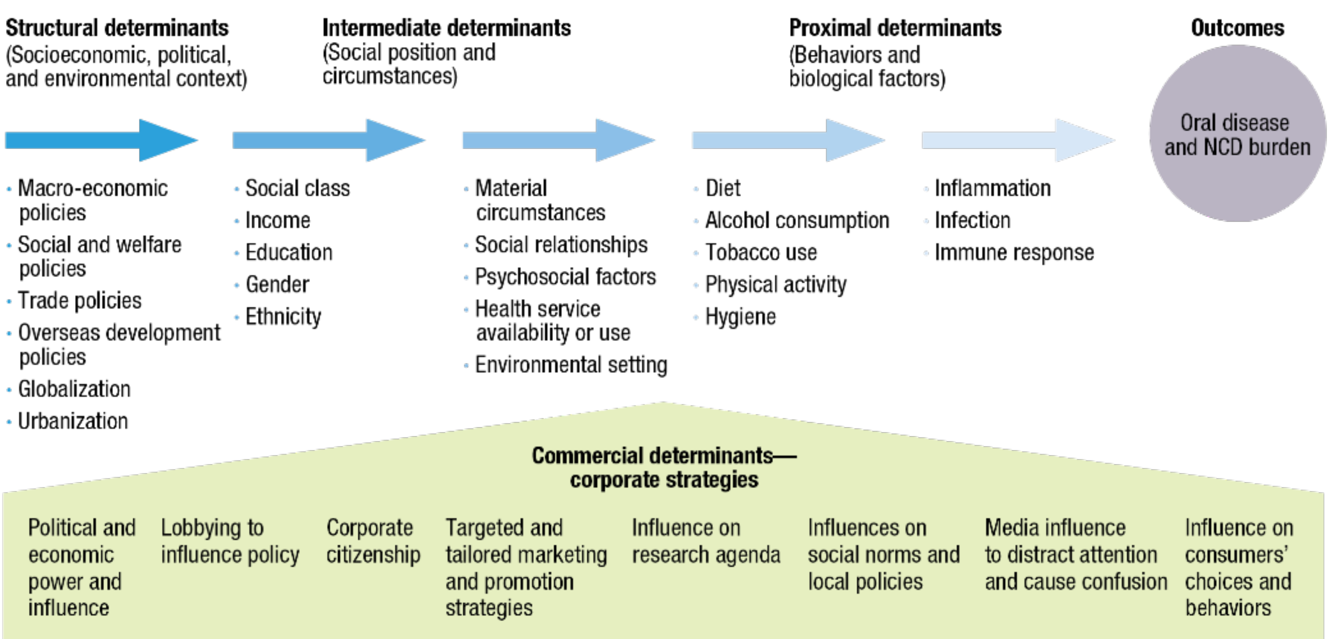
Source: FDI World Dental Federation, 2016.

Figure 1. Core elements of oral health



Source: FDI World Dental Federation (2020). © FDI World Dental Federation. Reprinted with permission.

Figure 2. Social and commercial determinants of oral health (Peres model)



Note: **NCD** = noncommunicable diseases.

Source: Peres et al. (2019). With permission from Elsevier.

The broader environmental context in which individuals live comprises both structural and intermediate determinants. Determinants at these levels generally are not under an individual's direct control and their linkage to oral health can seem less clear. Nevertheless, determinants at these levels are well understood to play an important role in influencing health status. Collectively, these structural and intermediate determinants are referred to as the social determinants of health (SDoH).

The World Health Organization (WHO) (2020) defines SDoH as:

> [T]he conditions in which people are born, grow, live, work, and age. These circumstances are shaped by the distribution of money, power, and resources at global, national, and local levels. The social determinants of health are mostly responsible for health inequities—the unfair and avoidable differences in health status seen within and between [social groups].

This definition is now commonly expanded to include the commercial determinants of health when they have contributed in important ways to health status. The commercial determinants of health are defined as the "strategies and approaches used by the private sector to promote products and choices that are detrimental to health" (Kickbusch et al. 2016 p. e895). Most notably, such products include cavity-promoting foods and beverages or substances such as tobacco products that are known to cause or promote oral disease. However, not all commercial determinants should be framed as negative, because commercial activity also results in continuously improving products for maintaining good oral health and can improve health education messages provided to the public about good oral hygiene habits.

The third broad-ranging theme involves the substantial ways in which dental care financing and delivery limit access to care and perpetuate disparities in oral health. The reasons that access to needed dental care remains challenging for many are complex, but they certainly are related to the historical separation of dentistry from overall health care, rendering dentistry one of the most siloed of the health professions. This partitioning of the dental profession is reflected in the educational model, in dental care financing (both public and private), and in how and where dental care services are provided. This contributes to an arbitrary disconnection between medicine and dentistry and results in dental care being viewed by some policymakers as a nonessential health service. This policy neglect is evident in the fragmented approach to dental care financing at both the federal and state levels. Public payment for dental care through Medicaid varies across states, with many offering only limited benefits, and in four states, no benefits at all for adults. Medicare, the main provider of medical insurance for older adults, contains no dental coverage. The scope of practice for some dental professionals, including, hygienists and dental therapists, also varies across states, and greater restrictions can contribute to the challenges of providing preventive dental services to reach vulnerable populations (including the institutionalized elderly, homeless people, and the rural poor).

When viewed from a population level, dental care financing and care delivery seem wholly insufficient to meet the needs of a diverse population. This existing system is not fulfilling its purpose (Vujicic 2018). Policy reform is urgently needed to resolve these structural barriers, to address social determinants that limit access to effective prevention, and to guarantee access to appropriate care for all. The benefits of these reforms can be demonstrated to fully justify the costs (Vujicic 2018).

Social Determinants of Health

SDoH have been a focus of public health for decades. Sydenstricker (1935) said that true improvements in population health required "control, so far as means are known to science, of all of the environmental factors that affect physical and mental well-being." That, he explained, includes economic security, healthy housing, availability of nutrient-dense food, opportunities for exercise, and efforts to provide social security for all. Link and Phelan (1995) described social factors such as low socioeconomic status and lack of social support (and arguably industry and market forces) as fundamental causes of disease. They base this assertion on evidence that the effect of SDoH persists even when intervening mechanisms such as individual health behaviors change.

Adler and colleagues (2016) noted that the best available evidence suggests using public funds to invest in addressing SDoH to achieve better population health, less inequality, and lower overall health care costs. Moreover, social determinants are not restricted to those issues that have proximate links to health, such as tobacco policy, which means public health policies can be viewed more broadly to include those related to education, labor, criminal justice, transportation, and social welfare, given their potential contributions to population health. Patterns of health-promoting or health-damaging behavior emerge early as one develops physiologically and socially, and then continue to be shaped by positive and negative life circumstances. Oral health disparities, therefore, are attributable in part to public priorities and spending decisions. For example, insurance coverage and the amount of public spending on social programs in a nation influence both oral health and quality of life. Nations that spend more on social programs have populations with better oral health status (Guarnizo-Herreño et al. 2013). Similarly, the coverage and amount of social spending in a nation, particularly a welfare state, can influence the magnitude of income-related disparities in oral health or differences in oral health among income groups, but more research is needed to clarify different types of spending approaches (Sanders et al. 2009).

These effects extend to dental care utilization, as well. In nations with more public insurance coverage, differences among the numbers of dental visits reported by population groups are smaller (Palència et al. 2013). Further, this effect on dental care extends throughout the life course (Listl 2011; 2012). Because the U.S. public investment in dental insurance and direct provision of services is a mixture of programs that operate at the federal, state, and local levels, inevitable gaps are created in insurance coverage, in turn contributing to the development of oral health disparities and inequities.

Oral diseases are not equitably distributed within society as a result of the contributions to oral health status that arise from the social and economic environment. Viewed from a population perspective, it can readily be seen that the burden of many oral diseases disproportionately affects marginalized subgroups, giving rise to oral health inequities. However, when these disparities are the result of differences in the availability of social and economic health-promoting resources—including access to affordable healthy foods, professional dental prevention and treatment services, and dental insurance—they are considered avoidable, unnecessary, and amenable to policy action. As such, these disparities are viewed as unjust and are correctly described as inequities (Whitehead 1991; Braveman 2003). Leenan (1985) defined equity in health care using the following basic conditions:

- Equal access to available care for equal need;
- Equal utilization for equal need, and
- Equal quality of care for all.

Even at the local level of a neighborhood or built environment, the same effect is seen; namely, that the social, political, and economic characteristics of small residential areas are associated with oral health—independent of the characteristics of the individuals who live there. For example, among Black families with incomes below 250% of the federal poverty level, the quality of housing and available social supports appear to ameliorate the effect of poverty (Sanders et al. 2008b). Specifically, when low-income adults and children resided in better quality housing and had social supports, they were more likely to retain 20 or more teeth and have less tooth decay (Sanders et al. 2008a; Sanders et al. 2008b). This suggests that, in addition to the importance of addressing poverty, improving the built and social environments can result in resilience as a response to the harmful health effects of poverty itself.

The federal Healthy People 2020 initiative addressed SDoH as one of its four overarching goals for the decade, and this was reaffirmed and expanded in the launch of Healthy People 2030 in August 2020 (Hubbard et al. 2020; U.S. Department of Health and Human Services 2020a). This emphasis on SDoH also has been shared by other U.S. health initiatives, such as the U.S. Department of Health and Human Services' (HHS) Action Plan to Reduce Racial and Ethnic Health Disparities (U.S. Department of Health and Human Services 2011) and the National Prevention and Health Promotion Strategy (National Prevention Council 2011). Healthy People 2030 is focusing on the following five key determinants: economic stability, education access and quality, social and community context, health care access and quality, and the neighborhood and built environment (Figure 3). These determinants are addressed by interventions related to food insecurity, housing instability, early childhood education, literacy, civic participation, social cohesion, access to primary care, and environmental conditions.

Figure 3. Social determinants of health

Source: U.S. Department of Health and Human Services, Healthy People 2030 (2020).

When structured in favorable ways, all five determinants contribute to better oral health and facilitate favorable oral health trajectories during the life course (Gomaa et al. 2019). The new FDI definition of oral health (Box 1) and the Peres model (Peres et al. 2019) (Figure 2) reflect the importance of these factors in determining oral health status.

As part of the commitment by HHS to support improved health and well-being of the population, the Healthy People 2030 initiative sets 10-year measurable goals and objectives for the nation related to health promotion and disease prevention. Several of these objectives have an important role in oral health, such as reducing untreated dental disease, increasing water fluoridation, expanding access to dental insurance and improving access to care; improving population health through efforts to reduce added sugar consumption; and enhancing the dental public health infrastructure. It is noteworthy that Healthy People 2030 places strong emphasis on the importance of SDoH (Figure 3); all the social determinants listed in the figure are directly related to oral health. Focusing attention on their importance can foster both policy and research that leads to improved oral health for all.

Health professional education, including dentistry, also has identified SDoH as an important component of the curriculum of future professionals (National Academies of Sciences 2016; Sabato et al. 2018; Tiwari and Palatta 2019). In clinical dentistry as well, there is growing emphasis on understanding and incorporating SDoH as part of patient-centered care (Lévesque et al. 2016; da Fonseca and Avenetti 2017; Northridge et al. 2017; Edelstein 2018; Chi and Scott 2019).

Commercial Determinants of Health

In addition to the conventional SDoH, the Peres model (Peres et al. 2019) emphasizes the broad influence that commercial determinants and corporate strategies exert across all other factors. This concept has its roots in the decades-long battles fought by the U.S. federal and state governments against the tobacco industry, but in recent decades it also has matured into an understanding of the pervasive effects on health generated by a broad segment of commodity industries. As important influencers of consumption and the cultural and societal norms around activities such as behavior and diet, markets and industry play a key role in determining the health of individuals and populations and can drive associated disparities (Kearns et al. 2015; Friel and Jamieson 2019; Kearns and Bero 2019; Kearns and Watt 2019; Watt et al. 2019).

There is increasing recognition that rates of noncommunicable diseases (NCD), such as dental caries, periodontal disease, and oral cancer, are influenced by corporate strategies. Specifically, marketing, pricing, and subsidization of unhealthy products influence and drive consumption patterns of sugar and other sweeteners, tobacco, alcohol, and other unhealthy foods and beverages, giving rise to the concept of "industrial epidemics," a term emphasizing that a higher incidence of NCD is driven in part by the producers and marketers of commodities that are harmful to individual and societal health (Jahiel and Babor 2007; Collin and Hill 2015).

Commercial determinants shape consumer preferences, affect physical and social environments, and influence public policy development (Collin and Hill 2015). When addressing the Global Conference on Health Promotion in June 2013, WHO Director General Margaret Chan described the need to counter corporate threats to health policy beyond those of tobacco, citing the need to contend with "Big Food, Big Soda, and Big Alcohol," and arguing that the formulation of public policy for health must be protected from vigorous opposition and distortion by commercial or vested interests (Chan 2013). The WHO

FCTC (Framework Convention on Tobacco Control), adopted in 2003, provided the first treaty that legally binds the 181 ratifying countries to measures to ensure health through control of tobacco and could provide a model for future treaties focused on other health threats. One organization addressing the problem identified by Director General Chan is the World Economic Forum (WEF). WEF aims to be a platform upon which business, government, international organizations, civil society, and academia can interact to achieve a global impact. Through organizations such as this, corporate threats to health policy can be addressed via stakeholder engagement and cooperation aimed at developing a shared vision (World Economic Forum 2020).

The Tobacco Industry

The significant role of commercial efforts to influence personal choices that lead to health consequences should not be underestimated. For example, it is known that low-income high school students are disproportionally exposed to tobacco advertising and fast food availability near their schools (D'Angelo et al. 2016). Tobacco companies spent US$8.2 billion on advertising in 2019, marketing cigarettes and smokeless tobacco in the United States (Federal Trade Commission 2021a; 2021b). This amount translates to about $22.5 million each day, or nearly $1 million every hour. Tobacco advertising commonly targets low-income individuals, particularly low-income women (Brown-Johnson et al. 2014). The use of tobacco products is a major preventable cause of oral diseases and conditions. Cigarette smoking was established as a primary cause of cancers of the oral cavity and pharynx many decades ago (U.S. Department of Health 1979; International Agency for Research on Cancer 1986).

Cigarette smoking is a major cause of periodontitis (U.S. Department of Health and Human Services 2014) and a likely risk factor for dental implant failure (U.S. Department of Health and Human Services 2014). The use of smokeless tobacco products is a cause of oral cancer and periodontal destruction (U.S. Department of Health and Human Services 1986; International Agency for Research on Cancer 2007). The use of tobacco products has been implicated in a wide range of other oral diseases and conditions, such as delayed wound healing and compromised prognosis of oral surgical procedures or periodontal treatment. Although causality cannot be inferred, a relationship with dental caries also has been suggested (Warnakulasuriya et al. 2010). Cigar smoking has been specifically and causally linked to oral cancer and other adverse dental effects (Rostron et al. 2019). Consequently, tobacco prevention and control is an important aspect of oral disease prevention and health promotion.

Adversarial positions borne of competing interests have come to characterize tobacco control, with widespread recognition in the public health community that tobacco companies should be excluded from the development of public policy for health—a principle enshrined in Article 5.3 of the WHO Framework Convention on Tobacco Control (World Health Organization 2008; Collin and Hill 2015). The 2014 U.S. Surgeon General's report, *The Health Consequences of Smoking—50 Years of Progress* (U.S. Department of Health and Human Services 2014), concluded that the tobacco epidemic was initiated and has been sustained by the aggressive strategies of the tobacco industry, which has deliberately misled the public on the risks of smoking cigarettes, including the use of advertising and promotional activities that cause the onset and continuation of smoking among adolescents and young adults. The report also found that litigation against tobacco companies reduced tobacco use in the United States by increasing product prices, restricting marketing methods, and making available industry documents for scientific analysis and strategic awareness.

The Alcohol Industry

The International Agency for Research on Cancer (1988) concluded more than 30 years ago that alcohol consumption is a cause of cancers of the oral cavity, pharynx, larynx, esophagus, and liver. The role of alcohol as a cause of oral and pharyngeal cancer, independently and in combination with tobacco consumption, has been confirmed by more recent reviews (Tramacere et al. 2010; Reidy et al. 2011; de Menezes et al. 2013; Druesne-Pecollo et al. 2014; Roswell and Weiderpass 2015; Ogden 2018). Emerging evidence suggests that the alcohol industry was engaged in extensive misrepresentation of evidence about the alcohol-related risk of cancer (Petticrew et al. 2017). Alcohol producers have also used advertising and retail outlets to disproportionately target low-income neighborhoods (Hackbarth et al. 1995; Brenner et al. 2015). These activities have parallels with those of the tobacco industry and are important because the industry is involved with developing alcohol policy and in disseminating health information to the public, including school children (Petticrew et al. 2017).

The Food and Beverage Industry

The commercial activity of the food and beverage industry has been identified as a potential determinant of ill health (Capewell and Lloyd-Williams 2018). This industry was first compared to the tobacco industry in 2009 (Brownell and Warner 2009). In 2012, *PLOS Medicine* published a series calling attention to the "gulf of critical perspectives" in medical journals on the food industry's role in creating the epidemic of obesity and associated diseases, including dental caries (PLoS Medicine Editors 2012). Since then, a growing number of studies have documented food and beverage industry strategies and tactics to maintain an environment that encourages obesity and dental caries, including aggressive lobbying of regulators, legislators, and governments; the co-opting of domestic and international nutrition experts; deceptive and attractive marketing to children; targeting of minorities and emerging economies; undisclosed conflicts of interest; shifting of the obesity research agenda toward physical activity; and opposition to beverage taxes and warning labels on sugar-sweetened beverages, among others (Nestle 2018).

Vulnerable Populations and Oral Health Disparities

Differences in oral health status among individuals and within groups can arise for a variety of reasons. Figure 2 provides a representation of these broad categories of disease determinants, including biological (genetics), behavioral (oral hygiene practices), and social or structural factors related to how society organizes, distributes, and incentivizes the use of resources such as dental insurance in ways that may either promote or harm oral health. The insidious effects of racism on health—not just as individually expressed bias, but as policies and practices that have been incorporated into the structures of health care delivery systems—also are now being recognized as major and complex determinants of health inequities (Bailey et al. 2021). The impact of these structural factors can be seen in dentistry as well.

Warnecke and colleagues (2008) make an important distinction between individual-level determinants and population-level determinants of health. Population-level determinants exert health effects, independent of individual characteristics, and consequently require population-level interventions to remediate their health-harming effects. They distinguish between population-level determinants that exert a health effect because of the inequitable distribution of health-promoting resources or that result from fundamental biological differences among groups. When it is the former, differences in health status are considered to be not only health disparities, but health *inequities* that require social or population-level remedies as a matter of social justice.

As defined by WHO, the SDoH are shaped by the distribution of money, power, and resources at global, national, and local levels. The distribution of money, power and resources are influenced by any number of policy choices (Marmot and Bell 2009). As a result, different forms of social and economic vulnerability or exclusion can be said to influence oral health and its related outcomes and result in disparities between groups when one is more advantaged and another less advantaged (Marmot and Bell 2009; World Health Organization 2020).

The federal government classifies certain groups as being at higher risk of developing health problems as a result of marginalization based on sociocultural status, reduced access to economic resources, age, gender, and ability. The Minority Health and Health Disparities Research and Education Act of 2000 [Public Law 106–525(d)] mandates that populations with health disparities include minority groups, as defined by the U.S. Office of Management and Budget, as well as rural populations, persons with low socioeconomic status, and sexual or gender minorities. The federal Healthy People 2020 initiative also identified the following groups as needing special attention and creative solutions to live a healthy life in the face of sobering health disparities and social injustices: (1) high-risk mothers, (2) chronically ill and disabled people, (3) people with HIV/AIDS, (4) mentally ill people, (5) individuals with substance use disorders, (6) homeless individuals, and (7) immigrants and refugees.

Several definitions of disparities have been adopted by the U.S. government. HHS describes health disparities as "differences in health outcomes that are closely linked with social, economic, and environmental disadvantage"

(U.S. Department of Health and Human Services 2011, p. 2). The National Institutes of Health defines a health disparity as a "difference in the incidence, prevalence, mortality, and burden of disease and other adverse health conditions that exist among specific population groups in the United States" (National Institutes of Health 2010). When these between-group differences are the result of unjust distribution of health-promoting resources, they are more appropriately referred to as inequities in health.

High-quality national data are available to document oral health disparities for several different population subgroups, including those with low income, African Americans (Black), Hispanics, Asian Americans, American Indians and Alaska Natives (AI/AN), and individuals with complex health conditions. However, the lack of nationally representative data or an adequate literature base hinders understanding of how differences in oral health may exist for other groups, such as the frail elderly, those with mental illness, and lesbian, gay, bisexual, transgender, queer, and other individuals.

Low-Income Populations

The idea that "the poor oral health of poor people is explained by personal neglect" (Sanders et al. 2006 p. 71) is not supported by research from the United States and Organization for Economic Cooperation and Development nations. Instead, oral health is determined by numerous factors that operate at the personal, social, and environmental levels. These determinants include genetics, behavior, and diet, as well as social, economic, and living conditions (Lee and Divaris 2014; Peres et al. 2019).

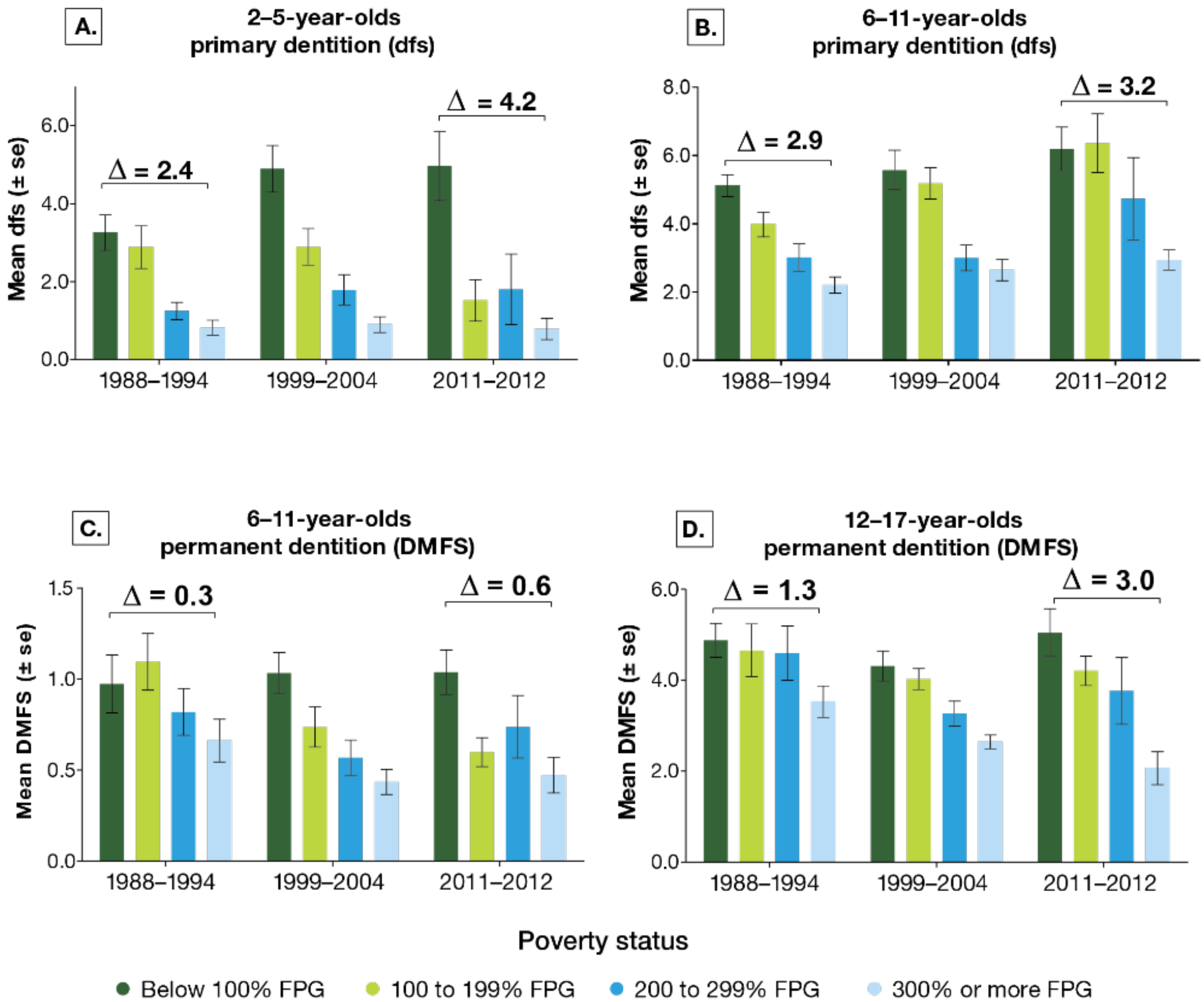
It is now generally recognized that the adverse relationship between economic circumstances and oral health spans the entire income distribution, although people who are worse off financially have more dental disease, on average, than those who are more affluent. For dental caries, not only has an income gradient persisted over time among U.S. children and adolescents, it may be worsening. Using nationally representative data from the National Health and Nutrition Examination Survey (NHANES) for three time points from 1988 to 2014, Slade and Sanders (2017) examined the income gradient for children and adolescents in three age groups. For each survey period, they computed four categories of the income-to-poverty ratio to illustrate this gradient in disease (Figure 4 A–D), adjusting for age, gender, race/ethnicity, rural–urban location, head-of-household education, and period since last dental visit. During 1988–1994, children aged 2 to 5 years living below the poverty threshold had 2.4 more decayed or filled primary tooth surfaces than their counterparts from families with income at least three times the poverty threshold. By 2011–2012, the disparity had increased to 4.2 affected tooth surfaces (Figure 4A). During the same interval, the disparity increased among older children in primary (Figure 4B) and permanent dentition (Figures 4C and 4D). For several groups, the magnitude of disparity in children's dental caries experience almost doubled during this period.

It is notable that this worsening of disparities in dental caries occurred during a period of increasing dental care utilization by low-income individuals aged 2 to 18 years, according to the Medical Expenditure Panel Survey. From 2000 to 2012, the rate of any use of dental services by children living in families below the poverty level increased from 27% to 36%, the greatest increase for any income group (Nasseh and Vujicic 2016b). Meanwhile, child poverty deepened in the United States, rising from 11% in 1999 to 15% in 2014 (Chaudry et al. 2016). Taken together, these findings demonstrate that, at a population level, increased utilization of dental care among low-income children did not lessen disparities in children's dental caries. One explanation could be that dental office visits alone have a limited capacity to prevent development of future carious lesions in primary teeth when disease risk is being driven primarily by social and commercial determinants.

Rural Populations

More than 60 million Americans (18%) reside in rural areas; of these, 34 million live in a dental health provider shortage area (Barnett et al. 2018). Compared to their urban counterparts, rural residents face worse oral health outcomes across the lifespan, are less likely to receive preventive dental services, and are more likely to seek dental care in the ED (Walker et al. 2014; Geiger et al. 2019). Rural adults have nearly double the prevalence of edentulism (tooth loss) than nonrural populations (Vargas et al. 2002). Rates of untreated dental caries are higher among rural populations in the South but not in other parts of the United States (Vargas et al. 2003; Maserejian et al. 2008; Dawkins et al. 2013).

Figure 4. Children's dental caries experience by primary or permanent teeth in four income categories: United States, 1988–1994, 1999–2004, and 2011–2012



Notes: Δ = absolute difference in mean caries between lowest and highest income groups; **FPG** = Federal Poverty Guideline.

Source: Slade and Sanders (2017). © The American Association of Public Health Dentistry. With permission from John Wiley & Sons.

Oral health disparities that persist in other subpopulations are compounded by rurality. Rural persons of color, including Black and AI/AN populations and migrant workers and their children, face disproportionately higher rates of untreated dental disease and have lower rates of dental utilization than their suburban and urban counterparts (Quandt et al. 2009; Wu et al. 2012; Schroeder et al. 2019). AI/AN adults and children, many of whom reside in rural areas, have extremely high levels of dental disease, including untreated dental caries, periodontal disease, oral pain, and tooth loss (Phipps and Ricks 2015; Phipps and Ricks 2016).

The causes of worse oral health outcomes in rural communities are multifactorial. Rural communities have fewer dentists and require longer travel time to reach dental care (Cao et al. 2017; Barnett et al. 2018). They also have lower rates of insurance coverage and Medicaid eligibility (Martin et al. 2012). Although rural dentists are more likely to accept Medicaid than their urban counterparts, rates of acceptance are still not high enough to meet the need for oral health services in the rural Medicaid population (Cao et al. 2017). In general, when compared to urban areas, rural areas have lower dentist-to-population ratios, more residents who lack dental insurance, and higher unemployment and poverty rates. As a result, roughly 2 in 5 rural Americans are essentially without access to dental care (National Organization of State Offices of Rural Health 2013).

In addition to these structural barriers to care, cultural norms, such as dental anxiety and pessimism about the achievability of oral health, also may contribute to rural-urban disparities in oral health outcomes (Chen et al. 2019). Rural populations have lower average levels of oral health literacy, a risk factor for poor oral health-related quality of life in rural communities (Gaber et al. 2017; VanWormer et al. 2018). Oral health literacy is defined as "the degree to which individuals have the capacity to obtain, process, and understand basic oral health information and services needed to make appropriate health decisions" (National Institute of Dental and Craniofacial Research 2005). Adding to these risk factors, rural populations have less access to the preventive benefits of fluoridated water and use tobacco products more—both combustible and noncombustible—than urban residents, with the accompanying increased risk of periodontal disease and oral and pharyngeal cancers (Roberts et al. 2016). Combined, these factors contribute to a rural oral disease disparity through increased disease liability and reduced access to preventive and reparative dental services.

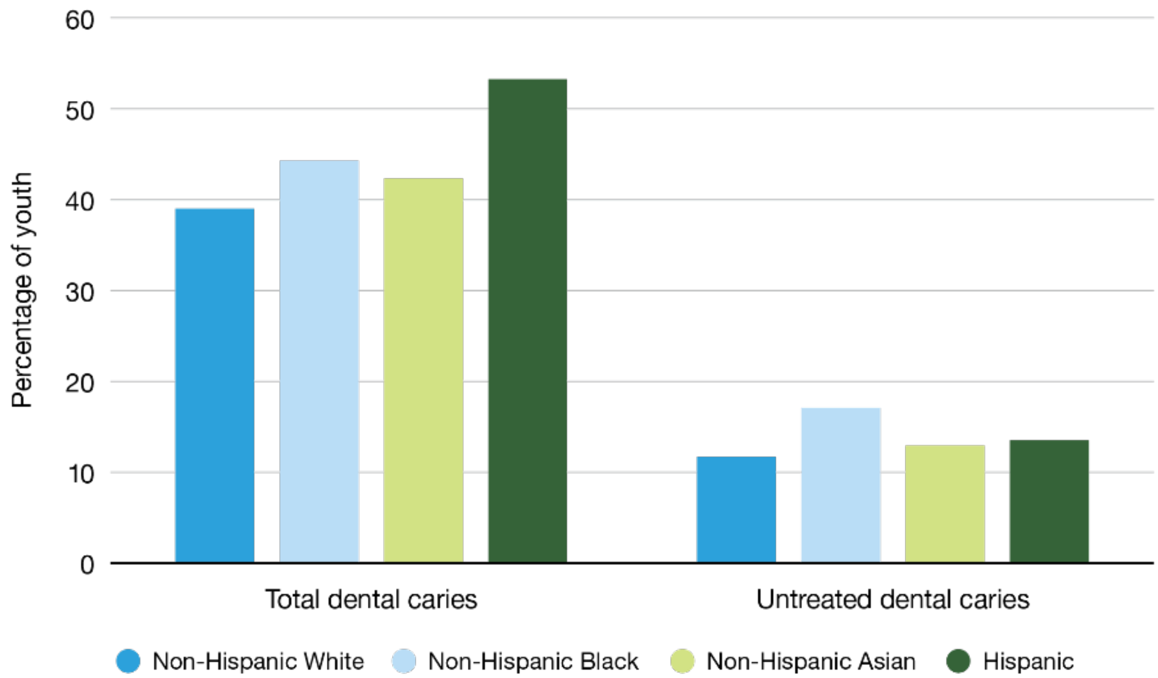
Black or African American Populations

Despite progress in past decades, more recent data show there are persistent and significant disparities in dental caries experience and untreated caries between non-Hispanic Black and non-Hispanic White populations. National Health Survey data have shown that among children and adolescents aged 2 to 19 years, the prevalence of total dental caries experience and of untreated caries were significantly higher in non-Hispanic Black youth compared with non-Hispanic White youth (Figure 5) (Fleming and Afful 2018). However, for working-age adults, dental caries were highly prevalent and consistent regardless of race/ethnicity, but substantial disparities do exist with the prevalence of untreated caries affecting 2 in 5 non-Hispanic Black adults (Figure 6). Root caries were significantly higher among non-Hispanic Blacks (40%) compared with non-Hispanic Whites (less than 20%) (Griffin et al. 2012).

Most current National Health Survey data show that the prevalence of periodontal disease among adults aged 30 years or older is higher among non-Hispanic Blacks (57%) and Mexican Americans (60%) compared with non-Hispanic Whites (37%), with severe periodontitis being more than twice as prevalent among Blacks (15%) compared to Whites (6%) (Eke et al. 2018). There also are clear disparities in tooth loss between Blacks and Whites, with complete tooth loss more prevalent among non-Hispanic Black adults 65 years or older (28%) compared with their non-Hispanic White adult counterparts (17%) (Dye et al. 2019). About 17% of Hispanics aged 65 and older are edentulous.

An analysis of 2000–2010 Surveillance, Epidemiology, and End Results incidence data showed that non-Hispanic White men had a higher age-adjusted incidence rate of oropharyngeal cancer (14.1 per 100,000) than non-Hispanic Black men (11.9 per 100,000) (Weatherspoon et al. 2015). This is contrary to the historical trend that Black men had a much higher incidence than White men (Morse and Kerr 2006). This reversal of incidence rates was linked to decreased rates of smoking and heavy alcohol use among Black men, decreased incidence rates

Figure 5. Percentage of youth ages 2–19 with total dental caries and untreated dental caries in primary and permanent teeth by race/ethnicity: United States, 2015–2016



Note: Includes dental caries in both primary and permanent teeth.
Source: Fleming and Afful (2018).

of human papillomavirus (HPV)-negative oral and oropharyngeal cancers, and an ongoing increase in the incidence of oropharyngeal cancer linked to HPV among White men and women (National Cancer Institute 2018). Non-Hispanic White women also had a higher age-adjusted incidence rate (5.3 per 100,000) than non-Hispanic Black women (4.0 per 100,000) (Weatherspoon et al. 2015).

Although the incidence trends in oral and oropharyngeal cancers have changed, disparities in survival rates persist. For example, in 2007–2013, the relative 5-year survival rate of cancers of the oral cavity and pharynx for Black men was 47%, compared with 68.7% in White men. A similar pattern was seen for Black and White women, with 60.3% and 70.1% survival rates, respectively (National Cancer Institute 2018).

Hispanic Populations

In the 1970s, ethnicity was introduced by the U.S. Census Bureau and used for categorizing Hispanics (Valdeón 2013); these were individuals who identified themselves as being of Spanish-speaking background. “Hispanic origin” currently is defined by the Census Bureau as “the heritage, nationality, lineage, or country of birth of the person or the person’s parents or ancestors before arriving in the United States. Individuals who identify as Hispanic, Latinx, or Spanish may be any race” (U.S. Census Bureau 2019). Hispanics comprise the largest ethnic group in the United States, estimated at 18.1% in 2017 (U.S. Department of Commerce 2018). Although Hispanics are of diverse heritage (Rumbaut 2006), the largest subgroup is of Mexican origin (Pew Research Center 2012; Brown and Lopez 2013). Available clinical oral health data from the NHANES has focused on the Mexican American subgroup because of an insufficient number of non-Mexican Hispanics for subgroup analysis.

Hispanic adults have a higher prevalence of oral disease than non-Hispanic Whites. Hispanic children appear to be worse off than their White counterparts on other indicators of oral or health status and access to care, based on national survey data. Analysis of the 2007 National Survey of Children’s Health (NSCH) found that Hispanic children aged 3 to 18 years had worse oral health status (based on mothers' rating as "fair or poor") and were less likely to have obtained preventive dental care services in the past year than were non-Hispanic White or Black children (Guarnizo-Herreño and Wehby 2012b). In 2016–2017 NSCH estimates, the condition of 7.2% of Hispanic children's (aged 1–17 years) teeth was characterized as "fair or poor," compared with 4.2% among non-Hispanic Whites (Data Resource Center for Child and Adolescent Health 2020).

NHANES estimates are available for Mexican Americans and those who identify as Hispanic. In the 2015–2016 NHANES, dental caries experience was highest among Hispanic youth compared to non-Hispanic Black, Asian, and White youth with more than half (57%) of youth aged 2 to 19 years having caries (Figure 5) (Fleming and Afful 2018). Based on the 2011–2016 NHANES, 37% of Mexican American adults aged 20 to 64 years experienced untreated dental caries (Figure 6) and, for Mexican American adults 65 years or older, 36% had untreated dental caries, the highest among race/ethnic groups for older Americans (Centers for Disease Control and Prevention 2019). National Health Survey data show that Mexican American adults 30 years or older had the highest prevalence of periodontal disease among all racial or ethnic groups (Eke et al. 2018).

Tooth loss is an oral health status indicator for which Hispanics appear to be doing as well as or better than other racial or ethnic groups. The prevalence of complete tooth loss among Hispanic adults 50 years or older was similar to non-Hispanic Whites (9% vs. 11%) from 2009–2014. However, larger differences benefiting Hispanics exist between them and non-Hispanic Whites living in poverty (12% vs. 28%) (Dye et al. 2019).

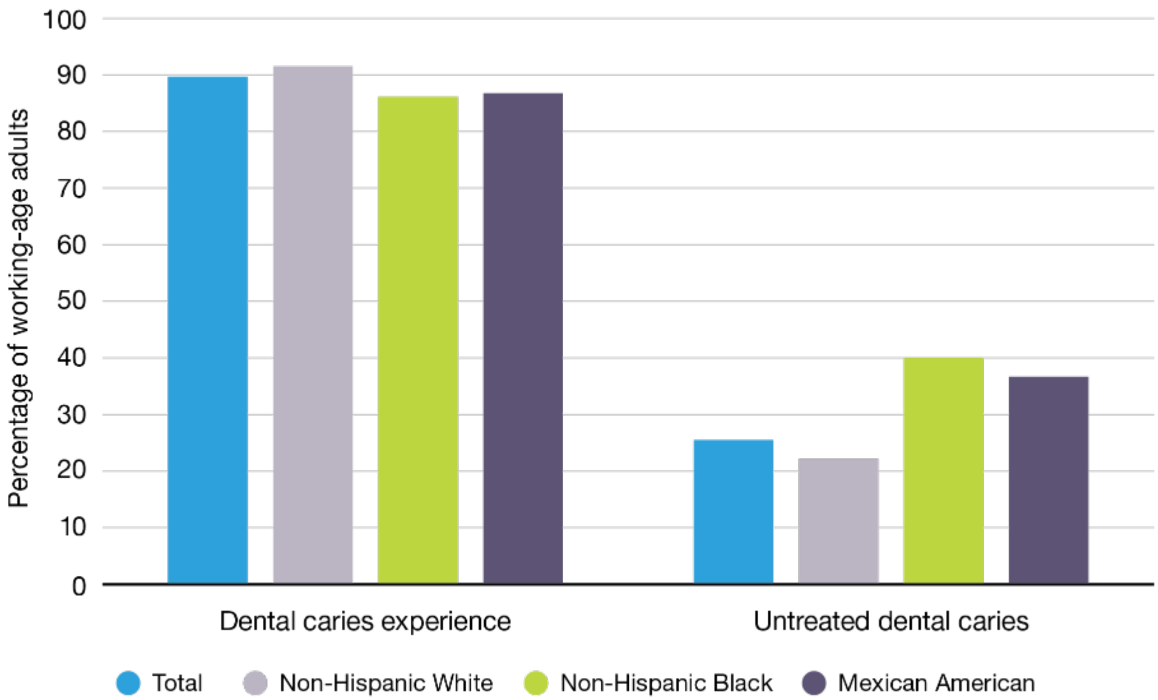
Currently, about half of Hispanic Americans were not born in the United States (Krogstad and Lopez 2014). Research with Hispanics often explores differences between U.S.-born and foreign-born people, and how those factors (e.g., duration of U.S. residence, level of acculturation, language preferences, ethnic identity) may influence health status and health behaviors. Acculturation plays a role in accessing adult dental services and may act to moderate differences in oral health behaviors and outcomes (Gao and McGrath 2010). English speakers are more likely to report a dental visit in the past year than Spanish speakers (Graham et al. 2005; Riley et al. 2008; Jaramillo et al. 2009). Spanish-speaking adults of Mexican origin in the 2009–2012 NHANES were 1.8 times more likely to have periodontitis than English speakers (Garcia et al. 2017).

A "Hispanic paradox" or "Latinx advantage" has been observed for many health conditions (McCarthy 2015), including some oral health status and related measures (Sanders 2010; Spolsky et al. 2012). Although many Hispanics live in poverty in the United States and may encounter access to care barriers, Hispanic immigrants often have better health outcomes than U.S.-born Hispanics. Better clinically assessed oral health also has been documented among Mexican immigrants compared to the U.S.-born (Spolsky et al. 2012) and the more acculturated immigrants (Gao and McGrath 2010). Better self-rated oral health quality of life also has been documented among first-generation Latino adults than among their U.S.-born Latino counterparts or Whites (Sanders 2010). However, varying elements of oral health quality of life can be influenced by the level of acculturation and Hispanic/Latino background (Silveira et al. 2020). Furthermore, a systematic review of Hispanic and immigrant paradoxes concluded that these health advantages are not consistently found across studies and groups (Teruya and Bazargan-Hejazi 2013).

American Indian and Alaska Native Populations

An estimated 5.2 million people identify as AI/AN, and about 29% live below the federal poverty line (Norris et al. 2012; Mauer 2017). For AI/AN adults, the burden of disease is greater than that of any other ethnic minority group (Batliner 2016). When compared to other racial or ethnic groups, AI/AN children aged 3 to 5 years have more than double the number of decayed teeth and nearly twice the overall dental caries experience than the next highest ethnic group, Hispanics (Mexican Americans), and almost three times that of White children (Figure 7) (Phipps et al. 2019). For AI/AN children aged 6 to 9 years, 80% have a history of dental caries compared with only 45% of the general U.S. population, and almost half of AI/AN children have untreated dental caries compared to just 17% of the general U.S. population in this age group.

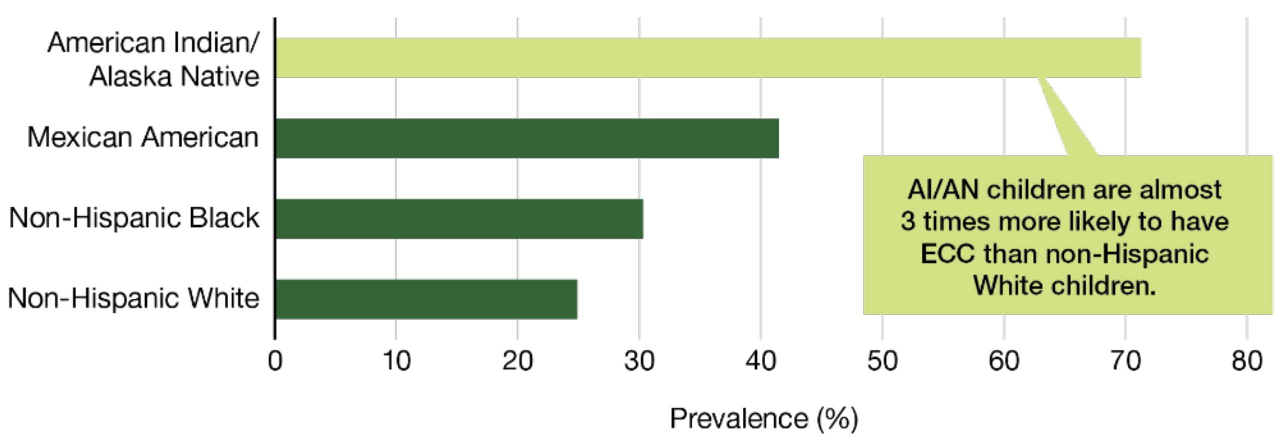
Figure 6. Percentage of adults ages 20–64 with dental caries and untreated dental caries by race/ethnicity: United States, 2011–2016



Notes: Prevalence of dental caries (DFT > 0) and untreated dental caries (DT > 0) in permanent teeth; Race/ethnicity is described as non-Hispanic White, non-Hispanic Black, and Mexican American.

Source: Centers for Disease Control and Prevention (2019).

Figure 7. Percentage of American Indian/Alaska Native (AI/AN) children ages 3–5 with early childhood caries (ECC) during 2018–2019 in relation to other same-age children in the United States by race/ethnicity during 2013–2014



Source: Phipps et al. (2019).

Severe periodontal disease was reported for 17% of AI/AN adults aged 35 years or older (28% for those who smoke), compared to 10% of U.S. adults (Phipps and Ricks 2016). Tooth loss was common in AI/AN adults aged 40 to 64 years, where loss of at least one permanent tooth occurred in 83% of AI/AN adults (Phipps and Ricks 2016), compared to 66% for adults in the U.S. population as a whole (NHANES 2011–2012) (Dye et al. 2015).

Oral Health and Structural Racism

The racial concerns that permeate American society unmistakably contribute to the oral health disparities that have been observed throughout the United States and, as described above, represent one of society's greatest challenges. Systemic, or institutional, racism is created by factors embedded in a social structure that reflects the perspectives and needs of a white majority and that, consequently, disadvantage people of color. Structural aspects of public organizations focused on education, housing, criminal justice, and health care incorporate these biases in a variety of ways (Feagin and Ducey 2014), and dental care is no exception. Black populations, Hispanics, and some other minority racial populations have much lower family incomes and experience much higher rates of poverty than does the White population (Semega et al. 2020). These financial disparities interact with the dental health care system to create major disadvantages for members of racial minority groups. Structural features of the dental care system result in high out-of-pocket costs for many, and family-level economic factors such as income, poverty status, and dental insurance play critical roles in the ability to access routine dental care (Vujicic et al. 2016a). The delivery of dental care services usually requires the ability to pay personally or through individual insurance, thereby directly limiting care to those with greater financial resources. The ability to access dental insurance, which comes more readily with higher paying and more stable employment is, in turn, also linked to race. Moreover, dental services may not be readily available in areas where many people of color live, because the structure of payment for services provides lower incentives for providers who would locate in those areas. As a major contributor to the SDoH, systemic racism also indirectly impacts oral health through various structural, sociocultural, and familial mechanisms, that, like financial and educational resources, are differentially distributed across racial groups. Historical experiences with health care that can create mistrust of the system may be linked to race as well. A scoping review of the persistence of oral health disparities of African American children (Como et al. 2019) found numerous factors had contributed to poorer oral health among African American families, including less access to affordable non-cariogenic food, fear and distrust of the care delivery system, lower health literacy, and social stigmatization.

These patterns can be seen in the few published studies of inequity in dental care. Treatment for existing dental disease, a measure of access to dental care, is highly correlated with race/ethnicity (Gupta et al. 2018). This is reflected by the national data that show clearly that African American, AI/AN, and Hispanic populations all have higher rates of untreated dental caries and tooth loss, as well as poorer access to preventive services (Koppelman 2016a). Dentists' treatment decisions, too, have been shown to be affected by unconscious racial bias; for example, in a randomized clinical study of tooth restorability, treatment recommendations were found to favor extractions over root canal treatment for Black patients (Patel et al. 2019). Adding to these broad social problems, the profession of dentistry reflects substantial underrepresentation of Black dentists in the workforce (Mertz et al. 2017).

Increasing the diversity of the dental workforce could contribute in important ways to oral health equity through changes in dental practice arrangements (Mertz et al. 2016b) and enhanced patient trust and satisfaction with care (Cooper et al. 2003).

Impact of COVID-19 on Oral Health Inequities

The coronavirus (COVID-19) pandemic has upended every aspect of life and has clear and significant implications for the inequities related to oral health and access to dental care that are the focus of this chapter. Inequities related to COVID-19 have already been theoretically and empirically identified in terms of the risk of acquiring the disease, experience with the disease, the ability to access testing and be treated for the disease, mortality associated with the disease, outcomes associated with interventions that limit transmission of the disease, and access to the personal protections provided by governments to facilitate survival during the pandemic.

Sadly, this is not surprising. It would make sense that, like almost all other diseases, medical conditions and/or associated preventive or curative treatments, exposure to SARS-CoV-2, and the outcomes of COVID-19 would be socially patterned and influenced by the social and commercial determinants of health.

In turn, such vulnerability may worsen existing inequities in oral health and access to dental care. The economic effects of COVID-19 have resulted in loss of work, income, insurance, and opportunity for individuals and families, which as this chapter has shown, are all causally linked to poor oral health and lack of access to dental care, whether at the individual or population level. Without appropriate supports, a racially, socially, and/or economically marginalized family may not have enough income to secure a healthy diet, will experience significant psychosocial stress, and will have less access to the benefits of dental care, all of which increase the risk for acquiring oral diseases and increasing their negative outcomes. Such a damning state of affairs represents a vicious cycle that engenders poverty and the loss of personal security, prosperity, and dignity (Armitage and Nellums 2020; Gausman and Langer 2020; Ji et al. 2020; Schmitt-Grohé et al. 2020; van Dorn et al. 2020; Van Lancker and Parolin 2020; Wang and Tang 2020; Yancy 2020; Yao et al. 2020).

Oral Health for Those with Special Health Care Needs

HRSA's Maternal and Child Health Bureau defines children with SHCN as "...those who have or are at increased risk for a chronic physical, developmental, behavioral, or emotional condition and who also require health and related services of a type or amount beyond that required by children generally" (McPherson et al. 1998; U.S. Department of Health and Human Services 2013 p. 5). Children with SHCNs become adolescents and adults with SHCNs and experience challenges throughout their lives. According to the 2017–2018 NSCH, about 1 in 6 children from birth to 17 years (18.51%) in the United States, or 13.6 million children, has SHCNs (Child and Adolescent Health Measurement Initiative 2020). In addition, an estimated 26% of U.S. adults, or 61 million people 18 aged years or older, have some type of disability (Okoro et al. 2018).

As the population of the United States is becoming more diverse, the incidence of SHCNs increasingly applies to persons with varying ethnic, racial, linguistic, and cultural backgrounds. It also includes individuals whose social living situations are restricted because of dependency needs or other factors that prohibit them from living in the community. These individuals include, but are not limited to, people residing in long-term care and institutional facilities, and prison settings. The presence of a special need, as described in this section, has a profound impact on the ability of an individual to function in society and on the organization, function, and economics of many societal structures.

Individuals with SHCNs may be at increased risk for oral diseases throughout their lives (Child and Adolescent Health Measurement Initiative 2020). Oral diseases can have a significant impact on the health and quality of life of those with certain systemic health problems or conditions. Patients with compromised immunity or cardiac conditions associated with endocarditis may be especially vulnerable to the effects of oral diseases (Thikkurissy and Lal 2009). Persons with physical, mental, and developmental disabilities who do not have the ability to understand, assume responsibility for, or cooperate with preventive oral health practices are susceptible, as well (Charles 2010; American Academy of Pediatric Dentistry 2016).

SHCNs also include disorders or conditions that manifest only in the orofacial complex (such as amelogenesis imperfecta, dentinogenesis imperfecta, cleft lip/palate, or oral cancer) (Charles 2010). Although these individuals may not exhibit the same physical or communicative limitations as other people with SHCNs, their needs are unique, impact their overall health, and require oral health care of a specialized nature (Charles 2010).

The importance of oral health care for individuals with SHCNs also was highlighted in the 2000 Surgeon General's Report on Oral Health and in Healthy People 2020 (U.S. Department of Health and Human Services 2000; 2010a). The Healthy People 2020 objectives included increasing the number of states (and the District of Columbia) that have an oral and craniofacial health surveillance system—a system for recording and referring infants and children with cleft lips and palates—and a system for referring such children to rehabilitative teams.

Oral Health in Correctional Settings

The United States has the highest incarceration rate in the world, with 2.3 million people incarcerated annually (Sawyer and Wagner 2019). Incarceration disproportionately affects people of color and those of low socioeconomic status. Incarcerated individuals are the only individuals in the country with a legal right to health care, a precedent that has been ruled to include access to timely dental treatment (Nolasco and Vaughn 2019). Nonetheless, incarceration is associated with higher rates of chronic illness, serious mental illness, infectious disease, and a lower life expectancy (Wildeman and Wang 2017). These health conditions have shared behavioral and socioeconomic risk factors with poor oral health. Rates of dental disease are similarly elevated in incarcerated populations.

Compared to the noninstitutionalized population, individuals residing in correctional facilities have higher rates of untreated decay, worse periodontal health, and a higher prevalence of urgent dental needs; the number of decayed, missing, or filled teeth in this population is 17.0–22.1 in adults and 3.6 in juveniles (Mlxson et al. 1990; Clare 1998; Heng 2000; Bolin and Jones 2006). Although oral health status may improve somewhat during the period of incarceration, presumably because of increased access to dental care while incarcerated, prevalence of untreated disease remains high even after 3 years of incarceration (Clare 2002). In the 2004 Bureau of Justice Statistics Survey of Inmates in State Correctional Facilities (now known as the Survey of Prison Inmates), 60% of respondents reported having a dental problem during incarceration, and only 80% of adults in prison with a dental problem reported seeing a dentist (Nowotny 2017; Maruschak 2019).

Financing Dental Care

The dental care financing mix continues to differ significantly from that of medical care. In 2019, Centers for Medicare & Medicaid Services (CMS) programs accounted for 37% of medical care spending, with out-of-pocket payments accounting for 11% and private medical insurance, 31% (Centers for Medicare & Medicaid Services 2019a). In contrast, 10% of costs for dental care were paid by a CMS source, 40% were paid out of pocket, and 46% were covered by private dental insurance in 2018 (see Figure 3, Section 4 in this monograph) (Centers for Medicare & Medicaid Services 2020a). Dental care spending has grown more slowly than overall medical care spending with dental care accounting for 3.7% of total health care spending in the United States in 2017, compared to 4.5% in 2000 (American Dental Association 2017).

The cost of dental care remains an obstacle for many Americans, with dental care consistently presenting the highest financial barrier of any health service in the United States (Vujicic et al. 2016a). Dental insurance alleviates this concern for some, and in 2018, roughly 80% of Americans had some form of private or public dental coverage (National Association of Dental Plans 2020). However, dental insurance coverage varies substantially by age group in the United States with the percentage of coverage declining with age (see Section 2A, Figure 36). The majority of Americans, about two-thirds, received coverage through employment-based plans or through organizations like AARP, and a small percentage (around 10%) purchased coverage through private dental plans or as part of a medical plan (National Association of Dental Plans 2020). In 2018, publicly funded dental insurance provided coverage for roughly one-fourth of Americans through a variety of programs, including Medicaid, the Children's Health Insurance Program (CHIP), the Veterans Health Administration, the U.S. Department of Defense (DoD), the Indian Health Service, and others.

The result is that dental insurance coverage, when available, consists of a patchwork of public and private plans that vary widely in eligibility requirements, the benefits provided, and the availability of participating dentists. Moreover, many of those with dental insurance still incur high out-of-pocket costs. In 2018, about 66.7 million Americans had no dental coverage with a dentally uninsured rate of 2.5 times higher than the medically uninsured rate (National Association of Dental Plans 2020). For those without coverage, routine dental care is often financially out of reach. For example, older adults are less likely to have employment-based dental insurance, yet as of this writing, Medicare, the primary provider of medical insurance for individuals aged 65 years and older, does not include routine dental care in its mandated services.

Having dental insurance, either public (Medicaid) or private, has been shown to improve access to dental care. Among older adults, having private insurance increased preventive service use by 25% and having Medicaid coverage increased major service use by 36% (Meyerhoefer et al. 2019). Expansion of dental coverage in Medicare also is estimated to improve access to dental care for older adults (Kreider et al. 2015). Insurance coverage alone will not be sufficient to increase access to dental services for older adults, however. Other factors, such as having an accessible and sufficient dental professional workforce, a culture of self-care and utilization of health care, and social support, particularly for older adults, must accompany improvements in dental care financing. Current federal government-sponsored dental health insurance programs include Medicaid and CHIP. Medicaid provides health coverage for millions of Americans, including eligible low-income adults, children, pregnant women, older adults, and people with disabilities. Medicaid is administered by states, according to federal requirements, and jointly funded by states and the federal government. CHIP provides health coverage to eligible children through both Medicaid and separate CHIP programs. To date, nearly all state Medicaid programs have expanded dental program services and are implementing a variety of models aimed at increasing dental care access and capacity for a growing number of eligible individuals, although earlier expansion had benefited children more than adults. There are currently two states that do not provide a Medicaid dental benefit to the adult base population (Figure 8) (Center for Healthcare Strategies, 2019).

Having dental insurance has been shown to provide a substantial increase in children's use of needed dental services, resulting in less untreated disease. Importantly, children enrolled in public insurance programs such as Medicaid or CHIP have been shown to receive the greatest benefit in terms of access and disease reduction, compared to those who are not publicly insured (Yu et al. 2017). Moreover, when Medicaid coverage is offered to adults there is some evidence that the benefits go beyond increased access to care and include improved oral health, improved job outcomes, and possibly decreases in oral health disparities (Kieffer et al. 2021). Additional discussion on dental insurance can be found in Section 4.

In addition to dental insurance, the federal government supports funding for direct patient care through the Health Resources and Services Administration (HRSA). HRSA's mission is to improve health outcomes and address health disparities through access to quality services, a skilled health workforce, and innovative, high-value programming (Health Resources and Services Administration 2019a). The agency provides primary health care to the geographically isolated and to the economically or medically vulnerable, such as people with HIV/AIDS, pregnant women, and mothers. HRSA supports the training of health professionals, the distribution of providers to areas where they are needed most, and improvements in health care delivery.

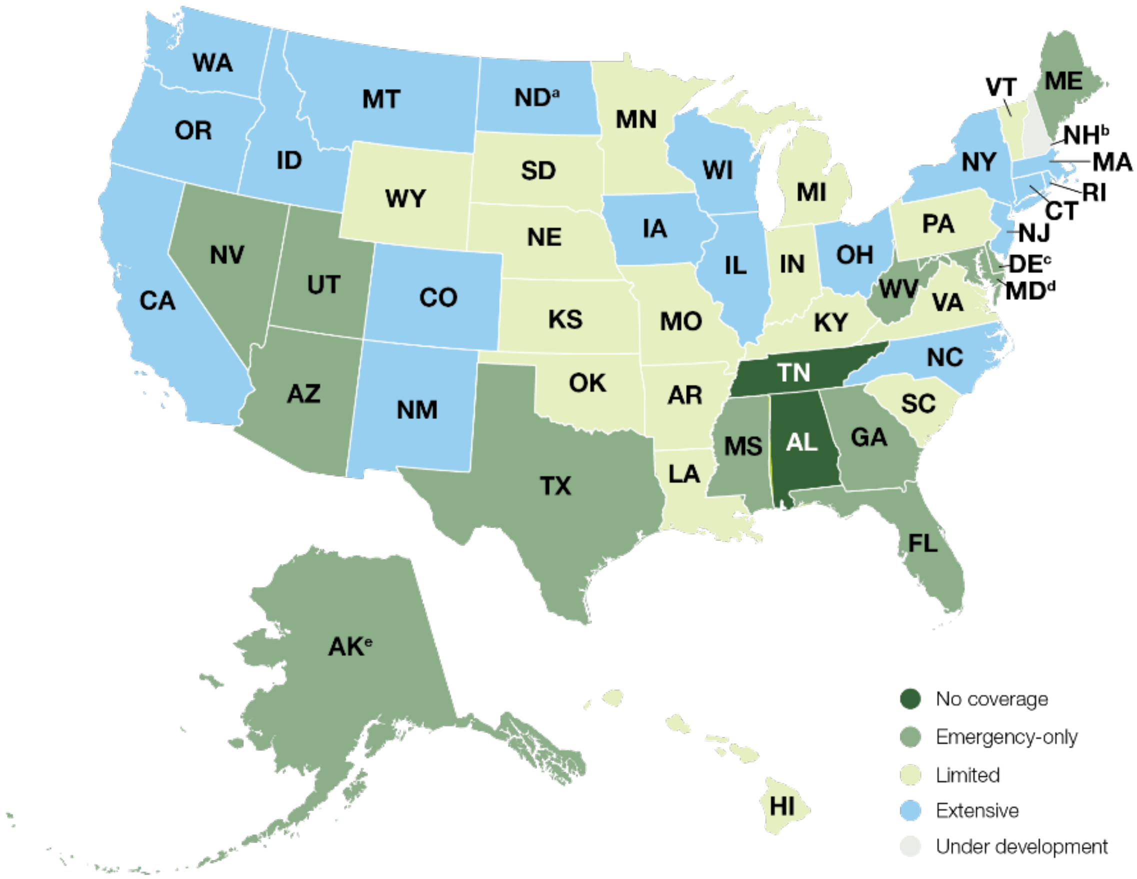
Dental Care Delivery Models

The delivery of dental care occurs in a wide variety of settings using different models of care that vary with respect to their financing and workforce structure. Dentists typically work in settings that include private practice, armed forces and other federal services (e.g., Public Health Service, U.S. Department of Veterans Affairs [VA]), Federally Qualified Health Centers (FQHCs), state or local government employees, dental school faculty and staff and hospital personnel, and a variety of other health/dental organizations. Licensed dentists also are enrolled as graduate students, interns, and residents. Detailed information on the members of the dental team is provided in Section 4.

Private Practice

In the United States, private practice has been and remains the predominant setting in which most Americans receive dental care. In 2018, an estimated 93% of dentists reported that private practice was their primary care delivery setting (American Dental Association 2020a). This proportion has been roughly stable since 2000, and private practice remains the career aspiration for most current dental students (Wanchek et al. 2015).

Figure 8. Status of Medicaid adult dental benefit coverage by state: United States, 2019



Notes:

[a] North Dakota does not offer adult dental benefits to its Medicaid expansion population.

[b] Under New Hampshire's bill, the Department of Health and Human Services is directed to develop a "comprehensive plan to ensure that Medicaid recipients can safeguard their smiles and their overall health."

[c] Under Delaware's bill, the state will offer preventive and restorative dental coverage to adult Medicaid beneficiaries.

[d] Maryland offers treatment for symptoms in emergency situations but does not cover emergency surgery.

[e] Alaska's state budget was passed, keeping adult dental coverage intact; however, the Governor's line-item vetoes in the budget will result in cuts to the state's Medicaid program, including dental, unless the legislature moves to rescind them.

Source: Center for Health Care Strategies (2019).

However, there have been changes to the structure of typical private practices since 2000. Namely, the proportion of dentists in solo practice has declined from 64% in 2000 to 50% in 2018, as dentists increasingly practice in larger group settings (American Dental Association 2021). There also is a growing interest among dental students in salaried positions in corporate or non-profit organizations (Wanchek et al. 2015).

Federally Qualified Health Centers

The federal Health Center Program (HCP) is authorized in Section 330 of the Public Health Service Act of 1944 (42 U.S.C. Sections 201 et seq.) and is administered by HRSA. FQHCs form a cornerstone of the health care safety net. They are required to provide health care to all individuals regardless of their ability to pay and must be located in geographic areas with relatively few health care providers (Heisler 2015; Crall et al. 2016). HRSA funds nearly 1,400 health centers operating more than 13,000 service delivery sites. Nearly 29 million people in every state, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and the Pacific Basin rely on HRSA-funded health centers for care. In 2020, HRSA's HCP provided primary health care to 1 in 11 individuals of all ages in the United States, 1 in 9 children, 1 in 5 rural residents, 1 in 3 people living in poverty, and more than 376,000 veterans (Health Resources and Services Administration 2021a). Most of these patients were publicly insured for medical care: 46.9% were covered by Medicaid/CHIP, 10.4% by Medicare, and 21.8% were uninsured (Health Resources and Services Administration 2021a). These groups generally face substantial barriers to oral health care access, thereby underscoring the importance of additional investments geared toward expanding the oral health care capacity at more FQHC sites.

FQHCs have become an important dental care access point for vulnerable populations. An estimated 25% of low-income dental care patients received their care at an FQHC in 2017, compared to 7% in 2001. In 2020, HRSA's HCP facilities provided more than 11.3 million dental visits to nearly 5.2 million patients (Health Resources and Services Administration 2021b). Most of these patients were publicly insured for medical care—46.9% were covered by Medicaid/CHIP, 10.4% by Medicare, and 21.8% were uninsured (Health Resources and Services Administration 2021a). These groups generally face substantial barriers to oral health care access, thereby underscoring the importance of additional investments geared toward expanding the oral health care capacity at more FQHC sites.

Nearly 93% of HRSA's health center grantees provide preventive dental services either on-site or by paid referral (Health Resources and Service Administration 2021b).

School-Based Health Centers and School-Based Dental Programs

School-based health centers (SBHC) are systems of interdisciplinary health services provided to students within pre-K–12 schools (school-based centers) or at offsite health facilities linked to the schools (school-linked centers). SBHCs often are established in schools that serve predominantly low-income communities. They must provide primary health care and also may include mental health care, social services, dentistry, immunizations, reproductive health services for adolescents, substance abuse counseling, complex case management—including management of such chronic illnesses as asthma and obesity—and nutrition and general health education. Student participation requires parental consent.

The 2013–2014 Census of SBHCs showed that there were 2,315 SBHCs nationwide, and 18% of SBHCs had oral health professionals on site. School-based oral health programs provide a range of services that encourage an ongoing relationship with a dentist, including oral health education and promotion, dental screenings and referrals, dental sealants, fluoride mouth rinses or tablets, fluoride varnish applications, case management, and restorative treatment. Advantages of school-based oral health programs include improvements in access to dental care, timelier oral health care for children with unmet treatment needs, positive peer modeling, the elimination of barriers (such as lack of transportation and need for parental time off from work), and fewer missed school days for dental appointments. The majority of school-based oral health programs are operated by dental organizations or state oral health programs and are funded by state and local governments (including state block grants), corporations, private foundations, and billings to Medicaid, CHIP, private insurance, and patients' families. Challenges in this setting include school leadership and staff buy-in, dependence on parental consents, care coordination for further treatment, and quality assurance tracking.

The Community Preventive Services Task Force (CPSTF), whose members are appointed by the Centers for Disease Control and Prevention (CDC), was established in 1996 to identify evidence-supported population health interventions that can save lives, increase lifespans, and improve quality of life (Community Preventive Services Task Force 2021). CPSTF recommends the implementation and maintenance of SBHCs in low-income communities, based on evidence that they improve educational and health outcomes and that their societal benefits are greater than the intervention costs (Community Prevention Services Task Force 2016a). CPSTF also recommends school-based sealant delivery programs based on evidence that dental sealants resulted in a significant reduction in tooth decay among school children aged 5 to 16 years and the economic benefits of this reduction exceeded the cost of the programs (Community Preventive Services Task Force 2016b).

Veterans' Health Administration

Although veterans usually qualify for health benefits from VA, most do not qualify for dental care. Dental services offered through VA facilities are more limited than medical services and are restricted to certain categories of veterans. Currently, less than 5% of the total U.S. veteran population is eligible to receive dental care from VA (U.S. Department of Veterans Affairs 2019). Because Medicare does not cover dental care and so few are eligible to access VA oral health services, many veterans—most of whom are older—have unmet dental needs. Overall, veterans have a higher prevalence of periodontal disease, dental caries, and missing teeth, compared to non-veterans, but this higher prevalence is strongly associated with membership in other groups at high risk for poor oral health (older adults, smokers, males, and diabetics) (Schindler et al. 2021). As a group, veterans' unmet oral health care needs are primarily related to periodontitis (Schindler et al. 2021).

The VA Office of Dentistry provided oral health care to more than half a million U.S. military veterans in fiscal year 2018, totaling 1.7 million visits. VA dental clinics provide care at 236 sites. These dental clinics are staffed by 3,500 dental team members made up of more than 1,000 dentists, 400 dental hygienists, and 1,500 dental assistants. VA manages the dental care of veterans through both in-house care and community provider networks. Twenty-one percent of veterans' dental care was provided by community care providers in 2018. Since 2000, the number of VA dental patients has increased 73%. In the past 8 to 10 years, the number of veterans needing dental care has risen nearly 24%. VA dentistry has responded to that challenge with a similar increase in dentists and a 33% increase in dental hygienists. Veterans seeking care through VA dental clinics often have a higher disease burden than the general adult population (Boehmer et al. 2001; Jurasic et al. 2014).

Teledentistry

Telehealth is the delivery of health care and the exchange of health care information across distances. Teledentistry is the application of telehealth to dentistry, using health information technology and telecommunications for oral care, consultation, education, and public awareness with the broad goal of improving oral health (Daniel and Kumar 2014).

The American Dental Association (ADA) defines telehealth as a broad variety of technologies and tactics to deliver virtual medical, health, and education services—not a specific service, but a collection of means to enhance care and education delivery (American Dental Association 2020b). In 2018, two teledentistry codes were added to the Current Dental Terminology code set, which will facilitate both inclusion of relevant services in dental practice and the relationship between dental care providers and relevant payer organizations. These two codes distinguish the two modalities commonly used in telehealth care. Synchronous telehealth is live videoconferencing—a two-way video link between a patient and health care provider. Asynchronous telehealth refers to "store and forward" transmission of health information for later review by a health care provider (Office of the National Coordinator for Health Information Technology 2020). For additional information about teledentistry, see Sections 4 and 6.

Teledentistry and telehealth studies and some few systematic reviews conducted in the United States and abroad agree that telehealth interventions appear generally equivalent to in-person care (Nutalapati et al. 2011; Khan and Omar 2013; Alabdullah and Daniel 2018; Shigekawa et al. 2018). High levels of validity and reliability have been found when comparing diagnostic information and treatment planning outcomes for midlevel screeners and a dental expert panel. In addition, providers and patients reported high levels of satisfaction with telehealth encounters (Estai et al. 2016a; Estai et al. 2016b).

The global pandemic of COVID-19, a coronavirus spread by short-range aerosol, contact, and droplet transmission, has been responsible for millions of cases of severe illness and hundreds of thousands of deaths worldwide since its emergence in late 2019 (Johns Hopkins University & Medicine 2021). This pandemic disrupted the delivery of dental care throughout the United States, leading to the closure of most of the nation's dental care facilities or restriction of services to emergency care only (American Dental Association 2020c). The sudden and widespread closure of most sources of oral health care led to a rapidly increased interest in teledentistry and its largely untapped potential (Emami 2020; Maret et al. 2020). Although there are no definitive data regarding the extent of teledentistry efforts during the COVID-19 pandemic, there are reports in the popular press that suggest widespread use of various teledentistry models throughout the country (Wicklund 2020).

Medical Settings

Interest continues to grow regarding the role of non-dental health care providers delivering dental services in non-dental settings. The value of this approach to dental service delivery is still being determined, but the rationale is clear. More Americans visit a physician than a dentist annually. Thus, integration of dental services into the primary care setting may better serve the needs of at-risk patient groups, particularly young children for whom pediatric well-child visit schedules result in 12 medical office visits before age 3. In addition, when medical personnel engage with patients over oral health issues, it can increase awareness among all parties about the importance of oral health to overall health and provide a rationale for closer coordination and integration of medical and dental care delivery (Haber et al. 2015; Vujicic 2015a).

Impact of COVID-19 on Dental Practice

The ADA Health Policy Institute has been examining the economic impact of COVID-19 on dentists in private practice, as well as those working in public health settings. When the White House Coronavirus Task Force, CMS, and CDC were recommending delaying elective dental care in March 2020, the vast majority of dentists were seeing only emergency cases. Informal reports indicate that during this period, many dentists and dental team members were supporting other departments by providing testing and screening services related to COVID-19.

The overall economic impact to the dental care sector of delaying elective care has been devastating. According to the Bureau of Labor Statistics, dentistry lost more than half a million jobs in April 2020 (U.S. Bureau of Labor Statistics 2020). ADA Health Policy Institute data indicate that 45% of dentists in private practice were not paying any of their staff in April (American Dental Association 2020d). Dentists in public health settings were not immune either, with 29% reporting being paid partially or not at all in April (American Dental Association 2020e).

Early forecasts of the medium- to long-term economic impact of COVID-19 on the dental economy suggest anywhere from a 30% to 66% reduction in U.S. dental spending in 2020 and up to a 30% reduction in 2021 (Nasseh and Vujicic 2020). However, these early analyses assumed a very gradual and slow U-shaped economic recovery in the United States and a lagging dental sector recovery. Early data on reopening suggest these early estimates were pessimistic. In other words, the data on the first 3 weeks of reopening—spanning May 4 through the end of the week of May 18, 2020—showed that patient volumes and economic activity in dental offices were rebounding (American Dental Association 2020b). Data for the week of May 18 indicated that, on average, patient volume in private practices was up to 38% of pre-COVID-19 levels. Looking only at the 27 early opener states (those that opened in late April through the first week of May 2020), patient volume had rebounded to 54% of pre-COVID-19 levels by the third week after reopening. Thus, the recovery data, at least in the first few weeks, suggests cautious optimism.

Beyond the economic impact, COVID-19 is likely to have a lasting impact on dental practices, both in private and public settings. Beyond the new protocols for personal protective equipment, innovations such as teledentistry are likely to remain in place. ADA Health Policy Institute data indicated that 24% of dentists in private practice had used and billed for teledentistry during the period when elective care was postponed (American Dental Association 2020f). COVID-19 also is likely to accelerate other trends in dentistry, such as practice consolidation.

The Burden of Oral Disease

Oral Health and the Economy

At the societal level, the impact of oral disease on economic activity and work participation often is underestimated or poorly understood. The annual total costs of dental disease at the global level in 2015 were estimated to be US$545.4 billion (Righolt et al. 2018). Among the 21 WHO Global Burden of Disease regions, the highest levels of per capita productivity losses were found for Western Europe, Australasia, high-income

North America, high-income Asia Pacific, and Central Europe. Severe tooth loss (having fewer than nine remaining natural teeth) accounted for 67% of global productivity losses because of dental diseases, followed by severe periodontitis (a Community Periodontal Index score of 4, a clinical attachment loss more than 6 millimeters [mm], or a gingival pocket depth more than 5 mm) at 21%, and untreated caries at 12% (Marcenes et al. 2013).

Listl and colleagues (2019) note that poor oral health can limit both the ability to secure employment and workplace productivity. These authors point to research suggesting that the appearance of the mouth and teeth influences hiring practices and earnings (Hamermesh and Biddle 1994; Harper 2000). For example, one study estimated that improved oral health enhanced earnings among U.S. women by 4%, with low-income women seeing the biggest effect (Glied and Neidell 2010). Another analysis found that 29% of low-income adults and 60% of low-income adults living in states that did not provide dental benefits to adults in Medicaid reported that the appearance of their mouth and teeth affected their ability to interview for a job (American Dental Association 2015a). Evidence from Canada indicated that improved oral health among social assistance recipients led to better job-seeking empowerment (Singhal et al. 2015a).

Research also has indicated that the appearance of a person's teeth may influence what characteristics others ascribe to them, such as intelligence, honesty, or leadership potential, and could affect employability (Henson et al. 2011; Pithon et al. 2014). Moreover, this link is strongest among low-income individuals. As Listl and colleagues (2019) argue, "with the resulting improvements in population oral health and overall wellbeing, such measures imply substantial economic benefits not only in terms of potentially reduced treatment costs and appropriate use of healthcare resources, but also due to fewer productivity losses in the labor market and beyond."

Globally, untreated oral disease has been considered one of the 10 leading causes of years lived with disability (Institute for Health Metrics and Evaluation 2016), contributing to missed workdays and reduction in usual activity (Australian Research Centre for Population Oral Health 2012). Moreover, dental pain has been demonstrated to predict productivity losses (Hayes et al. 2013). Overall productivity losses in the United States associated with untreated oral disease were estimated to be $45.9 billion in 2015, with the United States ranking highest among 195 countries (Righolt et al. 2018). In 2008, an estimated 67.5% of adults aged 18 years or older reported lost work or school hours because of unplanned dental visits, a total of 92.4 million lost hours for nonroutine care (Kelekar and Naavaal 2018). Furthermore, limited cross-sectional studies have found that parents of children who have a history of dental pain are more likely to report having missed work or school because of their child's dental problems (Seirawan et al. 2012; Ribeiro et al. 2015).

In addition, oral health issues have an impact on academic achievement among students, in turn, influencing the choices they make in adulthood. For many years oral health professionals have often circulated "51 million" as a statistic to quantify the expected number of missed school hours for children because of dental problems. Indeed, this number appears in the Surgeon General's report on oral health, published in 2000. Since that time, additional research has shown that U.S. children with poor oral health were more likely to have absences from school, poor grades, and self-image issues (Pourat and Finocchio 2010; Seirawan et al. 2012; Guarnizo-Herreño and Wehby 2012a). For example, the odds of children with dental problems completing all required homework were 24% less than children without dental problems (Guarnizo-Herreño and Wehby 2012a). Data based on students in the Los Angeles Unified School District indicated that students with toothaches were almost four times more likely to have a low grade-point average. About 11% of students who did not have access to needed dental care missed school, compared with 4% of those with access. For every 100 elementary and high school youth, 58 and 80 school hours, respectively, were missed each year as a result of dental problems (Seirawan et al. 2012). However, these reported hours also included missing school for nonurgent dental appointments.

Parents averaged 2.5 days absent from work or school per year because of their children's dental problems (Seirawan et al. 2012). These relationships are especially prevalent among disadvantaged children. For instance, in 2007, 59% of children in California with no dental insurance missed 2 or more days of school because of dental problems, compared with 33% of children with private dental benefits and 43% with public dental benefits (Pourat and Nicholson 2009). A systematic review reported an association between measures of poor oral health and poor academic performance. The authors cautioned, however, that the current evidence is of low quality (based on inconsistent methodology) and highlight the need for further research (Ruff et al. 2019). Although the actual number of hours missed from school or work because of serious dental problems or oral pain may not be known, the impact to the individuals and families affected is pronounced and consequential. As explained in an earlier commentary regarding the "51 million" lost hours, it's not the statistic that is important, but the real people affected by the pain and discomfort from the disease that matters (Edelstein and Reisine 2015).

Medical Costs

There is strong evidence linking oral health to overall health. Numerous studies have demonstrated associations between periodontal disease and conditions such as diabetes, heart disease, pregnancy outcomes, and dementia, although clear causation has been difficult to establish. Setting aside possible biological relationships, health services research has shown some beneficial effects of periodontal disease treatment on overall health care costs. However, the results are mixed. Several studies have shown that when periodontal therapy is provided to members of a health plan, overall costs for all health care decrease (Jeffcoat et al. 2014; Nasseh et al. 2017; Pihlstrom et al. 2018), whereas others have suggested the interpretation of findings from these types of studies needs to consider some limitations before drawing any definitive conclusions (Sheiham 2015; Pihlstrom et al. 2018).

Emergency Departments

The use of EDs to receive care for dental-related problems is an important concern to the U.S. health care system. For example, among all encounters at the Virginia Commonwealth University Health System ED during 2007–2009, 4.3% were for dental-related problems, more than half were uninsured (52%), 40% had Medicaid or Medicare, and only 8% had private health insurance (McCormick et al. 2013). During this period, national statistics estimated that ED visits for dental problems accounted for at least 1% of all ED visits, with uninsured patients accounting for nearly 41% of the encounters (Allareddy et al. 2014).

In 2014, there were 2.43 million ED visits for nontraumatic dental conditions (NTDC), representing more than $1.6 billion in charges; the average charge per visit was $994 for adults and $971 for children (Kelekar and Naavaal 2019). NTDC ED visit rates are highest among young adults and individuals who are uninsured or have Medicaid coverage. Medicaid was the primary payer for these visits, accounting for 67% of visits by children and 36% of visits by adults (Kelekar and Naavaal 2019). Analyses of national trends found that NTDC ED visits exceeded the growth rate for ED visits overall and for nondental ambulatory care-sensitive conditions (Lee et al. 2012; Okunseri et al. 2012a). NTDC visits represent significant costs in terms of both health outcomes and health care delivery system resources.

Care provided in the ED for NTDC is rarely comprehensive or curative. For instance, an estimated 90% of patients received only pain medication or antibiotics (Okunseri et al. 2012b; McCormick et al. 2013), and most patients were referred to dental providers for treatment of underlying disease (Lewis et al. 2003; Cohen et al. 2011; Hocker et al. 2012). Moreover, the majority of patients who sought dental treatment at an ED were doing so for nonurgent conditions that could have been treated at dental offices (Wall and Vujicic 2015). Because ED care is primarily palliative, it is essential to link patients to a source of dental care after the ED visit. Yet, evidence suggests this does not happen routinely. For example, fewer than half of Medicaid- and CHIP-enrolled children in Florida and Texas had a follow-up visit with a dental provider within 30 days of a dental ED visit (Herndon et al. 2017), and 48% of Medicaid-enrolled adults in Iowa did not have a dental visit within 6 months of a dental ED visit (Singhal et al. 2016). Although dental coverage may contribute to reducing dental-related ED visits (Cohen et al. 1996; Singhal et al. 2015b; Laniado et al. 2017), reduction of other barriers to accessing dental care, such as provider availability, also needs to be addressed (Fingar et al. 2015). In states opting to provide dental coverage for adults through Medicaid, adults are more likely to use routine dental service (Decker and

Lipton 2015), have a reduced likelihood of untreated dental decay with fewer broken or missing fillings (Decker and Lipton 2015), and have less periodontal disease (Silverstein 2015).

Oral Health and National Security

Maintaining the health status of members of the armed services is critical for ensuring an effective military force. Each branch of the armed services maintains a dental component charged with ensuring that dental conditions do not degrade military readiness. From this perspective, providing oral health care is essential for maintaining military readiness because service members are not deployable until they meet dental readiness criteria (Assistant Secretary of Defense for Health Affairs 2002). When concern arose over the large percentage of dental conditions and emergencies among service members (15% per year), DoD added dental readiness as one of the six categories of military readiness in 2002 (Lee et al. 2019).

The DoD dental readiness classification (DRC) system helps assess the oral health of personnel, with the following four levels of DRC for service members: 4 – Requires an annual examination because their dental readiness is unknown; 3 – Has some type of oral condition that is likely to result in a dental emergency within 1 year (these individuals are not considered to be worldwide deployable); 2 – Requires clinical preventive dental care or treatment for some type of oral condition which is unlikely to develop into a dental emergency within the next year (these individuals are considered to be worldwide deployable); and 1 – No dental treatment needed and are worldwide deployable (Assistant Secretary of Defense for Health Affairs 2002; King 2008; Assistant Secretary of Defense for Manpower & Reserve Affairs 2018). The predictive power of this classification system is reasonably good; for example, soldiers who were DRC 3 were up to 8 times more likely to have a dental emergency during field operations or deployment than soldiers who were DRC 1 (Chaffin and Moss 2008).

Dealing with dental injury and disease in a combat environment presents challenging logistical issues and must be properly managed to prevent loss of combat effectiveness. A RAND Corporation study of dental readiness noted the high cost in personnel time, and hence combat effectiveness, that result from dental emergencies in a combat zone (Brauner et al. 2012). The authors of the RAND study reported that, "a dental emergency can require three convoy vehicles with up to nine personnel for security in-theater for the sole purpose of medical evacuation" (Brauner et al. 2012 p. 3). Estimates of expected rates of dental emergency in deployed military members vary widely, depending on pre-deployment readiness and deployment length. Chaffin and Moss (2008) reported that rates between 156 and 170 dental emergencies per 1,000 deployed Army personnel should be expected. Monetary costs of dental injuries in deployed U.S. Army troops found that direct costs of dental conditions (nonbattle injury) totaled $21.9 million from July 1, 2010, through June 30, 2011; 32% of these injuries required additional follow-up care during a 2-year period (Colthirst et al. 2013).

Even in garrison, soldiers experience significant levels of dental treatment needs. The 2016 Sample Survey of Military Personnel showed that Army troops frequently experienced oral health-related difficulties that affected their daily lives (U.S. Army Research Institute for the Behavioral and Social Sciences 2016). Dental pain affected 23.5% of enlisted soldiers in garrison, and oral problems prevented 16.5% from eating certain foods, 26% from sleeping, and 20.6% from concentrating on work, and forced 14% to miss work because of sick call or healing time in quarters (Simecek et al. 2014).

The extent to which oral health affects military readiness of active-duty members varies by service branch and activity (i.e., combat, deployment, or garrison). All service branches are required to sort out the oral health status of incoming recruits and each service branch maintains its own oral health-related criteria for accepting new recruits. Poor oral health among potential recruits leads to either their disqualification for service or the need for costly dental treatment.

The U.S. Navy Dental Corps maintains dental readiness for a population of 327,577 active-duty sailors serving in the U.S. Navy and 185,830 active-duty marines serving in the U.S. Marine Corps across the world (Assistant Secretary of Defense for Manpower & Reserve Affairs 2018). The Navy Dental Corps comprises 1,125 active-duty dentists serving on a variety of platforms, including ships, Marine Corps bases, Navy Mobile Construction

Battalions, and overseas and shore facilities (Assistant Secretary of Defense for Manpower & Reserve Affairs 2018). According to the Navy Bureau of Medicine and Surgery, Navy dental clinics provide more than 1,485,000 patient visits annually. All dental care is provided free of charge.

The U.S. Army Dental Corps workforce comprises a mixture of military, government service, and contracted civilians. This workforce consists of 1,170 dentists, 263 registered hygienists, 154 prophylaxis (tooth cleaning) technicians, and 2,801 dental assistants. Dentist-to-population ratios guide workforce determinations in the Army Dental Corps. Variations in the size of the active-duty soldier population or the proportion of non-Army treatment-eligible patients who receive treatment from Army dental facilities present challenges for developing and managing an effective dental workforce. For example, during 2018, there were nearly 417,600 active-duty soldiers, but active-duty Army soldiers composed 80% of the population treated; others eligible to receive treatment included members of the National Guard and Reserve, retirees, and family members. Thus, an estimate of the average eligible population is closer to 522,000, with the estimated dentist-to-population ratio between 1:500 and 1:600. Because poor oral habits are common in this population, about one-third of soldiers are prone to developing new dental treatment needs every year; consequently, the larger cadre of oral health providers will likely be needed for some time to come (Joint Chiefs of Staff 2018).

The U.S. Air Force Dental Corps consists of more than 900 active-duty general dentists and specialists, along with nearly 2,000 enlisted dental assistants, hygienists, and laboratory technicians who serve in group practices at 76 Air Force bases around the world. They provide dental care for more than 300,000 active-duty airmen and numerous additional DoD beneficiaries, totaling nearly 1.3 million dental visits annually.

The general trend toward improved oral health of U.S. adults is not fully reflected in U.S. military recruits. On average, about 17% of potential Army recruits are found to have disqualifying medical conditions upon examination, and about 44% of those identified are granted waivers for their conditions (Joint Chiefs of Staff 2018). As a result, an estimated 10% of those examined are rejected for medical conditions. In 2008, the DoD Recruit Oral Health Study (Leiendecker et al. 2011) found that only 25% of new recruits did not require restorative dental treatment, which was a marginal improvement from 20% in the 1994 study. Nearly 53% of 2008 Army recruits were DRC 3 and could not deploy until their conditions had been treated, an increase from 33% in 1994 and 42% in 2000. Data from 2018 revealed that out of 94,516 new recruits examined, 21,971 (23.3%) were placed in DRC 3 (Military Health System 2019). To ensure that most of the new recruits were deployable, the Army has implemented a program called First Term Dental Readiness (FTDR), which attempts to treat all incoming DRC 3 conditions. The FTDR program has succeeded in meeting the 95% readiness goal set by DoD Health Affairs, with a DRC 3 prevalence of 4.66% among graduating soldiers for 2018 (Gourley 2018).

Fewer than 1% of potential Air Force recruits are rejected because of significant dental caries or severe malocclusion. However, of those new recruits who do enter the Air Force, nearly all have some level of unmet dental treatment needs and about a quarter (23%) suffer from severe oral conditions that prevent them from deploying (Irwin 2019a). In 2001, nearly half (45%) of airmen had either DRC 2 or DRC 3 oral health conditions that required treatment.

Today, all branches of the service report that roughly 90% of their personnel are DRC 1 or 2, and therefore dentally ready to deploy. Managing dental problems during field training or deployments, however, remains a major focus of military dentistry. Dental problems have accounted for between 5–22% of all sick-call patients presenting to U.S. Army field medical treatment facilities (Allen and Smith 1992; Nasser and Storz 1994; Dunn 2004; Darakjy et al. 2006). The top three oral conditions that affected soldiers during deployment were dental caries (including the pulpal disease caused by it), periodontal disease, and painful or infected third molars (Simecek et al. 2014). Wojcik and colleagues (2015) noted that incidence figures for dental disease and non-battle injuries (DNBI) for Iraq and Afghanistan operations (Joint Chiefs of Staff 2018) were much higher than the DNBI rates they had previously found among admissions for other medical conditions. In the most recent systematic review of the impact of dental conditions on military readiness, Lee and colleagues (2019) estimated that nearly 12% of all troops deployed to hostile environments will experience a dental emergency or an oral-maxillofacial injury with dental emergency rates varying by service and duty environment (Figure 9).

The National Defense Authorization Act of 2017 began the process of shifting responsibility for delivering the health care benefit for military beneficiaries from individual services to a single, mostly civilian-run organization, the Defense Health Agency (DHA) (National Defense Authorization Act 2016). This ongoing effort cedes the management and control of all nondeployed or afloat military treatment facilities (MTF) to DHA, with the services providing much of the clinical and administrative staffing. Consolidating three service medical enterprises into one is intended to improve business practices and reduce duplication as part of DoD's effort to reform business practices. Uniformed health care providers will be loaned to DHA-managed MTFs to maintain clinical skills and for educational purposes.

Oral Health and Quality of Life

Good oral health is fundamental for overall health and well-being. It contributes to effective chewing and healthy nutrition, speech, social confidence, and—in the case of older adults—better cognitive and functional capacity (World Health Organization 2002; Petersen and Yamamoto 2005; Stewart et al. 2008; Scannapieco and Cantos 2016). The WHO Active Ageing Policy Framework supports the maintenance of oral health as a key piece in the overall strategy to foster active aging (World Health Organization 2002).

In moving away from a disease-based focus toward a biopsychosocial model, the broader determinants of health were recognized in an updated definition for oral health adopted by the World Dental Federation in September 2016 (Box 1) (Glick et al. 2016). This definition has implications for clinical practice and policy.

Dental, periodontal, and mucosal diseases typically are chronic in nature and tend to accumulate during a lifetime. Objective measures of dental disease status, such as the Decayed Missing and Filled Index (Klein et al. 1938) or the International Caries Detection and Classification System (Ismail et al. 2007), and such measures as periodontal probing depths (Holtfreter et al. 2015) are useful for staging disease severity and planning treatment. However, these clinically derived measures fail to capture how patients experience both disease processes and treatment. It is now widely acknowledged that disease affects individuals differently. Each person's perception of well-being, pain, physical function—their quality of life—varies based on personal and sociocultural factors (Baiju et al. 2017).

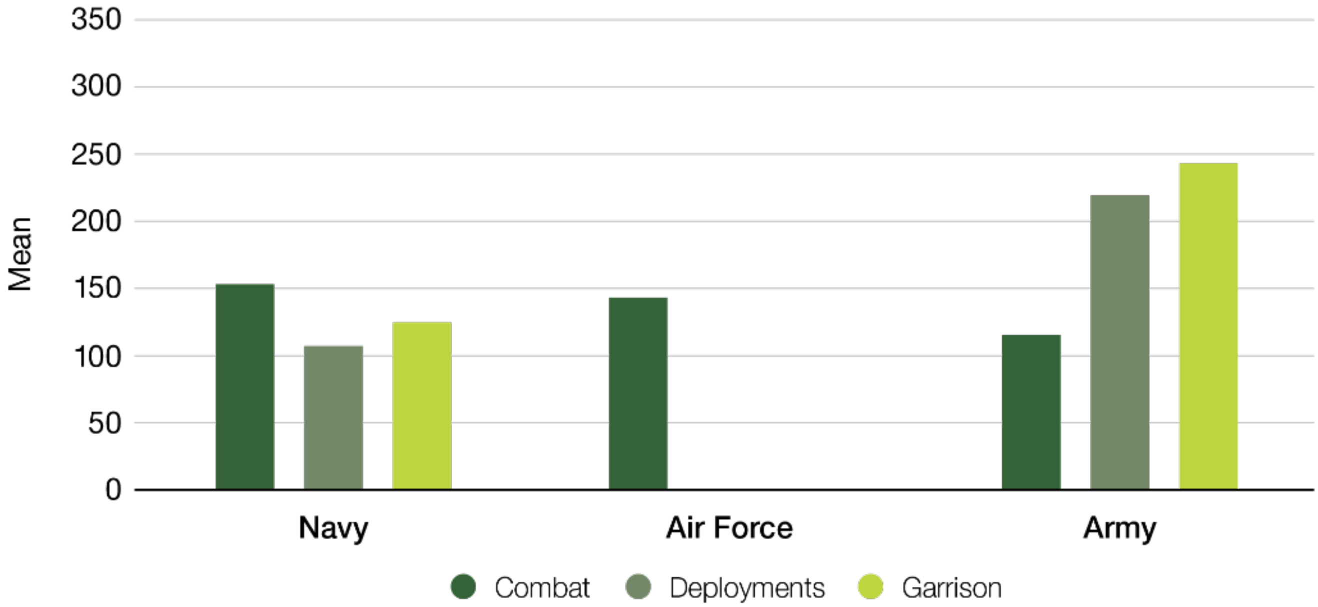
Assessing quality of life is important for guiding public health interventions and for providing a foundation for patient-centered care. Quantitative measures of health-related quality of life are now in common use in descriptive population surveys and clinical intervention studies.

Oral Health Promotion and Oral Health Literacy

Health promotion is "the process of enabling people to increase control over, and to improve, their health" (World Health Organization 1986). Oral health promotion activities include individual behaviors, such as eating healthy foods and brushing teeth, as well as health care provider behaviors, such as adhering to prescribing guidelines and counseling patients to quit smoking. They also include public policies and programs, such as public health insurance programs, dental sealant programs, and media campaigns to discourage smoking (Griffin et al. 2017) and to encourage community water fluoridation (Horowitz 1996). Health promotion programs often are developed to help individuals make healthy decisions, generally through education and communication to raise awareness about healthy behaviors.

How a health promotion message is communicated will affect a person's understanding and community actions. For example, messages that use jargon or highly technical words may lessen the patient's understanding. Nine in ten adults reported having difficulty understanding basic health information (Institute of Medicine 2004). This is because individuals have different levels of health literacy, which is "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Ratzan and Parker 2000, p. vi).

Figure 9. Dental emergency rates by military service and environment: United States, 1966–2012



Notes: Means and standard deviations of dental emergency (DE) rates by service and environment. Number of DE rates reported for each environment and service: Navy: Combat N = 6; Deployed N = 3; Garrison N = 1. Air Force: Combat N = 3. Army: Combat N = 10; Deployed N = 3; Garrison N = 5. Mean = average annual DE rate per 1,000 personnel per year.

Source: Lee et al. (2019).

Low health literacy is associated with lower use of preventive care, poorer health, and higher mortality rates compared to individuals with adequate health literacy (Berkman et al. 2011). The knowledge of, and ability to, understand benefits and payments associated with medical and dental insurance, also known as health insurance literacy, influences the use of dental care (Paez et al. 2014).

Older adults are more likely to have low health literacy compared to younger adults (Macek et al. 2011). Social determinants also have been associated with health literacy disparities (Sørensen et al. 2012; Shin et al. 2013). Blacks, Hispanics, and people for whom English is not their first language are more likely to have low health literacy compared with White and Asian/Pacific Islander adults and with adults who are native English speakers (Kutner et al. 2006; Lee et al. 2011; Kobayashi et al. 2015; Macek et al. 2017; Baskaradoss 2018).

Across populations, individuals with lower oral health literacy are more likely to have poorer oral health status (Jamieson et al. 2013; Baskaradoss 2018) and are less likely to follow preventive oral health care recommendations (Parker and Jamieson 2010; Mejia et al. 2011) and to miss dental appointments (Holtzman et al. 2013). Whether a direct, causal relationship exists between oral health literacy and dental visits is not known, in part because low health literacy corresponds closely with other predictors of access to dental care, such as education, dental insurance, and income.

Quality of Oral Health Care

Transformation in the Quality Landscape

Over the past 20 years, many advances have been made across the public health landscape to improve the quality of programs and services. These advances have made their way to commercial and government programs focused on the development of quality measures for dentistry. Federal and state public health and delivery system programs are using quality measures to improve program performance. Such measures now are being used to drive *quality assurance*, as well as *quality improvement* processes. These steps support achievement of the Institute for Healthcare

Improvement's Triple Aim for Populations by applying integrated approaches to simultaneously improve the health of populations, enhance the experience of care for individuals, and reduce the per capita cost of health care (Berwick et al. 2008).

The 2000 Surgeon General's report on oral health noted the lack of performance measures for assessing the oral health care delivery system. More than a decade later, the National Academy of Sciences and the National Academy of Medicine (formerly the Institute of Medicine [IOM]) issued reports focused on oral health and highlighted persistent access barriers and disparities in care. In doing so, they also brought into sharper focus the need for quality measurement and identified the lack of quality measures as a primary barrier to improving the quality of oral health care (Institute of Medicine 2011; Institute of Medicine and National Research Council 2011). The IOM's report, *Leadership by Example: Coordinating Government Roles in Improving Health Care Quality*, noted that in "providing leadership to effect the needed changes in health care, the federal government should take full advantage of its unique position as a regulator, purchaser, health care provider, and sponsor of research, education, and training" (Institute of Medicine 2003, p. 6). Although Medicare, as a large public program, has the ability to drive market change, it has limited influence on dentistry because dental benefits are rarely provided through Medicare. Medicaid and CHIP, on the other hand, cover close to 40% of U.S. children and thus have the market power to effect change (Rudowitz et al. 2019).

In response to growing recognition of the need for dental quality measures, in 2009, the CHIP Reauthorization Act directed CMS and the Agency for Healthcare Research and Quality (AHRQ) to convene a representative group of stakeholders to develop health care measures for dentistry. CMS petitioned ADA to take a leadership role in this effort, which triggered the formation of the Dental Quality Alliance (DQA). DQA's mission is "to advance performance measurement as a means to improve oral health, patient care, and safety through a consensus-building process" (Dental Quality Alliance 2019).

DQA has since accepted the definition of quality set forth by IOM as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge" (Institute of Medicine 2001, p. 44). This definition addresses both individuals and populations, connects care delivery to outcomes, and is grounded in the best available knowledge. Thus, quality can be assessed at different levels within the care delivery system, including the clinician/practice level, facilities (for example, hospitals), Managed Care Organizations (MCO), and public insurance and public health programs. Currently, there are three adult and a dozen pediatric DQA quality measures related to oral health (Table). AHRQ's National Quality Measures Clearinghouse has identified five clinical quality and population health measure domains: access, structure, process, outcomes, and patient/population experience (Agency for Healthcare Research and Quality 2019). These domains form the framework for quality measurement across both the public health and health care delivery systems, including those for dentistry.

Given that dental public health and dental delivery systems operate different types of programs and services, measures and metrics developed for one type of program may not be suitable for another. In addition, measures developed for use at the plan level may not be suitable at the provider level. Several measures developed in recent years demonstrated this challenge to state program policymakers when they were tested in various dental environments (Dental Quality Alliance 2019).

Using Quality Measures to Improve Care

Over the past several years, DQA, educational institutions, and MCOs have developed dental quality measures for use by Medicaid and CHIP dental programs. Such efforts have led the way toward advancing value-based programming and value-based care. In the quest for value for the dental care dollar, both CMS and state Medicaid administrators are seeking to understand whether the Medicaid system enables the delivery of quality oral health/dental health care services to program beneficiaries and improved population health management through medical-dental integration. Measures that have been developed and used by Medicaid programs during the past decade typically assess *access* and specific *utilization of preventive services*.

Table. Dental Quality Alliance (DQA) Administrative claims-based measures

Measure Name	Description	Measure Domains
Pediatric Measures		
Utilization of Services	Percentage of all enrolled children under age 21 who received at least one dental service within the reporting year	Access/Process
Preventive Services for Children at Elevated Caries Risk	Percentage of all enrolled children who are at "elevated" risk (i.e., "moderate" or "high") who received a topical fluoride application and/or sealants within the reporting year	Related Health Care Delivery: Use of Services
Treatment Services	Percentage of all enrolled children who received a treatment service within the reporting year	Related Health Care Delivery: Use of Services
Oral Evaluation	Percentage of enrolled children under age 21 who received a comprehensive or periodic oral evaluation within the reporting year	Process
Topical Fluoride for Children at Elevated Caries Risk	Percentage of enrolled children aged 1–21 years who are at "elevated" risk (i.e., "moderate" or "high") who received at least 2 topical fluoride applications within the reporting year	Process
Sealant Receipt on Permanent 1st and 2nd Molars (by age 10 or by age 15)	Percentage of enrolled children who have received a sealant on permanent first molar by age 10 and percentage of enrolled children who have received a sealant on a permanent second molar by age 15 within the reporting year	Process
Care Continuity	Percentage of all children enrolled in two consecutive years who received a comprehensive or periodic oral evaluation in both years	Process
Usual Source of Services	Percentage of all children enrolled in two consecutive years who visited the same practice or clinical entity in both years	Access/Process
Ambulatory Care Sensitive Emergency Department Visits for Dental Caries in Children	Number of emergency department visits for caries-related reasons per 100,000 member months for all enrolled children	Outcome
Follow-Up after Emergency Department Visits for Dental Caries in Children	Percentage of ambulatory care sensitive emergency department (ED) visits for dental caries among children 0–20 years in the reporting period for which the member visited a dentist within (a) 7 days and (b) 30 days of the ED visit	Process
Per Member Per Month Cost of Clinical Services	Total amount that is paid on direct provision of care (reimbursed for clinical services) per member per month for all enrolled children during the reporting year	Related Health Care Delivery: Efficiency and Cost
Adult Measures		
Periodontal Evaluation in Adults with Periodontitis	Percentage of enrolled adults aged 30 years and older with history of periodontitis who received a comprehensive or periodic oral evaluation or a comprehensive periodontal evaluation within the reporting year	Related Health Care Delivery: Use of Services
Ongoing Care in Adults with Periodontitis	Percentage of enrolled adults aged 30 years and older with a history of periodontitis who received an oral prophylaxis OR scaling/root planing OR periodontal maintenance visit at least 2 times within the reporting year	Process
Topical Fluoride for Adults at Elevated Caries Risk	Percentage of enrolled adults aged 18 years and older who are at "elevated" risk (i.e., "moderate" or "high") who received at least 2 topical fluoride applications within the reporting year	Process

Source: American Dental Association. Dental Quality Alliance, 2022.

These measures help program administrators determine the degree to which program beneficiaries are receiving essential preventive dental services, whether health plans are promoting such quality services, and whether providers across their networks are centering care around primary prevention.

In 2020, CMS updated one of two oral health care measures within the Core Set of Children's Health Care Quality Measures for Medicaid and CHIP (CMS Child Core Set): receipt of sealants on first permanent molars replaced the former measure—dental sealants for children aged 6 to 9 years who are at elevated dental caries risk (SEAL-CH) (Centers for Medicare & Medicaid Services 2021a). The second measure —percentage of eligible children who received preventive dental services (PDENT-CH)—remained. While reporting of the Child Core Set measures currently is voluntary, it will become mandatory in 2024 (Center for Medicaid and CHIP Services 2020).

It should be noted, however, that dental program quality measurement continues to be hampered by limited infrastructure and capacity to effectively assess oral health status and the oral health care outcomes of beneficiaries. The current dental coding system, which does not account for patient-level oral health status and dental diagnostic information, is a primary contributor to this problem. Although other more advanced dental coding systems with diagnostic codes currently exist, the shift to such data systems has not yet been implemented at the dental care delivery level.

The move to Medicaid managed care and accountable care by state Medicaid dental programs has supported quality improvement across state Medicaid programs. In 2016, 68% of Medicaid beneficiaries were enrolled in comprehensive care programs, including some that provided dental benefits, and 9.7% of the total Medicaid population were enrolled in limited-benefit dental prepaid ambulatory health plans, including dental-only benefit plans (Medicaid and CHIP Payment and Access Commission 2021b). Within Medicaid managed care, a key lever for quality improvement is the requirement that states incorporate performance improvement projects (PIP) in their contracts with MCOs. A PIP is a quality improvement effort designed to address identified gaps in clinical or nonclinical aspects of care delivery, with the goal of achieving significant and sustained improvement through targeted interventions. To achieve this, MCOs must propose interventions and submit measurable objectives with metrics and adhere to strict timelines used by states to monitor performance and success. Such measures often are tied to financial incentives and disincentives. As such, the need for relevant, valid, and reliable oral health performance measures cannot be overstated.

As the current health care environment evolves, performance measures will be necessary to support plan and provider performance incentives, pay-for-performance programs, and population-based payments. The existing DQA measures provide a start. Monitoring their utility will be essential to ensure validity across all aspects of program measurement. From 2017 to 2019, CMS assisted three states under its Medicaid Innovation Accelerator Program to develop models to align payment with oral health care improvement goals. Such models will align payment with oral health care improvement goals (Centers for Medicare & Medicaid Services 2019b).

More recently, a move has emerged to identify and work with high-risk individuals with chronic conditions to measure the value of dental care based on the degree to which dental services may advance overall health and support medical care. These patients may seek dental care while still experiencing other critical health care gaps. Integrating medical screenings into dental visits provides the opportunity to identify high-risk medical patients and link them to care or programs that support and address SDoH. Measures for these types of programs are under development in some states. They do not yet exist at the national consensus level.

Chapter 2: Advances and Challenges

The oral health status of Americans, in general, has been improving since the 2000 Surgeon General's report on oral health (Rozier et al. 2017). Dental caries severity in the permanent teeth of children has declined to historically low levels, and long-standing inequalities in untreated caries appear to be narrowing. Declines in caries prevalence affecting children's permanent teeth have stabilized at a low level and likely will contribute to future reductions in caries experience in adults. Although the prevalence of periodontal disease is high in adults, only a small percentage have severe forms of the disease. Tooth loss as a consequence of dental disease has declined markedly during the last half century and has been all but eliminated in high income groups.

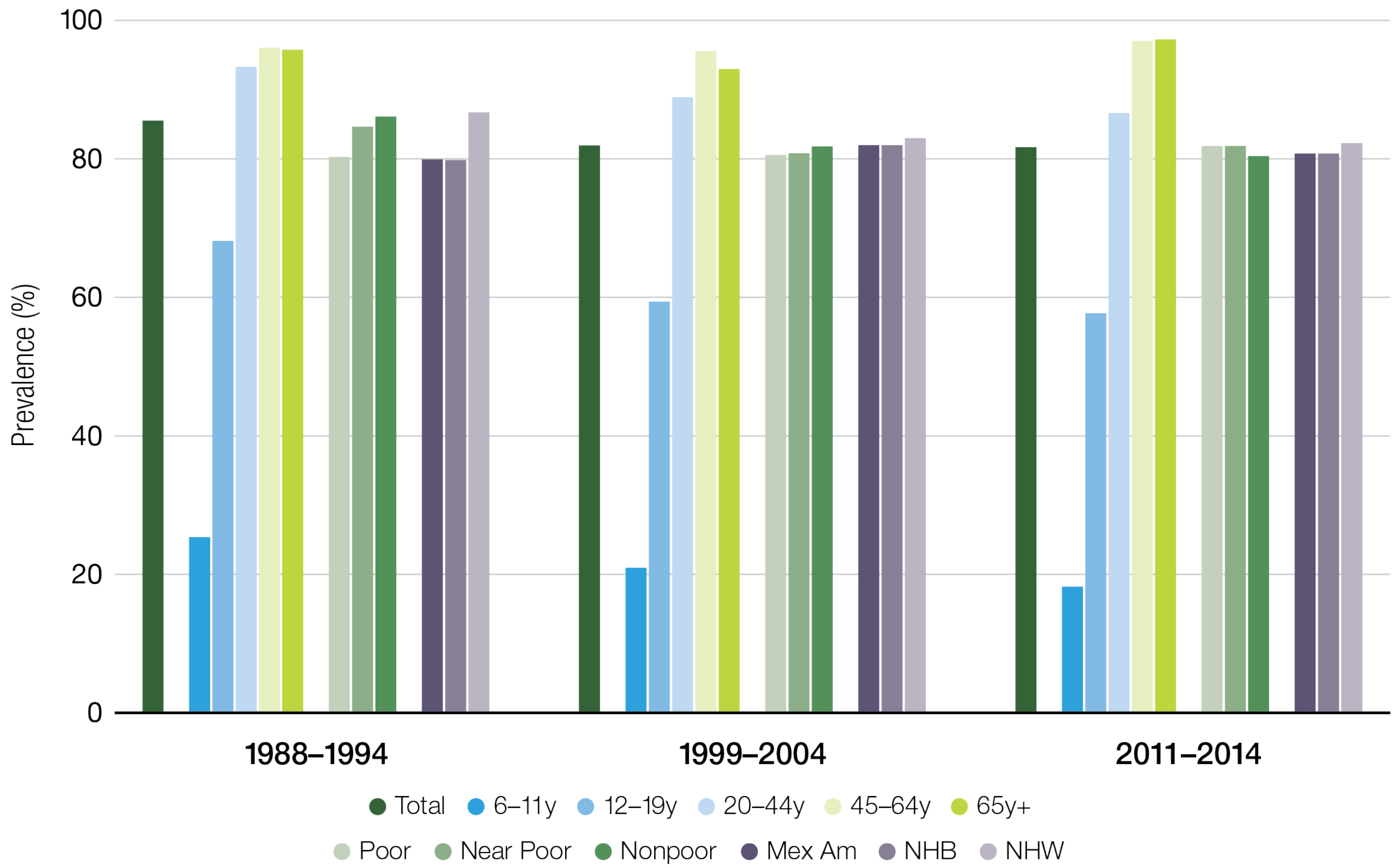
Although oral health is improving nationally, significant concerns persist. Dental caries, periodontal disease, and tooth loss remain significant public health concerns. As a nation, at least 4 out of 5 Americans aged 6 years and older have experienced tooth decay, irrespective of poverty or race/ethnicity status (Figure 10). The prevalence of dental caries increases as Americans age, and this has remained unchanged for the past 2 decades. But the overall prevalence of dental caries is starting to show a downward trend, especially among people younger than 45 years (Figure 10). However, most of this progress has only been realized for those living in households at 200% or higher of Federal Poverty Guidelines.

Overall, the prevalence of untreated dental caries in permanent teeth has not changed since the release of the 2000 report, with nearly 25% of all Americans aged 6 and older affected by untreated caries (Figure 11). Although untreated caries has declined for children, it has increased for working-age adults during this period. The prevalence of untreated caries is higher among working-age adults compared to children, adolescents, and older adults. Untreated caries among those living in poverty remains about twice that for those not living in poverty and disparities continue to persist by race/ethnicity status. These collective experiences clearly suggest that challenges persist in preventing dental caries in permanent teeth from occurring at the population level in the United States. Advances in reducing the loss of permanent teeth because of dental disease have been substantial. In general, tooth loss has been on the decline for all Americans in recent decades (Slade and Sanders 2017). When the Surgeon General's report on oral health was published, people aged 6 years and older had on average six teeth missing attributable to dental disease, whereas now that has been reduced by half (from nearly six, to about three mean teeth lost) (Figure 12). Among all age groups, improvements in tooth loss have affected older adults the most, decreasing from about 16 missing teeth to less than 11 missing teeth. Although the decreases in mean tooth loss are also occurring across all income levels, significant differences between those living in poverty and those who do not still exist. The complete loss of teeth (edentulism) still affects 18% of adults aged 65 years or older in 2009–2014, with those living in poverty twice as likely to be edentulous, compared to those not living in poverty (Dye et al. 2019). Additional information on advances and challenges influencing oral health status across the lifespan is provided in Sections 2 and 3 of this monograph.

Improvements in access to oral health care services have been observed steadily for the last 2 decades and have primarily helped children increase access to preventive and restorative care. State Medicaid and the Children's Health Insurance Program (CHIP) have substantially facilitated the use of dental services among poor and near-poor children and adolescents (Centers for Medicare & Medicaid Services 2020b). A near-doubling of the percentage of children with public dental insurance from 1996 to 2015 resulted in a 15-point increase to 88% in any dental coverage among all children (Ku et al. 2013; Steinmetz et al. 2014). For older adults aged 65 and older, modest increases in both public and private dental insurance coverage decreased the proportion uninsured from 68% to 62%, whereas the percentage of working-age adults aged 19 to 64 years with no dental insurance increased slightly from an estimated 33% to 35% (Nasseh and Vujicic 2016a).

Progress in expanding public coverage for youth, which has contributed to the decrease in the numbers of uninsured children, has also paralleled a considerable reduction in out-of-pocket dental expenditures for children (from mean of $155 to $100) and for adolescents (from mean of $444 to $418) between these two periods (Figure 13). However, with no change in dental insurance coverage for older adults, mean out-of-pocket expenses have continued to climb even after adjusting for inflation (2015 dollars) from $539 to $568. This mean out-of-pocket expenditure relationship observed for children and older adults persists for overall mean dental expenses as well. The mean reduction in total dental expenses for children was nearly $62 between these two periods ($438 to $376) whereas for older adults there was a mean increase in overall dental expenses to nearly $851 from $731, after adjusting for inflation (Figure 14). The ongoing lack of dental benefit/insurance coverage remains a persistent challenge and is a growing dental public

Figure 10. Percentage of individuals ages 6 and older with dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental caries (DMFT > 0). NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American. FPG = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

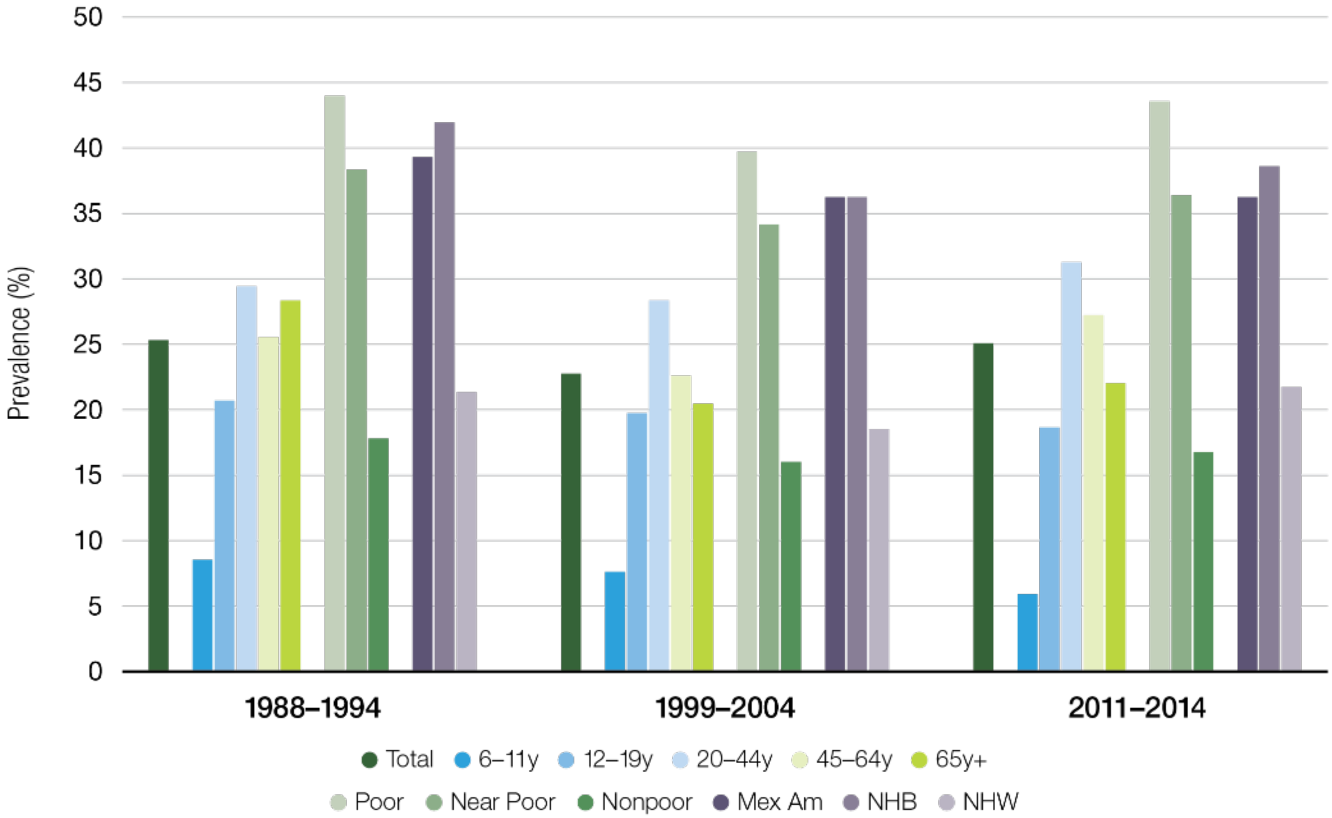
Source: CDC. National Health and Nutrition Examination Survey, public use data, 1988–1994,1999–2004, 2011–2014.

health problem. Because older adults are much more dependent on a fixed income, continual increases in out-of-pocket dental expenditures, along with increasing overall costs for dental care, will result in increasing deferred dental care when substantial improvements in tooth retention are occurring for an aging population that is increasing in numbers in the United States.

Social and Commercial Determinants of Health

Since 2000, emphasis on the role of social determinants of health (SDoH) (Figure 3) has increased substantially. Traditionally, risk factor identification for oral diseases, such as caries or periodontal disease, focused heavily on individual-level choices and behaviors such as oral hygiene behaviors, diet, and tobacco use. It is now widely accepted that SDoH need to be considered true risk factors with causal links to oral health outcomes. Risk factors generally are considered to be exposures that are statistically and causally related to a health outcome (Burt 2001). The result has been a growth in the epidemiological conceptualization of where health risk factors arise and an associated improvement in research methodology that supports the study of multilevel social determinants alongside lifestyle and biological risk factors.

Figure 11. Percentage of individuals ages 6 and older with untreated dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014

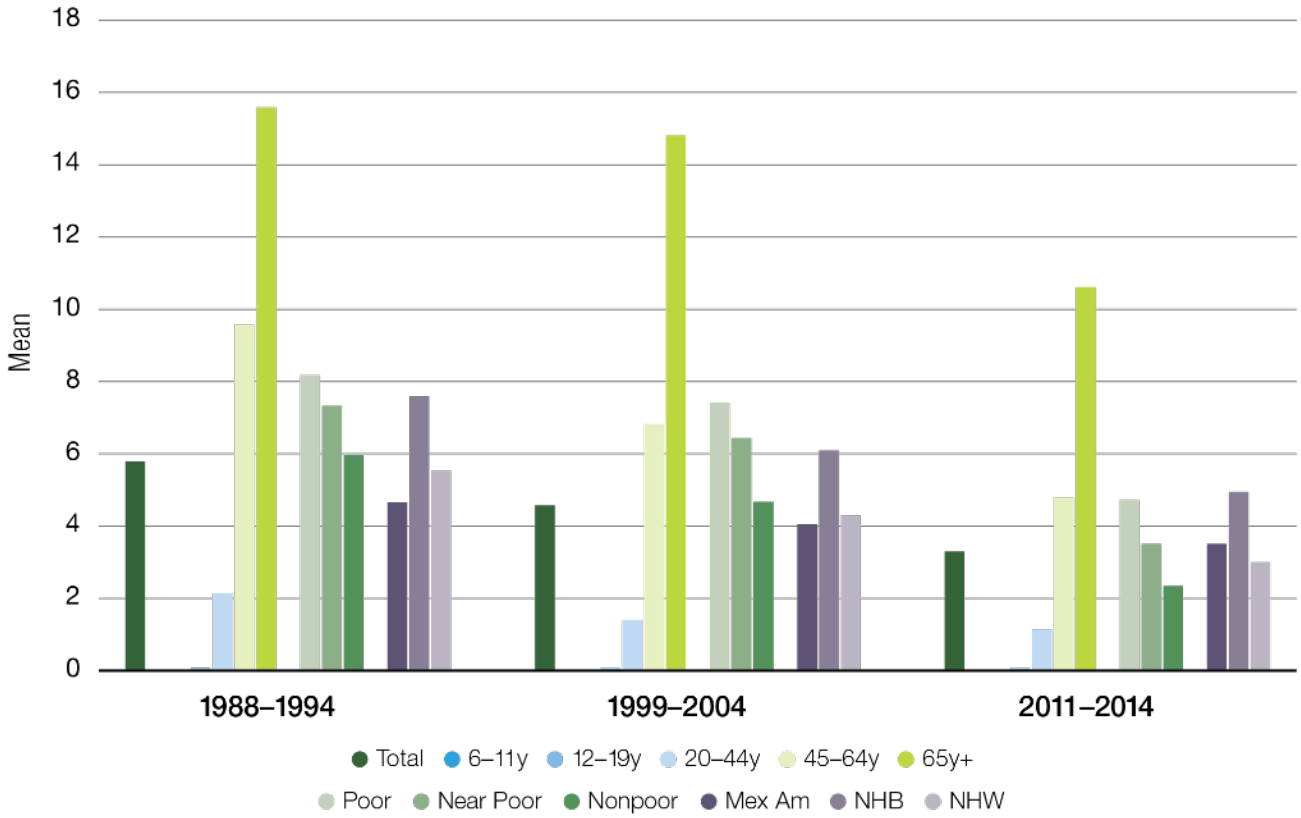


Notes: Prevalence of untreated dental caries (DT > 0). NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American. FPG = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey, public use data, 1988-1994,1999-2004, 2011-2014.

How does the world around us become part of our biology? Krieger (2001) provided insight into this by introducing a hierarchical, or multilevel, theory of causation. Her Ecosocial Theory provides a framework for analyzing how social factors across many levels (individual, family, community, and culture) can potentially influence health. A core concept of that theory is embodiment, "a concept referring to how we literally incorporate, biologically, the material and social world in which we live, from in utero to death; a corollary is that no aspect of human biology can be understood in the absence of knowledge of history and individual and societal ways of living" (Krieger, 2005 p. 352). Krieger described the pathways to embodiment as being structured by "(a) societal arrangements of power, property, and contingent patterns of production, consumption, and reproduction, and (b) constraints and possibilities of our biology, as shaped by human evolutionary history, its ecological context, and individual histories—that is, trajectories of biological and social development" (Krieger 2005 p. 352). The implication is that each individual's pathway to embodiment will result from dynamics related to the interactions of exposure, susceptibility, and resistance.

Several important developments emerged from this growing emphasis on social epidemiological methodologies for the study of oral health.

Figure 12. Mean number of missing permanent teeth due to dental disease among individuals ages 6 and older by age group, poverty status, and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Mex Am = Mexican American, NHB = Non-Hispanic Black, NHW = Non-Hispanic White; per the Federal Poverty Guidelines (FPG), Poor = income <100% FPG, Near-poor = income 100–199% FPG, and Nonpoor = income ≥200% FPG.

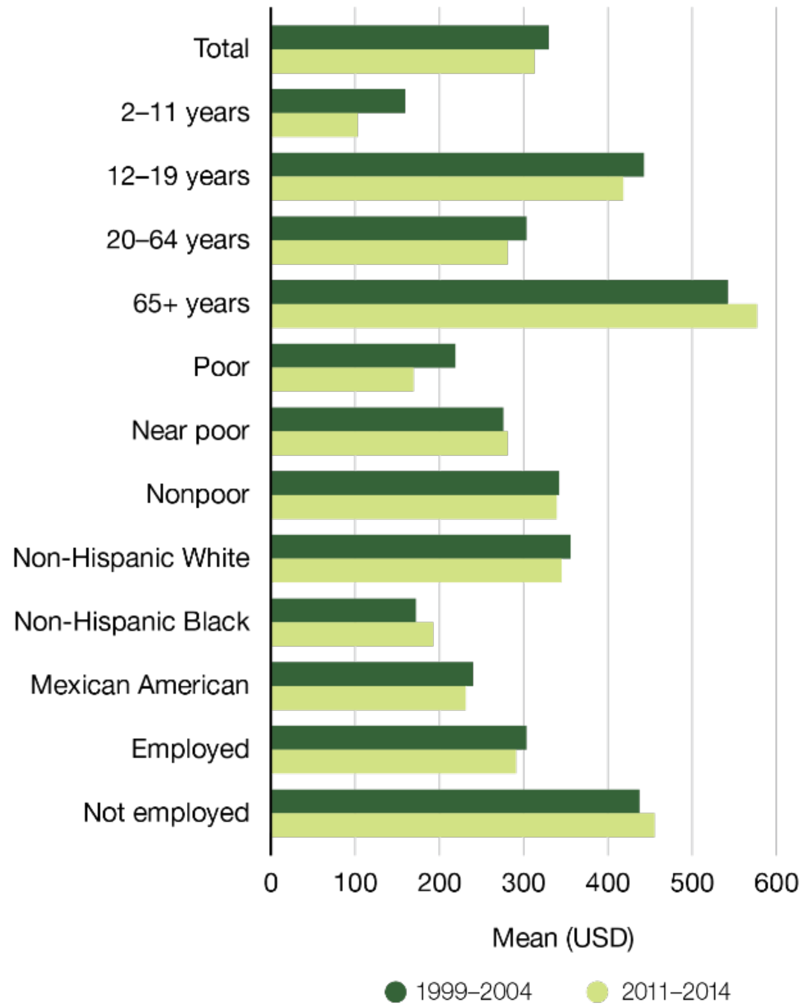
Source: CDC. National Health and Nutrition Examination Survey, public use data, 1988–1994,1999–2004, 2011–2014.

First, a large empirical literature emerged documenting the extent of the role of social factors in determining the oral health of populations. It became clear that ethnic minorities, lower income and education groups, and other vulnerable communities had greater oral disease liability (Evans and Kleinman 2000; Dye et al. 2007). These findings were consistently robust and demonstrated substantial effects on oral health. Consequently, additional efforts were made to understand the underlying mechanisms that could account for these effects. As a result, a wide variety of theoretical models and analytic frameworks have been developed for studying SDoH and the embodiment of the environment. Several of these approaches seem to have particular relevance to oral health.

The Life Course Approach

An earlier onset and faster progression of oral diseases, including tooth decay, tooth loss, and root caries, have been seen in ethnic minorities and among those with low education (Crimmins et al. 2009; Kim et al. 2012). Vulnerable groups tend to have poor access to routine preventive and reparative dental services and less access to fluoridated water, which can have lifelong effects on oral health and result in larger inequities among ethnic minority adults. In addition, chronic exposure to stress (for example, living in poverty) has been associated with altered physiological functioning, which may increase risk factors for oral diseases or faster progression of disease (Crimmins et al. 2009). Persons of disadvantaged social status report elevated levels of stress and may be more

Figure 13. Mean out-of-pocket dental expenditures per person in dollars (adjusted): United States, 1999–2004 and 2011–2014



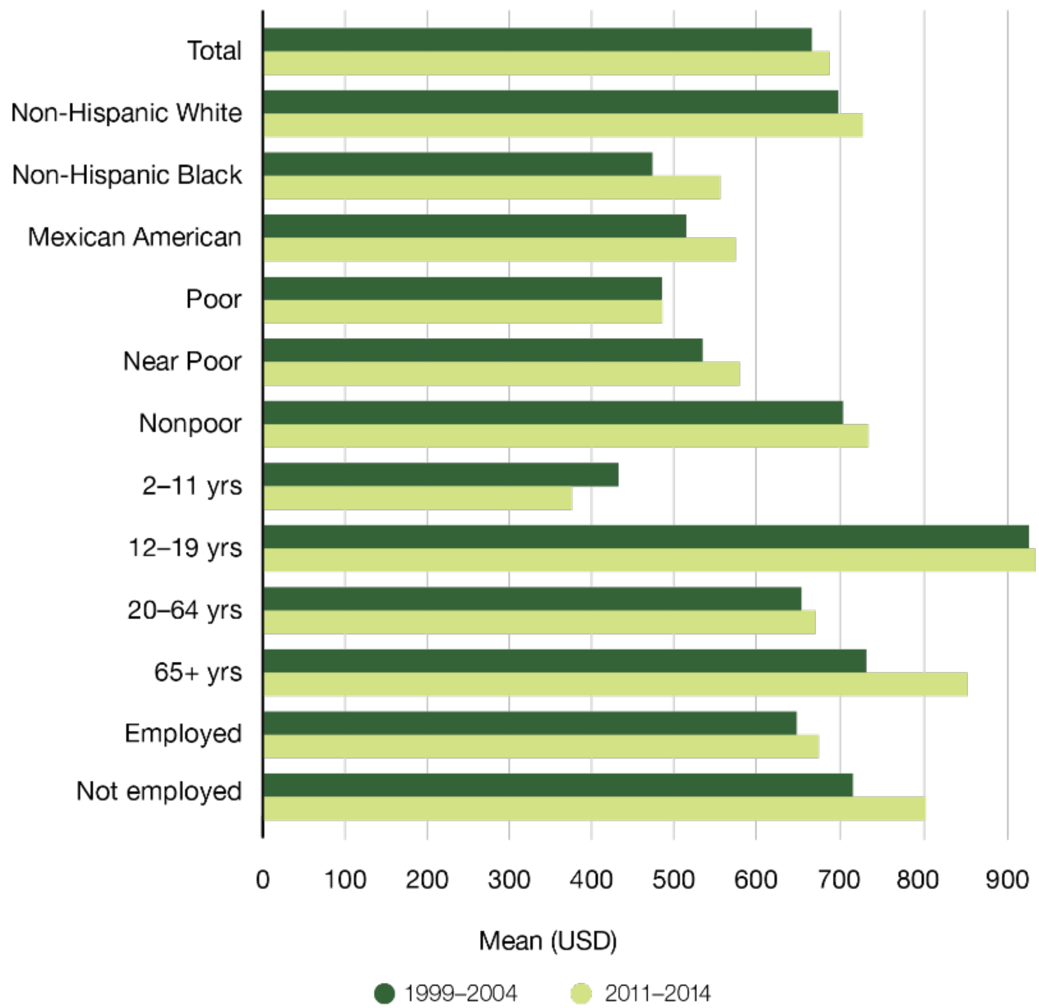
Notes: Expenses adjusted to 2015 US Dollars (USD). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. Employment calculated for people ages 16 years and older.
Source: Agency for Healthcare Research and Quality. Medical Expenditure Panel Survey (MEPS), public use data, 1999–2004 and 2011–2014.

vulnerable to the negative effects of stressors, including increased disease vulnerability for many diseases (Williams and Jackson 2005).

The Access Effect

The largest disparities in access to dental care are related to income, race, and ethnicity (Vujicic and Nasseh 2014; Henshaw et al. 2018; Northridge et al. 2020). For example, low-income adults are less likely to have seen a dental provider within the past year compared to higher-income adults (Licata and Paradise 2012). One in five low-income adults reported that they had not had a dental visit in 5 years or more or had never had a visit (Licata and Paradise 2012). Not having regular access to dental services or an ongoing relationship with a dentist has long-term and cumulative effects on the oral health of low-income and racially diverse adults (Wu et al. 2011; Zhang et al. 2019). Deferral of care increases the need for advanced dental services, which require payments for services that are even less affordable to these already vulnerable populations, thereby leading to even greater disparities (Licata and Paradise 2012).

Figure 14. Mean total dental expenditures per person in dollars (adjusted): United States, 1999–2004 and 2011–2014



Notes: Expenses adjusted to 2015 US Dollars (USD). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. Employment calculated for people ages 16 years and older.

Source: Agency for Healthcare Research and Quality. Medical Expenditure Panel Survey (MEPS), public use data, 1999–2004 and 2011–2014.

Diminished Returns Theory

Given the current social structure and socioeconomic stratification, as well as existing biases in the labor market and education system, the same economic resources may generate larger health gains for White Americans than for individuals belonging to ethnic minorities (Assari 2018). This means that the protective effects of higher socioeconomic status are less for racial and ethnic minority groups than for Whites (Assari 2018). This could be the result of a reduced effect of education on employment and income. Conscious and unconscious bias also plays a role in employment, even among employees with the same education level, and leads to an increased chance of discrepancy in salary. Such structural and institutional-level barriers can result in health disparities (Assari 2018).

Culture/Acculturation Effect

Cultural factors play a significant role in oral health inequalities and lead to disparities. Living in a multicultural environment can affect the attitudes, beliefs, and knowledge of persons who are different from the mainstream population (Tiwari and Albino 2017).

The challenges of acculturating to the mainstream population can lead to distance from former sources of social support and cause emotional distress, which are linked to lower use of health services and poor oral health outcomes (Tiwari and Albino 2017). However, high acculturation is associated with higher education, preference for the English language, and social networks that potentially lead to greater utilization of dental services (Maupome et al. 2016; Macy et al. 2018).

Commercial Determinants Affecting Oral Health

Another important change in the past 2 decades is improved understanding of the conditions that lead to poor oral health, including the need that much greater attention should be paid to social and economic organization and the role of markets and industry as risk factors. Some commercial influences contribute to the persistent prevalence of oral disease. Population-level interventions are needed to address commercial determinants of oral health, income inequalities, health literacy, unhealthy eating habits, and more. For example, excise taxes on sugary beverages and other policy approaches to reduce sugar consumption have been associated with a reduction in new dental caries and lower dental treatment costs (Schwendicke et al. 2016), but these approaches remain underutilized as methods for shaping consumption and improving health and social outcomes (von Philipsborn et al. 2019).

Reducing two of the major risk factors for oral health—tobacco and excess alcohol consumption—remains a challenge for policymakers. In 2019, nearly 50.6 million U.S. adults used a tobacco product (34.1 million currently smoke) (Cornelius et al. 2020), and about 4.47 million middle and high school students used at least one tobacco product, including e-cigarettes (Cornelius et al. 2020; Gentzke et al. 2020). Every day in the United States, about 1,600 young people under the age of 18 years smoke their first cigarette (Substance Abuse and Mental Health Services Administration 2019). Moreover, e-cigarette use by adolescents and young adults increased at an alarming rate between 2018 and 2019 (Cullen et al. 2019; Wang et al. 2019), although it declined in 2020 (Gentzke et al. 2020). Alcohol use remains a challenge; in 2015, 66.7 million people in the United States reported binge drinking in the past month (U.S. Department of Health and Human Services 2016a). Additional information on tobacco and alcohol use is discussed in Section 5.

Vulnerable Populations and Oral Health Disparities/Inequities

Rural Populations

Although the 2000 Surgeon General's report on oral health noted the gravity of rural oral health disparities, its conclusion was limited by lack of sufficient data. Since then, the health outcomes of rural populations have been prioritized. The Health Resources and Services Administration (HRSA) released reports on oral health in rural communities in 2004 and 2018 (Barnett et al. 2018). These reports identified agency priorities for improving rural oral health, most notably provider recruitment and training, oral health literacy and education, and medical-dental integration. In 2013, the Federal Office of Rural Health Policy funded the development of a publicly available Rural Oral Health Toolkit to disseminate successful rural oral health care delivery models (NORC Walsh Center for Rural Health Analysis et al. 2013).

Geographic and socioeconomic factors continue to create rural oral health disparities. More than half of all uninsured rural adults live in states that did not expand Medicaid under the Affordable Care Act, thus restricting their access to insurance coverage (Foutz et al. 2017). Variations in Medicaid coverage for dental procedures also affect rural providers and patients more dramatically than those in urban settings (Fish-Parcham et al. 2019). Recruitment of dentists to rural areas is an ongoing challenge, with the vast majority of dental school graduates—even those originally from rural areas—choosing to practice in more urban locations (Vujicic et al. 2016b). Because rural dentists are, in general, older than the average practicing dentist, the sustainability of the rural dental workforce may be increasingly under threat in the coming decades (Doescher et al. 2009).

One of the largest innovations since 2000 with the potential to have an impact on rural residents has been the adoption of dental therapy in the United States to address ongoing rural dental workforce challenges. Dental therapists are members of a dental team who provide preventive and restorative dental care. Although dental therapists have practiced globally in rural areas since the early 20th century, it was only in 2003 that the first cohort of dental therapists began to treat Alaska Natives as part of the Indian Health Service's (IHS) Community Health Aide Program. In 2009, Minnesota became the first state to pass legislation permitting dental therapists to practice statewide, with subsequent adoption by the predominantly rural states of Vermont and Maine (Koppelman et al. 2016b). As of 2019, eight states had passed dental therapy legislation that allows these professionals to practice independently (Grant 2019) and 12 states allowed dental therapy in some capacity. Research indicates that dental outcomes were equivalent or superior when dental teams included therapists (Wright et al. 2013). In spite of these advances, there are only about 100 dental therapists practicing across the country (Koppelman et al. 2016b). See Section 4 for more information on dental therapists.

Scalability of effective oral health prevention interventions in rural areas is a special challenge. Water fluoridation in small, rural communities is costlier than in cities; however, the estimated return on investment for community water fluoridation in communities of fewer than 5,000 people still approaches $30 per person (Griffin et al. 2001; O'Connell et al. 2016). Higher use of well water rather than community water sources further complicates efforts to provide this important preventive measure. Yet, prevention is especially important in rural areas because many patients face long travel times to reach a dentist in rural dental health professional shortage areas. Limited transportation options, especially for older rural dwellers, may further restrict access (Arcury et al. 2005).

Low-Income Populations

The 2000 report on oral health highlighted the disproportionate burden of dental caries borne by people living in poverty. Overall, income and economic status disparities in oral health persist. Cost continues to be the greatest barrier to accessing dental care. Dental cost as a percentage of total income is a metric that highlights how low-income families often are unable to access professional dental services. Halasa-Rappel and colleagues (2019) analyzed 2018 Medical Expenditure Panel Survey data and reported two associated and troubling findings. Among individuals living in poverty, 93% had unmet dental care needs, compared to 58% of those in the high-income group. They also reported that as a percentage of income, individuals living in poverty spend nearly 10 times more of their income for dental care, compared to high-income families (Halasa-Rappel et al. 2019).

Public health interventions intended to reduce disparities can inadvertently worsen them; however, working with community partners can improve implementation practices that can increase the likelihood of success and improved health outcomes of community participants. For example, population level interventions that depend on voluntary behavior change typically are adopted by the most advantaged. As health technologies advance, such as in the field of precision dentistry, economically advantaged groups are likely to benefit most from these potentially costly services, resulting in a widening of income disparities in oral health. For example, as technologies have improved treatment outcomes over the past 2 decades, increases in tooth retention have led to more affluent adults having more natural teeth retained compared to those living in poverty, but observed disparities in tooth retention by income status increased (Dye et al. 2019).

Decreasing health disparities depends in large part on programs and policies aimed at providing more equitable distribution of evidence-based, health-promoting interventions. Generally, this means programs that are not dependent on individual behavior change or compliance, such as community water fluoridation programs. Increasing the proportion of the population served by community water fluoridation not only benefits the entire population but disproportionally benefits economically vulnerable groups, producing a flatter socioeconomic gradient in dental caries among children (Slade et al. 1995; Riley et al. 1999; McLaren and Emery 2012; McLaren et al. 2016) and reducing the need for expensive dental treatment.

To redress such inequities, the federal Healthy People 2000 initiative introduced an overarching goal to reduce health disparities. Healthy People 2010 expanded this goal based on characteristics of race and ethnicity, geographic location, gender, sexual orientation, disability status, educational attainment, and family income. Healthy People 2020 retained elimination of health disparities as an overarching goal and added achieving health equity and improving the health of al groups. This has been further expanded for Healthy People 2030, where an overarching goal is to eliminate health disparities, achieve health equity, and attain health literacy to improve the health and well-being of all (U.S. Department of Health and Human Services 2020b).

Black or African American Populations

The gaps between the status of non-Hispanic Black populations relative to other racial groups remain similar to those reported in the 2000 Surgeon General's report on oral health. A comparison of the National Health and Nutrition Examination Survey (NHANES) data from 1999–2004 and 2011–2014 revealed that the racial disparities between non-Hispanic Black and White school-age children for untreated dental caries have broadly not improved but when race and poverty are both considered, the disparities for low-income non-Hispanic Blacks aged 6–11 become more pronounced but are nearly eliminated among more affluent youth (Dye et al. 2017). Non-Hispanic Black populations in the United States continue to experience greater morbidity from oral diseases than their counterparts of other racial groups (Henshaw et al. 2018). For low-income Blacks in the United States, the challenges of having adequate dental benefits and access to a workforce that is willing and available to meet their oral health needs is an ongoing challenge. That only 3.3% of U.S. dentists are Black is an important aspect to this challenge (Mertz et al. 2017).

As the number of older adults in the United States increases, it is important to note that there are persistent disparities between Black and White older adults, especially with regard to untreated dental caries (Centers for Disease Control and Prevention 2019). Continuing barriers to receiving needed dental care services for older adults include lack of dental coverage in Medicare and limited access to adult dental benefits through Medicaid (Friedman et al. 2014a). Because many individuals lose their employment-based dental insurance upon retirement, Manski and colleagues (2011) estimated that non-Hispanic Black retirees were three times more likely to stop using dental services than were their White counterparts, even after controlling for other factors, such as income and education.

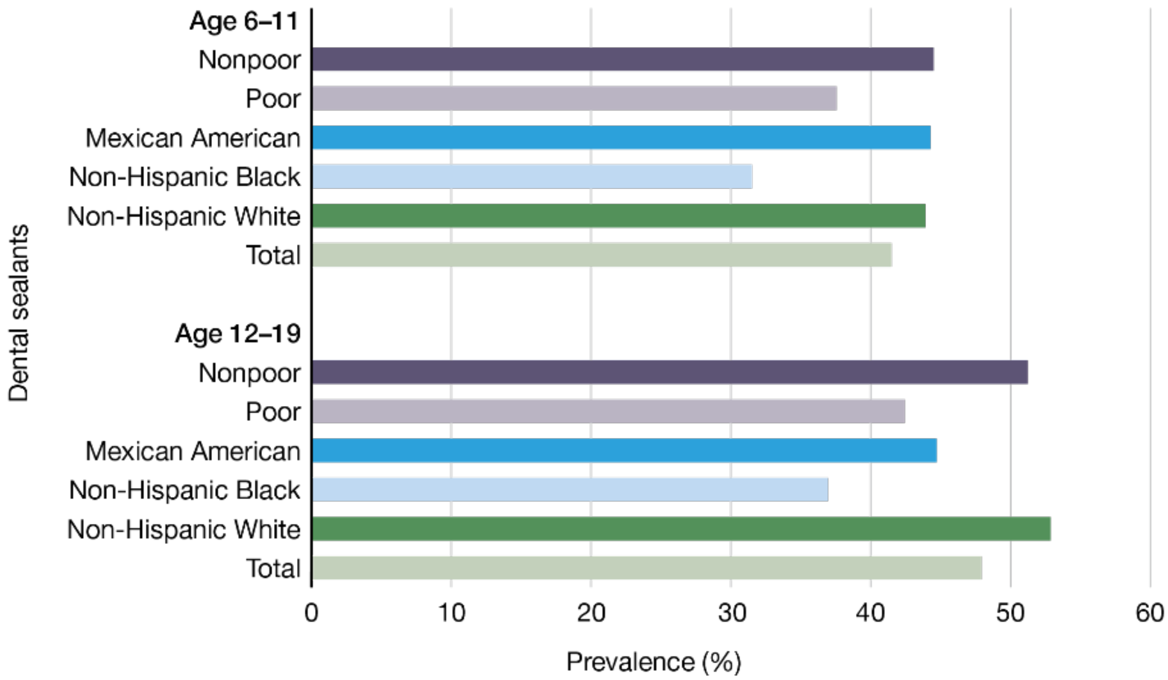
Effective promotion of oral health among non-Hispanic Blacks also requires an improved understanding of how social determinants function to influence oral health and access to care across cultures. Although living in poverty and disadvantaged neighborhoods, and having more exposure to chronic stressors (Sanders and Spencer 2004; Turrell et al. 2007; Finlayson et al. 2010; Braveman et al. 2011), can affect anyone living with those hardships, the interaction of these factors with race remains unclear. For example, among child populations where Medicaid and CHIP are available, the percentage of those who were uninsured varied in important ways across racial and ethnic groups. Among the insured, moreover, substantial differences exist between public and private insurance coverage. Among Black children, 49.1% had public insurance and 42.8% had private insurance, whereas for White children, 17.5% had public insurance and 76.2% had private insurance. Children with public insurance receive less dental care than those with private dental coverage. This often is attributed to lower reimbursement rates by Medicaid in most states, leading to a smaller number of dentists willing to provide services to Medicaid patients (Flores and Tomany-Korman 2008). These factors limit access to and utilization of regular dental services, especially preventive services (Edelstein and Chinn 2009; Pourat and Finocchio 2010). As a result, there are continuing disparities in access to important preventive services, such as dental sealants, between Black and White children (Figure 15) (Centers for Disease Control and Prevention 2019).

Hispanic Populations

Hispanic Americans, especially those of lower socioeconomic status, continue to experience a high burden of oral disease and challenges with low dental utilization and access to culturally competent dental care. Based on National Health Interview Survey data, the proportion of Hispanic children without dental visits in the past year declined between 2000 and 2014 (Larson et al. 2016). However, dental coverage is more variable for adults than for children and dental care continues to pose a significant cost for many adults who report more financial barriers to obtaining dental services than other types of health services (Vujicic et al. 2016a).

Statistics from more current NHANES cycles revealed that young Hispanic children (aged 2–8 years) had higher prevalence of untreated decay in primary teeth and greater dental caries experience compared to other racial and ethnic groups (Satcher and Nottingham 2017). An important advancement since 2000 has been the development of more recent national data available for Hispanic adults aged 18 to 74 years for 2008–2011 (Beck et al. 2014). These data allow reporting on oral health status for different Hispanic subgroups, unavailable since the 1982–1984 Hispanic Health and Nutrition

Figure 15. Percentage of youth ages 6–19 with dental sealants by age group, poverty status, and race/ethnicity: United States, 2011–2016



Note: **FPG** = Federal Poverty Guidleline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: Centers for Disease Control and Prevention (2019).

Examination Survey, which included Mexican Americans, Cubans, and Puerto Ricans (Ismail and Szpunar 1990). Baseline data from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) provide a new national dataset that can support exploring diversity across Hispanic population groups in an attempt to better understand the connection between oral health and other diseases. For example, among all ethnic Hispanic subgroups, half have some form of periodontitis (mild, moderate, or severe), but more than a third of Cubans and Central Americans have the highest prevalence of moderate periodontitis among all subgroups (Jiménez et al. 2014). The HCHS/SOL enables accounting for traditional oral health risk factors, as well as other important cultural factors.

Acculturation, education, language barriers, transportation deficiencies, ethnic identity, and lack of dental insurance remain significant factors affecting dental utilization among Hispanic adults (Stewart et al. 2002; Eke et al. 2011; Strouse et al. 2013; Velez et al. 2017; Silveira et al. 2020). In addition, the lack of an ongoing relationship with a dentist, lack of available transportation, and difficulty getting time off from work for dental visits are more common barriers among Hispanic communities (Kim et al. 2012; Vujicic and Nasseh 2014). Hispanic dentists remain largely underrepresented among dentists nationwide and, like other minority dentists, Hispanic dentists tend to practice in communities with a large proportion of minorities (Mertz et al. 2016a).

American Indian and Alaska Native Populations

In 2010, IHS implemented an ongoing oral health surveillance system designed to monitor trends in oral health among the American Indian and Alaska Native (AI/AN) population served by IHS and tribal programs. Since the implementation of the surveillance program, oral health data have been obtained from four different age groups: preschool children (2010, 2014, and 2018–2019), elementary school children (2011–2012 and 2016–2017), adolescents (2012–2013), and adults (2015). The IHS Oral Health Surveillance Plan provides detailed information regarding past, present, and future-planned oral health surveys of the AI/AN communities (Indian Health Service 2015).

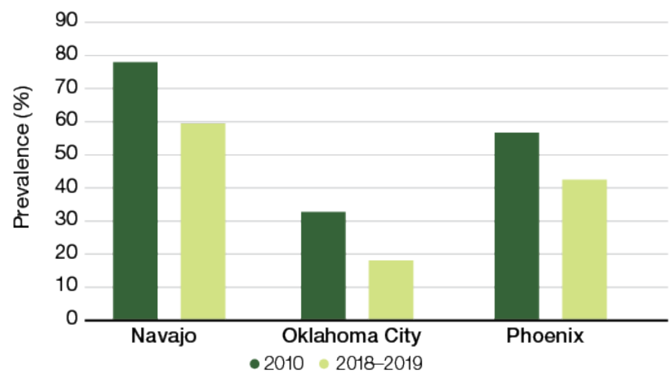
The IHS Division of Oral Health has conducted seven surveys since the launch of the original oral health surveillance plan in 2010 (Indian Health Service 2021a). Each survey used the Basic Screening Survey instrument (Association of State and Territorial Dental Directors 2021) as the tool to conduct community-based, clinic-based, and school-based surveys. Survey results are available as IHS Data Briefs on the IHS Division of Oral Health website (Indian Health Service 2021b). However, despite the fact that more recent data from the IHS surveillance system appear to be showing improvements in the oral health of some AI/AN preschool children (Figures 16 and 17), these children continue to suffer disproportionately from common oral diseases (Phipps et al. 2019).

The relative geographic isolation of many tribal populations may limit access to dental care. AI/AN patients also face difficulties in receiving routine and preventive dental care as a result of other reasons, such as the chronic shortage of dentists within IHS (Batliner 2016). The IHS struggles to attract physicians and dentists to rural and geographically isolated locations. The dentist-to-population ratio exceeds 1:5,000 in AI/AN communities (Mertz et al. 2017), compared to an average of 1:1,600 for the entire U.S. population (Munson and Vujicic 2018). In addition, dental services provided through IHS often are underfunded, resulting in a need to concentrate on providing basic emergency care services, with restorative and preventive care provided primarily to children. As a result, availability of adult restorative care may be compromised (Soeng and Chinitz 2010).

Sexual and Gender Minorities

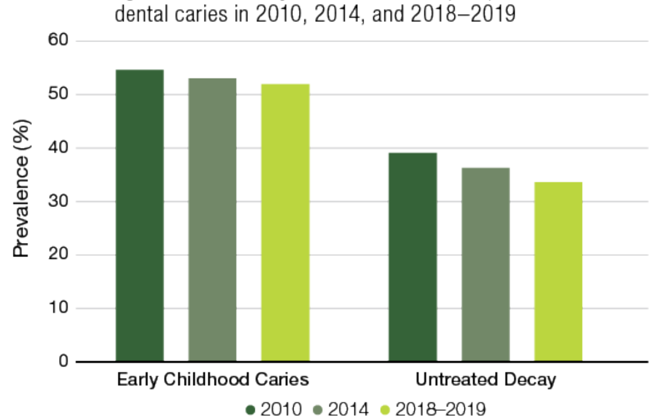
Sexual and gender minority populations (SGM) likely constitute groups at higher risk for oral diseases and oral health inequities by virtue of their lower access to care and lower levels of social influence (Schwartz et al. 2019). The National Institutes of Health established an SGM Research Office to expand the knowledge base related to SGM health and well-being and to advance SGM-related research (National Institutes of Health 2020). However, to date, research related to the oral health of this group is extremely limited. In the 2000 Surgeon General's report on oral health, attention was drawn to the lack of

Figure 16. Change in percentage of American Indian/Alaska Native (AI/AN) children ages 1–5 with early childhood caries (ECC) by select Indian Health Service areas between 2010 and 2018–2019



Source: Phipps and Ricks (2015); Phipps et al. (2019).

Figure 17. Percentage of American Indian/Alaska Native (AI/AN) children ages 1–5 with early childhood caries (ECC) and untreated dental caries in 2010, 2014, and 2018–2019



Note: Information surveyed from 53 IHS service units.
Source: Phipps and Ricks (2015); Phipps et al. (2019).

information on lesbian, gay, bisexual, transgender, queer, and other populations. Little has changed in the intervening 2 decades. The only current report is from Schwartz and colleagues (2019), which noted that "subjective measures of oral health were worse among gay, lesbian, and bisexual adults versus heterosexual adults" (Schwartz et al. 2019, p. 18).

Oral Health for those with Special Health Care Needs

Although access to dental care services and achieving and maintaining good oral health is a challenge for many people, this is especially the case for individuals with disabilities and complex medical conditions (Institute of Medicine and National Research Council 2011). In the past 20 years, the population of individuals with special health care needs (SHCN) has increased at the same time that many more are residing in community living arrangements. One in five children have SHCNs (Chi 2018a). Lewis (2009) responding to the 2000 report on oral health, reported that dental care was the most frequently cited health care need among children with SHCNs. As a result, dentists are increasingly called upon to provide dental care services in their offices for people with complex conditions. This often requires close consultation and collaboration with others on the patient's health care team. It also may present challenges for dental professionals without the in-depth training required to care for the wide variety of physical, medical, and cognitive conditions that these patients present. Currently, the population with the highest per-visit expenditures in dental offices is the elderly population. This also is the group most likely to have disabilities and complex health care conditions (Wall et al. 2013). See Sections 2A and 3B for more information on these special needs populations.

Training of oral health providers in providing clinical dental services for patients with complex health conditions remains distressingly inadequate (Furlini et al. 2018) and accreditation requirements for predoctoral dental education programs require that graduates only be competent to assess the needs of individuals with special needs (Commission on Dental Accreditation 2018). Unfortunately, the number of people with special needs or complex health conditions continues to grow in absolute terms and as a percentage of the population (Institute of Medicine 2007; Okoro et al. 2018; Child and Adolescent Health Measurement Initiative 2020). Moreover, those with the most complex conditions are more likely to be isolated in facilities providing specialized health care. Finally, payment systems typically do not recognize complexity and as a result, dental care is still paid through one-size-fits-all reimbursement mechanisms (set procedure or visit fees with no modifiers). Understandably, all these factors disincentivize dentists and worsen the disparities experienced by many individuals living with complex health conditions.

Social Determinants and Health Policy

Many oral diseases, such as dental caries and periodontal disease, share common risk factors with other chronic disorders, including diabetes, obesity, and cardiovascular disease. These risk factors include tobacco and alcohol use and an unhealthy diet. Increasing awareness of the presence of common risk factors across multiple chronic diseases could help to coalesce powerful health advocacy groups. Combining the voices speaking for both oral diseases and related chronic diseases would provide a stronger lever for advancing health promotion messages and for advocating for health policy change (Watt and Sheiham 2012).

The realization that oral health fits into a broader health agenda already has enabled changes in health promotion and service delivery. It now is seen as appropriate for oral health advocates to focus on high-level policy changes, such as those aimed at reducing consumption of foods and beverages with added sugars (Navia 1994). Moving oral health promotion and service delivery to new venues, such as medical offices, schools, and community services sites, also has been stimulated by these changes.

Health-related policy and social marketing aimed at social and commercial determinants have had an impact on population-level health behaviors. In terms of dietary risk factors, added sugar intake decreased for both men and women across all age groups between 2001–2004 and 2007–2010 (Millen et al. 2016). Nonetheless, most Americans continue to exceed the U.S. Dietary Guidelines' recommendation to limit added sugar intake to less than 10% of calories per day (U.S. Department of Health and Human Services 2016b).

Use of conventional, or combustible cigarettes has declined during the past several decades among all age groups including youth and young adults in the United States (U.S. Department of Health and Human Services 2014). Although federal restrictions on where smoking can occur have not been enacted, many state and community laws prohibit smoking in workplaces, restaurants, and bars. Nevertheless, 39% of the U.S. population remains uncovered by comprehensive smokefree indoor air policies (American Nonsmokers' Rights Foundation 2021). Rising state excise taxes on cigarette sales also have reduced per capita consumption of cigarettes.

Since the first Surgeon General's report on smoking and health in 1964, there have been 34 different reports related to tobacco use, including the most recent report in 2020 on smoking cessation. A 2012 Cochrane Collaboration systematic review on interventions for tobacco cessation in the dental setting suggested that behavioral interventions for tobacco cessation conducted by oral health professionals and incorporating an oral examination component in the dental office or community setting may increase tobacco abstinence rates both among people who smoke cigarettes and those who use smokeless tobacco (Carr and Ebbert 2012).

Understanding of policy approaches for reducing tobacco use, alcohol misuse, and added sugar consumption has greatly improved. Excise taxes, which raise the price of taxed products, are highly effective in reducing consumption of tobacco products, alcohol, and sugary beverages (Bloomberg et al. 2019). Their impact tends to be stronger among the less affluent and youth, suggesting that these groups would receive the greatest health benefits. Increasing taxes on these three products should not only improve health and reduce costs but also improve market efficiency. Such taxes are justified by the large and growing health and economic costs they impose on users, such as smoking-related illnesses or alcohol-related automobile accidents, as well as economic arguments regarding fiscal efficiency.

The introduction of the human papillomavirus (HPV) vaccine also is critical because it will provide some protection against oropharyngeal and other cancers (Chaturvedi et al. 2008; Chaturvedi et al. 2011). Although the incidence of oropharyngeal cancers has decreased, this has not been the case for HPV-positive oropharyngeal cancers. Thus, the HPV vaccine has the potential to be a key public health intervention and may have an equity effect among men and women if HPV vaccination programs can be provided in a broad-based manner similar to other mandatory vaccines. According to the National Immunization Survey-Teen, rates of HPV vaccine initiation are higher among adolescents living in poverty than among higher-income groups (Bednarczyk et al. 2013). More information on HPV and oral health is found in Sections 2B and 3A.

The federal Earned Income Tax Credit and Child Tax Credit are broader policy developments that redistribute income to low-income families with children. Along with rises in the minimum wage, these policies may alleviate the magnitude of income-related inequalities in oral health. In this way, contemporary understanding of what determines health—namely that structural factors play a stronger role than individual factors—is a fundamental change in the current policy and health research environment that should not be ignored. It also is an area where evidence of the effects of interventions is developing (Waters et al. 2008; Bambra et al. 2009; Cochrane Public Health 2015).

The Food and Beverage Industry

Policy and population-level initiatives are being employed to begin to address commercial determinants of poor oral health. Cost is a powerful tool to modify behavior. For example, states impose different levels of excise tax on the sale of cigarettes and their impact on consumption is well established. Whether these efforts affect smoking-related diseases is less clear. Sanders and Slade (2013) examined state cigarette excise tax and its associations with per capita consumption, exposure to secondhand smoke, and chronic periodontitis in U.S. nonsmokers. They found that for each additional 10 cents in excise tax, cigarette sales would decrease by 0.74 packs per person per month and the adjusted odds of moderate or severe periodontitis by 22%. These authors found that the odds of periodontitis for those exposed to secondhand smoke were elevated, suggesting that a cigarette excise tax also could protect nonsmokers against periodontitis.

More recently, taxes on sugar-sweetened beverages have been implemented in a number of countries and localities, yet no analysis has been published about their effect on dental caries (Schwendicke et al. 2016). Nevertheless, simulation studies suggest that such a tax could reduce tooth decay and its associated economic burdens and that improvements would be most concentrated in younger age groups (Sowa et al. 2018; Jevdjevic et al. 2019)

Financing Dental Care

Dental spending has increased substantially in the past 2 decades. Much of this increase comes from increased access to public programs, in particular Medicaid, with smaller shares coming from private dental insurance and out-of-pocket spending. For example, in 2018, 10% of national dental spending was financed by public programs, and 40% was paid out of pocket by patients. Another 46% was financed by private dental insurance

(See Section 4, Figure 3). In 2000, only 4% was financed by public programs, 44% through out-of-pocket payments, and 50% from private dental insurance. The shifts in the mix of dental care financing have been occurring gradually, driven largely by changes in dental care utilization patterns (Vujicic 2015b; American Dental Association 2020g).

Among adults 65 years and older, retirement often brings a loss of employment-based medical and dental insurance. After reaching age 65, older adults typically transition from employment-based medical insurance to Medicare. Because Medicare includes only limited coverage for dental care, an estimated 1 in 3 older adults have any dental insurance with the majority having some private dental insurance and a few enrolled in Medicaid (Nasseh and Vujicic 2016a; Yarbrough and Vujicic 2019). Consequently, older adults relying on Medicare for health insurance incur substantial out-of-pocket expenses for dental services. More than 40% of dental expenses are paid out of pocket, compared to only 9% of medical expenses for Medicare-enrolled older adults (Kreider et al. 2015). As a result, many adults fail to receive needed dental care. Fewer than half of Medicare beneficiaries (49%) had a dental visit within the past 12 months. For some ethnic groups, utilization rates for Medicare beneficiaries were even lower. Only 29% of Blacks and 35% of Hispanics aged 65 years and older had a dental visit in the past 12 months. Other older adult groups also had low utilization rates—only 30% of low-income and 41% of rural residents sought dental care in the previous 12 months. This is particularly concerning because older adults are at higher risk for periodontal disease and oral cancer, both of which have a worse prognosis if diagnosis and treatment are delayed (Medicaid and CHIP Payment and Access Commission 2020).

Current public insurance programs are struggling to provide coverage for many. This is primarily attributable to the expanding number of Americans eligible for public assistance. These numbers are growing, and states are challenged to keep up with the demand. Although federal law restricts routine dental care for Medicare beneficiaries, many Medicare enrollees more recently have begun to access preventive dental services under Medicare Advantage (MA) programs. These programs offer seniors dental services as incentives to plan selection (Freed 2021). In most MA plans, dental care is limited to preventive and simple restorative services.

Public Dental Insurance

Use of dental care services across population groups has steadily increased since 2000. Among Medicaid and CHIP beneficiaries, children enrolled in the Early and Periodic, Screening, Diagnostic, and Treatment program under Medicaid or CHIP were reported to have increased utilization of any dental service from 6.3 million in fiscal year (FY) 2000 to 19.6 million in FY 2019 (Centers for Medicare & Medicaid Services 2021b). Population growth and changing demographics across the United States have driven changes in Medicaid program policy, administration, and eligibility across states and have accounted for much of this increase. Medicaid expansion implemented in many states as a result of the Affordable Care Act (ACA) has led to steady increases in both pediatric and adult Medicaid enrollment since 2010. Similar enrollment increases have been observed across states with CHIP. Between 2013 and 2018, nonexpansion states observed only a 10.2% increase in Medicaid enrollment, compared to a 35.9% increase in expansion states during the same period (Medicaid and CHIP Payment and Access Commission 2020).

Since 2010, many states have combined their CHIP and Medicaid programs. This shift in program administration provides greater access to a wider range of dental benefits because Medicaid policy is less restrictive than CHIP. In 2017, only 13 states operated a separate CHIP program, compared to nearly all states in 2000 (Medicaid and CHIP Payment and Access Commission 2017). Increased enrollment of children in Medicaid can improve access to care and reduce untreated disease. However, the structure of dental coverage for children in the ACA has presented new challenges for implementation. These structural barriers include complex benefit designs, lack of affordability protections in some plans, and no mandate to purchase dental coverage (Snyder et al. 2014). The ACA does not require dental insurance for adults and the result has been negligible improvement in dental coverage among working-age adults. Nearly 2.5 times as many adults have medical insurance, compared to dental insurance (Kreider et al. 2015).

For adults, dental benefits are not mandated under federal law, although many state Medicaid agencies have expanded dental policies and benefits during the past 2 decades. This increase in access to dental care came about because of increases in enrollment through Medicaid expansion and the advancement of Medicaid dental policy for adults (Medicaid/Medicare/CHIP Services Dental Association 2019a; 2019b). Current status of dental Medicaid benefit expansion is shown in Figure 18. In 2017, more than half of state Medicaid dental programs reported including preventive and restorative oral health care services for adults: comprehensive oral examination (33 states), dental cleaning (33 states), and amalgam and composite fillings (32 and 31 states, respectively). Thirty states covered upper and lower dentures, 24 states covered root canal treatment for adults, and 31 states covered scaling and root planing and scaling services for pregnant women 21 years and older (Medicaid/Medicare/CHIP Services Dental Association 2019a).

Although the national average is 38% of dentists participating in Medicaid or CHIP to provide services for children, there is considerable variation across states. For example, the participation rate in Iowa is 85.5%, with greater than 70% participation in Alabama, Michigan, Montana, North Dakota, and Vermont. On the low end, with participation rates below 16%, were California, Maine, and New Hampshire. Factors that are associated with participation include dental provider gender and age, with participating providers more likely to be younger or female (American Dental Association 2020h). However, other factors, such as state poverty level, the number of health professional shortage areas within a state, and a state's decision to not participate in the Medicaid expansion of the ACA, are associated with lower rates of dentist participation in Medicaid and CHIP (American Dental Association 2020g).

Still, there has been much improvement with regard to dental providers enrolled in Medicaid and CHIP since the early 2000s. According to the most recent data, 38% of general and pediatric dentists participate as Medicaid or CHIP providers. It is important to note that simple participation rates do not fully measure the availability of dental services for the Medicaid beneficiaries because they do not include billing rates or patients treated (Warder and Edelstein 2017).

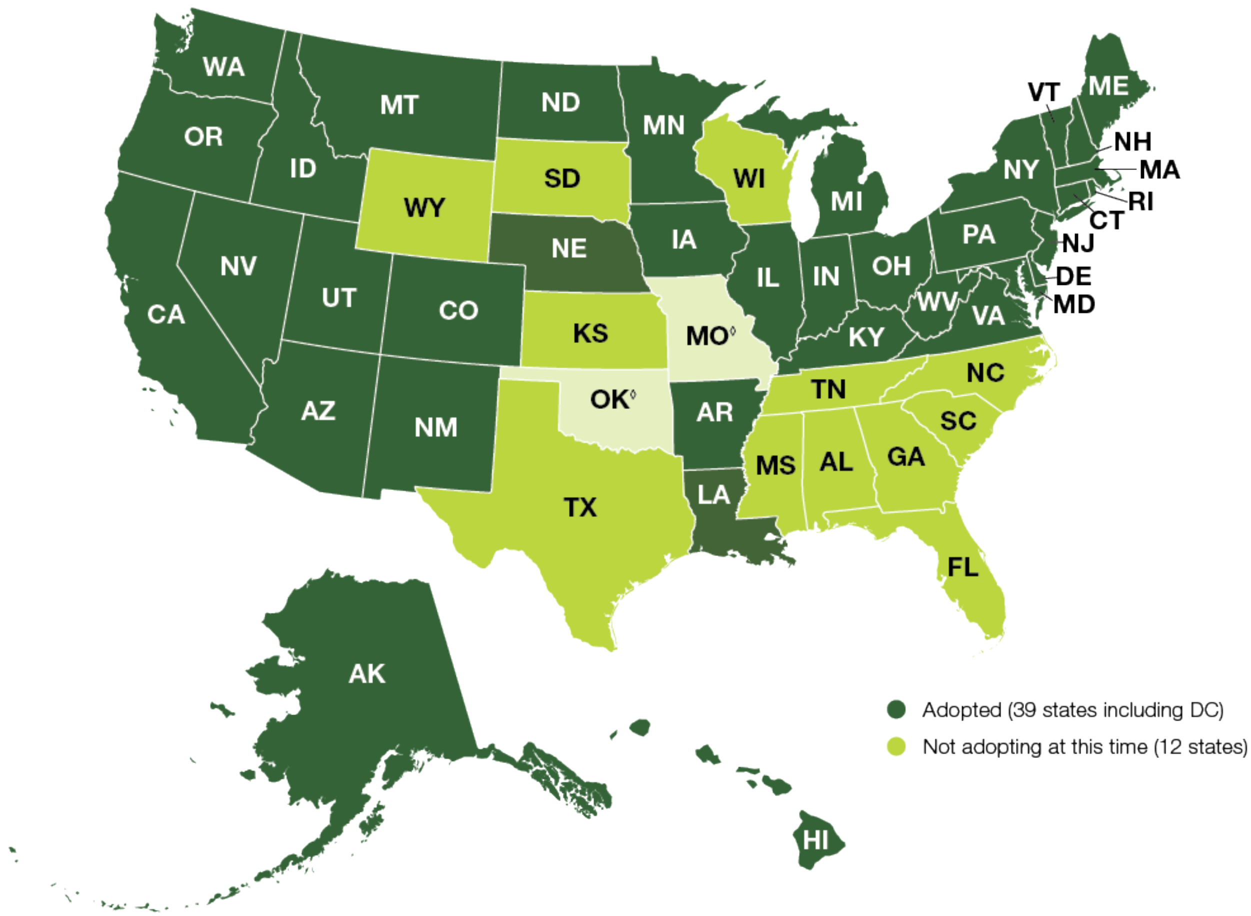
Other Governmental Activities Supporting the Dental Health Care System

Over the past 2 decades, HRSA, in collaboration with the Centers for Medicare & Medicaid Services (CMS), has continued to support and expand dental care access for low-income Americans. The HRSA Health Center Program (HCP) has supported health centers with Section 330 grant funding, whereas CMS and state Medicaid agencies cover fees associated with the delivery of health care services (110th United States Congress 2008). In 2011, CMS established a federal regulation allowing Federally Qualified Health Centers to contract with private dental offices for the delivery of dental care services. In so doing, a new pathway was cleared in which health center dental program infrastructure and capacity could expand so that patients could more easily access dental care services in their communities. As a result of this regulation, many health centers across the United States have been able to significantly increase their capacity to meet the dental needs of their patients.

Nearly 93% of HRSA's Health Center Program grantees provide preventive dental services either onsite or by paid referral. Between 2001 and 2020, HRSA-funded health centers increased the number of dental visits from 3.2 million to more than 11.3 million and the number of dental patients from 1.4 million to nearly 5.2 million (Health Resources and Services Administration 2021b). In FY 2016, 420 health center program grantees received nearly $156 million to expand oral health services as part of the FY 2016 Oral Health Service Expansion awards (Health Resources and Services Administration 2016).

More recently, in 2019 HRSA awarded more than $85 million to 298 health centers to expand their oral health service capacity through new infrastructure enhancements (Health Resources and Services Administration 2019b). These investments are the first by HRSA to focus solely on oral health infrastructure and will enable HRSA-funded health centers to provide new, or enhance existing, oral health services.

Figure 18. Status of Medicaid expansion decisions by state: United States, 2020



Notes: Current status for each state is based on Kaiser Family Foundation tracking and analysis of state activity.
◊ Expansion is adopted but not yet implemented in MO and OK.
Source: Kaiser Family Foundation (2021).

Provision of Oral Health Care in Nontraditional Settings

Fragmented care delivery continues to characterize much of the U.S. health care system. The resulting lack of access to care for many, as well as poor coordination among health care providers, exacerbates poor health outcomes and contributes to health disparities (Wasserman et al. 2019). Moreover, dental delivery systems and regulatory environments still emphasize and provide disproportional support for surgical interventions provided in high-cost surgical suites (Suga et al. 2014). One result is that the understanding and adoption of evidence-based prevention and conservative management approaches to dental caries management have been slow over the last 2 decades. This lag in adopting or advocating for effective but minimally invasive prevention interventions, such as silver diamine fluoride or fluoride varnish, limits the provision of dental services in nontraditional settings (care provided outside a traditional dental office) by public health dental hygienists, dental therapists, or others who may be more available than dentists.

Care delivery outside of traditional dental care facilities continues to be problematic. The need for adequate equipment, such as a dental operatory and patient safeguards such as infection control and privacy, often creates financial and logistical barriers to providing care for some patients. The most important population in this regard is the institutionalized elderly or disabled, who often have limited or no mobility and may have significant oral health treatment needs. Although regular dental care delivered onsite would be possible for many, few long-term care facilities currently provide such care. In states where dental practice regulations permit care delivery by dental hygienists or other expanded-function professionals, some opportunity exists for onsite care.

Supply of Dental Services

In the past 20 years, several successful initiatives have been established to bridge the artificial separation between oral health and overall health by addressing the oral health knowledge gap in medical education, training medical personnel to look for oral disease and provide oral hygiene and dietary counseling, and engaging them in interprofessional practice. The Smiles for Life National Oral Health Curriculum, launched in 2005, covers oral health across the lifespan and is a free, open-access resource that provides continuing education credit for both medical and dental professionals (Society of Teachers of Family Medicine 2021). The curriculum, which is endorsed by 20 professional organizations, has more than 100,000 registered users. As of April 2021, more than 400,000 courses had been accessed for continuing education credit (Society of Teachers of Family Medicine 2021).

Medicaid pays medical providers in all 50 states and the District of Columbia for child oral health services, including fluoride varnish application (Pew Charitable Trusts 2011; Clark et al. 2014). The MORE Care program (DentaQuest) specifically trains rural primary care practices in primary and secondary oral health preventive services and provides technical assistance to integrate the work of medical teams and their oral health counterparts. Some of these programs also train general dentists who have not previously treated young children to start offering early childhood examinations and preventive services, particularly in rural areas where pediatric dentists are scarce (Colorado Department of Public Health and Environment 2020). Integration of oral hygiene counseling, dietary advice, and fluoride varnish application fits nicely into the well-child primary care conducted by rural family physicians, physician assistants, and nurse practitioners, provided the necessary additional time is built into their schedules or other clinical staff are trained to help.

Medical Settings

Better integration of dental and medical care could lead to more people receiving preventive dental services. Efforts to improve integration of medicine and dentistry have been slow to develop since 2000. Although interest has grown in the role that nondental health care providers and settings could play in improving oral health, dental care delivery within medical settings requires providers to have knowledge beyond what traditionally has been provided in their training. In response to this need, oral health curricular content in medical, nurse practitioner, and physician assistant programs has increased, and some family medicine residency programs have begun requiring rotations in dental clinics for resident physicians. However, the impact of increased curricular exposure on practice and patient outcomes remains unclear, especially in the absence of interoperable electronic health records, common referral processes, and insurance coverage (Dwiel et al. 2019).

The specific role of frontline medical providers in delivering dental care is still not well defined. However, it has become common for pediatric medical providers to apply fluoride varnish to children's teeth, a service that is recommended by the U.S. Preventive Services Task Force and universally reimbursed by Medicaid, as well as by most private insurers. Dental hygienist-led screening and preventive treatments, such as dental prophylaxis, have been successfully integrated into the pediatric primary care setting, including in the Colorado Medical-Dental Integration Project (Braun and Cusick 2016). Similar care models have been proposed for adult populations, although lack of insurance coverage for adults is a barrier to expanding equivalent services. Additional information on medical-dental integration is provided in Section 4.

Community Settings

Efforts to improve population health and reduce inequities, particularly for chronic diseases such as those often experienced by low-income and other vulnerable populations, can be enhanced through integration of community-based preventive service with professionally delivered clinical services as well as efforts aimed at increasing family-level engagement and empowerment

(Dietz et al. 2015). Delivery of clinical preventive services, long a focus of U.S. dental care, can be highly effective in addressing the chronic oral diseases of caries and periodontal disease. However, delivery of these services is largely dependent on access to routine dental care. Furthermore, financing for dental prevention is weighted toward the clinical interventions that focus on individual patient encounters with dental professionals. Community-based prevention programs, a foundation of public health, occur outside of the clinical care delivery system (e.g., water fluoridation, school-based programs, health-promoting policies). As such they do not rely on access to dental offices and generally reach a broader population and fill in gaps in access to prevention services, particularly for those individuals who do not regularly seek care in dental offices.

Sometimes overlooked is the important role of individual behaviors as contributors to oral disease prevention. As Dietz and others (2015) note, motivation and a supportive family environment are critical for developing and maintaining healthy behaviors and should be considered part of an integrated health care system. For example, community-level programs that reinforce the importance of appropriate self-care, such as toothbrushing with fluoride toothpaste and reduction of risky behaviors such as smoking, can provide broad benefits for population oral health.

Full integration across all levels of the health system will likely lead to optimal benefit for population health and reduction in oral health inequities. This requires that public and private policymakers at all levels (local, state, and national) create the environment that allows for maximum access to prevention services as well as access to health-promoting food and other conditions. Assuring that prevention efforts will benefit the broadest number of individuals and have maximum impact on population health generally depends on the degree to which prevention services are delivered at all levels. Coordination and integration can be especially important to ensure that low-income and other vulnerable populations receive the benefit of prevention interventions. As dental care delivery continues to evolve into more complex multi-provider systems of care and these systems integrate with primary medical care, new opportunities will arise for integration of clinical services with community programs.

Quality of Oral Health Care

The Triple Aim of health care articulated by Berwick and colleagues (2008)—improving the health of populations, improving patient experience with care, and reducing costs—laid the foundation for the value proposition in health care. A value-based system drives improvement based on outcomes relative to resource use and focuses particularly on those outcomes that are most important to patients (Porter 2010). Access, structure, and process measures that are associated with improved outcomes are useful tools for assessing and improving quality of care. Current oral health care performance measures fall largely in the process of care domain (Righolt et al. 2019). Ultimately, however, the true markers of success are whether patient and population outcomes have improved. Although several endeavors are beginning to identify tools to assess outcomes (Liu et al. 2016; FDI World Dental Federation 2018; Mittal et al. 2019), there are continued challenges in implementing data collection systems and infrastructure to aggregate clinical data from each patient encounter to ultimately achieve a population-level learning health system (Institute of Medicine 2013a).

Several areas offer promise for improving the quality of care, including the development of new dental diagnostic codes and clinical practice guidelines. Yet the adoption is slow in the majority of clinical practice settings. National metrics on oral health status, such as those within the federal Healthy People initiative and the CMS Child Core Set, offer promise for informing better oral health policy. However, at present, new policy initiatives aimed at improving access and prevention are not evident.

Oral Health Literacy

Interest in oral health literacy has increased substantially during the past 2 decades. Research on the relationship between health literacy and oral health shows that low levels of health literacy are correlated with poor oral health knowledge (Hom et al. 2012; Horowitz et al. 2013; Macek et al. 2017), suboptimal oral health behaviors such as limited use of preventive care (White et al. 2008; Bennett et al. 2009; Henderson et al. 2018), and negative oral health outcomes (Vann et al. 2010; Batista et al. 2017).

Ensuring that individuals understand what their medical and dental plans cover is important because out-of-pocket costs can discourage the use of dental services (Vujicic et al. 2016a). Many coverage options are now available. For example, some dental benefits are embedded in medical plans (Cousart et al. 2015). Dental services covered by commercial insurers and state Medicaid programs vary greatly (Willink et al. 2016), and their explanations of benefits can be confusing.

Informed consent is another essential aspect of patient care that requires participation among patients and providers. A patient's signature on a consent form, however, does not guarantee complete understanding of the risks, benefits, and alternatives associated with the proposed treatment (Kinnersley et al. 2013). A study of consent forms used for dental care indicated that the average American adult would have difficulty understanding most of them (Glick et al. 2010), suggesting that considerably more work is needed to ensure that all patients fully understand their options for dental treatment. Patients with low health literacy are less likely to understand to what they are consenting, although understanding of the consent process is poor regardless of literacy skills and may lead to unnecessary refusal of treatment (Aldoory et al. 2014). One study demonstrated the effectiveness of a simple teach-back technique to ensure comprehension of informed consent procedures for low health-literate populations (Sudore et al. 2006).

Effective communication is a patient safety issue. The medical community has long recognized the importance of health literacy in developing providers' skills for communicating effectively with patients to ensure safety. An Institute of Medicine (IOM) white paper describes 10 desirable attributes of a health-literate health care organization (Brach et al. 2012). These include preparing the workforce to be health literate, using health literacy strategies in interpersonal communications, and confirming understanding of health information at all points of contact. The Joint Commission initiated a public policy initiative in 2001 to address issues that could affect health care providers' delivery of safe, high-quality health care. In 2007, it launched a new perspective on the initiative, with a framework that highlighted health literacy as a way to protect patient safety. The framework has three components: (1) making effective communication an organizational priority to protect the safety of patients, (2) incorporating strategies to address patients' communication needs across the care continuum, and (3) pursuing policy changes that promote improved practitioner–patient communications (The Joint Commission 2007).

A culture of patient safety in dentistry involves not only making oral health information clear and accessible but also contextualizing that information in patients' lives. Dental providers who use effective communication techniques contribute to greater oral health literacy—the patients' ability to understand and act upon the information provided to improve their oral health (Horowitz et al. 2012; Maybury et al. 2013). Yet some studies show that dental providers continue to need support in using evidence-based communication practices with their patients (Rozier et al. 2011; Tseng et al. 2020). Furthermore, evidence suggests that dental and dental hygiene students graduate without the skills necessary to meet the literacy needs of their patients (Bress 2013; McKenzie 2014). Consequently, the Commission on Dental Accreditation (CODA) recently suggested a revision to its standards to include health literacy to help ensure that dental students are able to effectively communicate with their patients. Although CODA Accreditation Standards for Dental Hygiene Education include a standard that requires oral and written communication be included in the general education content, and another standard that requires graduates to have an understanding of how cultural influences can affect delivery of care, there are none specific to health literacy (Commission on Dental Accreditation 2018).

Educating the professional dental community about health literacy remains a major challenge. Environmental scans of health center dental clinics in Maryland showed that current practices related to oral health literacy lacked consistency (Horowitz et al. 2014). Prioritizing health literacy as a means to protect patient safety in dentistry starts with the dental education system and training future providers how to effectively communicate interpersonally with patients. Continued learning opportunities after graduation also may improve patient safety, as well as patient and population oral health status, and contribute to decreased disparities. Recent calls for required continuing education on health literacy and cultural competency for all dental providers is one approach that may help to improve the use of effective communication techniques (Rozier et al. 2011; Bress 2013; McKenzie 2014).

In the only reported population-based study linking oral health literacy and attitudes toward population-level oral health promotion strategies, Curiel and colleagues (2019) showed that an increase of one standard deviation in health literacy scores predicted a 12% increase for support of community water fluoridation. There is evidence that health literacy may contribute to sociodemographic differences in oral health behavior. For example, Bennett and colleagues (2009) found that health literacy significantly mediated education disparities related to utilization of dental care among older adults.

In reviewing oral health literacy measurement, Dickson-Swift and colleagues (2014) identified 14 different measures used in 32 studies. However, the majority of investigators relied on one of two measures—the Rapid Estimation of Adult Health Literacy in Dentistry or the Test of Functional Health Literacy in Dentistry. There is a need for development and assessment of improved methods to measure oral health literacy across diverse populations. In addition, the mechanisms through which health literacy influences oral health in general and how health literacy might differ across social subgroups need to be clarified (Jones et al. 2016), because such understanding is required to appropriately target literacy interventions.

In 2010, health literacy became the focus of both national legislative efforts and federal agency research after the ACA was signed into law. The ACA emphasized the need to increase health literacy among the general public, especially for those with lower income and/or education levels (HealthCare.gov 2021). In addition, the Plain Writing Act of 2010 mandated that federal documents designed for public audiences (e.g., Medicaid applications) be written in plain language. The law specified that each federal agency should train employees in the use of plain language, create and maintain a plain writing section on the agency's website, and establish a process to oversee agency compliance (111th United States Congress 2010).

Two federal agencies also contributed to the national focus on health literacy. In 2010, the Agency for Healthcare Research and Quality published the first edition of the Health Literacy Universal Precautions Toolkit. A second edition was released in 2015 (Brega et al. 2015). The aim of the toolkit is to guide primary care providers in implementing system-wide changes to improve communication with, and support for, patients of all health literacy levels. In an earlier effort, in 2004, the National Institute of Dental and Craniofacial Research convened a workshop aimed at promoting the national oral health literacy research agenda. The workshop—which targeted researchers in oral health, cognition, adult education, and communications—served to educate the research community about the need to expand understanding of oral health literacy (National Institute of Dental and Craniofacial Research 2005).

More recently, the Healthy People 2030 national initiative increased attention to health literacy by making "increase the health literacy of the population" one of its overarching goals. The initiative also includes new definitions of health literacy that address both personal and organizational health literacy. Personal health literacy is defined as "the degree to which individuals have the ability to find, understand, and use information and services to inform health-related decisions and actions for themselves and others." The definition of organizational health literacy, which aligns with the U.S. Department of Health and Human Services' National Action Plan to Improve Health Literacy (U.S. Department of Health and Human Services 2010b), is "the degree to which organizations equitably enable individuals to find, understand, and use information and services to inform health-related decisions and actions for themselves and others" (U.S. Department of Health and Human Services 2020c).

Professional organizations also took a greater interest in health literacy as a public health concern. In 2010, the Oral Health Section of the American Public Health Association developed the policy "Health Literacy: Confronting a National Public Health Problem" (American Public Health Association 2010). The policy statement was broad; it urged Congress to require government documents to be written in plain language and urged federal and state agencies to increase health literacy among children in grades K–12 and train health providers in the use of recommended communication techniques. The American Dental Association (ADA) established a National Advisory Committee on Health Literacy in Dentistry, part of the ADA's Council on Advocacy for Access and Prevention (formerly called the Council on Access, Prevention, and Interprofessional Relations). The committee developed a long-range plan that included providing education on health literacy at the ADA annual session, analyzing ADA's written patient materials to ensure they are written in plain language, and conducting surveys of their members' and dental students' use of recommended communication techniques (Rozier et al. 2011; Podschun 2012).

In 2013, the IOM Roundtable on Health Literacy published the proceedings of a workshop on oral health literacy (Institute of Medicine 2013b). Interestingly, when the roundtable was established in 2006, its membership included no dentists. In 2019, however, two dentists were active members and most of the roundtable's workshops now include a focus on oral health.

In 2000, oral health literacy was barely on the radar screen. Since that time, numerous instruments for measuring oral health literacy have been developed and investigators have pursued research aimed at understanding the link between health literacy and oral health. Health literacy has become a national priority, receiving attention from federal agencies, foundations, and professional organizations.

Oral Health and Quality of Life

Measures of oral health-related quality of life have been used in national surveys and as an outcome measure in clinical trials. In the case of population-based oral health surveys, the most widely used instrument has been the shortened version of the Oral Health Impact Profile (OHIP-14) (Slade 1997). The data from these studies have shed useful insights into the varying impacts of oral diseases and their treatment at the population level (Locker and Quinonez 2009; Benn et al. 2015; Parker et al. 2016; Zusman et al. 2016; Tsakos et al. 2017; Torppa-Saarinen et al. 2018; Masood et al. 2019). Developments during the past 20 years have enabled movement toward patient- and population-centered outcomes for several oral conditions and their treatments. These advancements align with the World Health Organization's conceptualization of health as more than the absence of disease, but a state of physical, mental, and social well-being (World Health Organization 1946). For example, pediatric oral health-related quality-of-life measures have been used to gauge the social impact of such conditions as early childhood dental caries (Tinanoff et al. 2019). Oral health-related quality-of-life measures have been used to assess the impact of dental care at the individual level, such as endodontic treatment (Neelakantan et al. 2019), implant-supported overdentures (Sharka et al. 2019), or orthodontic treatment (Ferrando-Magraner et al. 2019), as well as the impact of policies and programs at the population or community levels (Ha et al. 2012; Burgette et al. 2017; Ho et al. 2019; Seo and Kim 2019; Tomazoni et al. 2019).

Oral Health Surveillance for Population Health Planning

Public health surveillance provides data and information on the burden and distribution of disease and other health-related conditions. This information helps to monitor interventions and disease control measures that have been implemented to improve health, set public health goals, and assess for emerging conditions that might pose a threat to public health. In the past 2 decades, rapid advances in information technology have transformed our ability to use data for decision making, ushering in new fields of interest in health informatics, particularly in public health informatics (Groseclose and Buckeridge 2017).

Public health practitioners utilizing these informatics tools can have an important impact on the health and well-being of populations at local, state, and national levels (Friede et al. 1995; McNabb et al. 2006). Although the application of health informatics is substantially advanced in medicine and health care, it remains in an early stage of development in dentistry and oral health care. This presents several challenges. Many oral health surveillance activities in the United States are dependent on active surveillance measures, which are resource intense and are often periodic. Active surveillance also requires a substantial commitment to maintain the infrastructure. On the other hand, an ongoing passive surveillance system using informatics concepts can potentially provide more consistent and timely oral health data about population health for many important planning purposes. Such systems require greater functionality within dental electronic health records than exist today. Nevertheless, enhanced investments in oral health monitoring and surveillance activities, including in dental public health informatics, could facilitate the evaluation of interventions and disease control measures and could lead to evidence-based approaches that improve oral health and reduce health disparities.

The goal of surveillance programs is to provide essential data for program planning and support efforts that lead to improved population health and decreased oral health inequities. The Association of State and Territorial Directors cautions that, to meet those goals, data collection alone is insufficient. Features that support an effective surveillance system include collection of standardized and actionable health information, rapid analysis and dissemination of findings, and buy-in from policymakers when policy solutions are indicated (Phipps et al. 2013).

Oral Health and National Security

The military continues to face challenges in meeting recruitment goals and military readiness because of oral health-related issues. Today, fewer than 1% of potential Air Force recruits are rejected because of extremely severe dental conditions. However, among new recruits entering the Air Force, nearly all have some level of unmet dental treatment needs, and about a quarter (23%) suffer from serious oral conditions that prevent them from deploying (Irwin 2019a).

In the deployed environment, disease and nonbattle injuries (DNBI) accounted for the majority (75%) of all casualties (Zouris et al. 2008). Of DNBIs, 15–22% were dental-related emergencies (Dunn 2004). During Operation Iraqi Freedom, nearly 17% of deployed members required acute dental care while deployed. In FY 2018, 20% of dental visits during deployment were emergency related (Irwin 2019b). These dental emergencies can risk a deployed unit's ability to complete a mission and require costly and dangerous medical evacuations by ground convoy, helicopter, and/or fixed-wing aircraft. In FY 2017, nearly one-fifth (18%) of all medevacs were the result of dental emergencies in locations where dental teams were not deployed, and each medevac cost an average of nearly $100,000.

Meeting recruitment goals for dental professionals is another challenge, with recruitment of oral and maxillofacial surgeons a particular challenge. Specifically, between FY 2012 and 2016, the Navy was not able to recruit additional oral and maxillofacial surgeons (U.S. Government Accountability Office 2018). Instead, the Navy maintained high levels of dental readiness by training the necessary oral and maxillofacial surgeons through in-house training programs fully accredited by CODA. Continued focus on recruiting and/or training the necessary numbers and types of oral health providers will be needed to maintain high levels of readiness.

The services, in turn, are reevaluating the number and specialty mix of uniformed providers needed to support the warfighting mission (Philpott 2019). This will include some reduction in total numbers of providers as those positions are transferred to warfighter roles to meet the Secretary of Defense's priorities. The intention is to use purchased care to handle the potential reduction in access to military facilities. It is unclear how this might affect dental wellness.

Over the past 20 years, the U.S. Navy has made significant progress integrating dental and medical care. The dental technician rating merged with hospital corpsman. Consequently, all active-duty enlisted personnel with assignments primarily related to dental care receive more advanced medical skills training and acquire greater understanding of how dental health relates to overall health and well-being. Additional training in oral health issues is now provided for the hospital corpsman. This allows greater flexibility and utilization of medical enlisted personnel and a broadening of individual career opportunities (U.S. Department of the Navy 2005).

The U.S. Air Force has made significant progress in improving the dental readiness of airmen over the past 2 decades. In 2001, nearly half (45%) of airmen had a dental readiness classification (DRC) of either DRC 2 or DRC 3 for oral health conditions that required treatment. By 2018, just 22% of the force had any current dental treatment needs. Similarly, over the last 2 decades, the percentage of airmen classified as high risk for caries has decreased 50% (from 11% in 2001 to 5.6% in 2017) (Schindler et al. 2021). Today, more than 95% of active-duty airmen are DRC 1 or 2 and dentally ready to deploy.

Tobacco smoking among airmen also declined substantially during this period—from 22% in 2001 to just 8.9% in 2017—a 60% reduction (Schindler et al. 2021). Although the prevalence of smoking historically has been higher in the military than in the general U.S. population, overall the prevalence of smoking today is actually lower among airmen (8.9%) than among the civilian population (14%) (Creamer et al. 2019). A key contributing factor to the decline in smoking includes intervention efforts of Air Force dentists through free smoking cessation programs for airmen. Air Force Dental Service (AFDS) providers are being trained to provide tobacco cessation counseling and related pharmacotherapy to tobacco and e-cigarette users. E-cigarette use is highly prevalent among youth and young adults, some of whom are beginning to enter the Air Force. Data from an ongoing Air Force public health assessment revealed that among all airmen, the prevalence of e-cigarette/vaping product use had risen from 5% to nearly 8% since October 2017. Studies indicate that e-cigarette use among young populations may increase the risk of using combustible and other types of tobacco products (Soneji et al. 2017). In the coming years, vaping/tobacco cessation interventions to aid cessation of tobacco use, including vaping products, by AFDS providers may be key to preventing an increase in overall tobacco use among airmen. In addition, the Air Force Dental Corps have developed certified tobacco treatment specialists who provide training to dental providers to improve access to smoking cessation treatments.

Chapter 3: Promising New Directions

Social Determinants of Health and Commercial Determinants of Health

Watt and colleagues (2014) argued that the social determinants of oral health disparities were the same as those associated with other health disparities, such as those related to diabetes and cardiovascular disease, and that improving social and economic conditions supported improvements in health generally, including oral health. For example, by improving someone's income and education, or by providing broader income supports and access to education for a population, it is reasonable to assume that improvements in diet and reductions in stress would occur. In turn, these improvements could be expected to reduce risks related to a broad array of diseases, including dental caries, periodontal disease, prediabetes, diabetes, metabolic syndrome, and hypertension.

Many of the social and commercial determinants of health are structural in nature. Alleviating the inequities they create will require interventions that focus not only on individual behavior and biological determinants of oral health but also on social and commercial determinants (Sabbah et al. 2009). This means that there is potential to mitigate inequities in oral health with large-scale policy changes that alter the structural determinants of health. These policy changes, including regulations supporting such issues as income security and food security, are politically challenging. However, these conversations are becoming more prevalent in societal and political discourse today.

Vulnerable Populations and Oral Health Disparities

Policy changes advanced by the Affordable Care Act (ACA) include promotion of the patient-centered medical home (PCMH) (Agency for Healthcare Research and Quality 2018). The PCMH emphasizes comprehensive and coordinated patient-centered care, accessible services, quality, and safety. However, dentistry has not yet become a significant partner in this initiative. As Wasserman and colleagues (2019) note, although the impact of the PCMH has not yet been empirically demonstrated, the increased emphasis of the PCMH on primary care, prevention, and community-based service delivery holds promise. Incorporating oral health services is a logical next step in the development of this initiative.

Rural Populations

Well-documented disparities in rural oral health outcomes have led to inquiry and innovation. Integration of oral health into primary care, interprofessional practice, teledentistry, school-based oral health services, and the addition of dental therapists to the dental professional workforce provide opportunities to reduce oral health disparities among rural populations (National Advisory Committee on Rural Health and Human Services 2018).

Integrating oral health into primary care is particularly important because primary care medical providers—particularly family medicine physicians and pediatricians—are widely distributed across the United States, including rural areas where they offer preventive care, early diagnosis of disease, and prompt referral when subspecialty care is indicated. Primary care medical providers, therefore, are well-positioned to work with dentists to comanage diseases with known oral-systemic connections, such as diabetes and periodontitis.

As rural areas acquire increased Internet bandwidth, telemedicine and teledentistry are becoming viable methods for delivering expertise to rural areas, saving patients the time and expense of travel, and expanding available services. In response, some states are modifying health care providers' scope of practice to accommodate virtual doctor-patient interactions. The Federal Office of Rural Health Policy, operating under the Health Resources and Services Administration, has more than doubled its budget since 2016 and provided substantial grant funding for teledentistry and mobile dentistry initiatives. These teledentistry models, such as California's virtual dental home, may expand access to dental care in remote and underserved areas, with the understanding that effective payment models and mechanisms for timely referral for more intensive dental needs will need to be developed (Glassman et al. 2014).

Opportunities to expand access and improve the rural dental safety net are being explored and developed. Because most professional practice policies are implemented at the state level, these include changes in state law related to scope of practice and the oral health workforce. An example of coalition building to advocate for change in state law to improve oral health is the Foundation for Health Leadership and Innovation, North Carolina Oral Health Collaborative. This collaboration brings together a diverse group of stakeholders focused on improving access to oral health care in rural areas and among populations with high oral health disparities (Box 2). Other states are amending their state practice acts to improve population health, including Pennsylvania, which now certifies public health dental hygiene practitioners to provide care in a variety of public health settings without the supervision or prior authorization of a dentist.

Expansion of dental therapy is another promising model, given the evidence of improvements in dental outcomes in rural areas where dental therapists practice (Koppelman et al. 2016b). Minnesota authorized a dental therapist program in 2009, and other states now have similar pending legislation regarding dental therapists. The original goal for developing this new category of oral health provider was to fill the unmet needs of rural and underserved children (Nash and Nagel 2005; Friedman and Mathu-Muju 2014b), but there is evidence that they also are helping to meet the needs of the rural elderly (Fish-Parcham et al. 2019), particularly those in extended-care facilities. Both school-based programs for children and extended-care facilities for the elderly exemplify population-based approaches to improving access to care by meeting people where they live, work, and play.

Program evaluations in Alaska and Minnesota found that the clinical care provided by therapists was clinically competent, appropriate, and provided in safe ways. An evaluation of the Alaska program by Chi and colleagues (2018b) found that villages that employed therapists had increases in access to dental services and prevention services and less need for extractions and treatment under general anesthesia. The success of these programs speaks to the potential of this model to benefit vulnerable rural populations in varied geographic settings.

Programs intended to recruit and train rural dentists also have the potential to create major improvements in rural access. Several dental schools have developed programs to incentivize dentists to practice in rural communities, including the University of Washington's RIDE program, the University of Minnesota's Rural Dental Scholars program, and the University of Mississippi's Rural Dentists Scholarship program. The National Health Service Corps (NHSC) scholarship and loan repayment programs support almost 500 rural dentists, although the number of dental providers in the program has not increased as substantially as that of other clinicians supported by the NHSC (Pathman and Konrad 2012). National rural primary care training programs—such as the HRSA-funded academic unit, Rural Primary Care Research, Education, and Practice—may serve as models for future rural oral health expansion (Rural Primary Care 2019).

Box 2. How can diverse groups of stakeholders collaborate to improve access to oral health care in their state?

The North Carolina Oral Health Collaborative (NCOHC), a program of the Foundation for Health Leadership & Innovation, was established in 2013 to increase access and equity in oral health care for North Carolina's most vulnerable populations. Policy advocacy is a major activity for NCOHC. By bringing together community organizations, professional societies, health providers, academics, and legislators, NCOHC leverages diverse perspectives for the development of evidence-based policy reforms. In 2020, NCOHC influenced a regulatory rules change that allows dental hygienists to provide preventive services (cleanings, x-rays, sealants, fluoride applications, screening) in high-need settings without a prior examination by a dentist. This change increases direct access, builds a culture of community-based dentistry, and brings care to people where they are.

In 2021, NCOHC and its key stakeholders drafted and introduced legislation in the North Carolina General Assembly to codify teledentistry in the state's Dental Practice Act. To support this pending change, NCOHC provided financial support to Federally Qualified Health Centers and local health departments for implementation of teledentistry.

NCOHC recently completed a 2-year community capacity building mini-grant initiative. Grants were awarded to seven organizations working with populations with high oral health disparities. Activities included NCOHC-organized events and trainings and focus group meetings to discuss local oral health needs. One of the goals was to develop the 2019–2024 North Carolina oral health change agenda, which was completed and published in 2019.

There now are more than 1300 partners and organizations in NCOHC. Current and former funders include the Blue Cross Blue Shield of North Carolina Foundation, The Duke Endowment, the Kate B. Reynolds Charitable Trust, and the CareQuest Institute for Oral Health (formerly the DentaQuest Partnership for Oral Health Advancement).

As already discussed, the existing rural primary medical care workforce could provide a substantial resource for improving rural oral health. Nationally, delivery of preventive oral health services within pediatric practices occurs at lower rates in rural communities (Geiger et al. 2019). Because of higher rates of primary medical—rather than dental—utilization, the primary medical care setting can serve as an access point for oral health screening, treatment, and referral (Davis et al. 2010; Caldwell et al. 2017). Several states with large rural populations have implemented integrated practice models, often focused on pediatric populations. In these models, such as North Carolina's Into the Mouths of Babes program (Pahel et al. 2011) and the Colorado Medical-Dental Integration Project (Braun and Cusick 2016), families receive preventive oral health care services and screening within the primary care setting (Blackburn et al. 2017).There are 4,500 rural health clinics widely distributed across the nation delivering primary medical care, but they currently are not required to provide preventive dental services. Adding dental services to the scope of care in these clinics would significantly expand the dental safety net (American Dental Education Association 2018) while efficiently leveraging existing resources and personnel.

Shifting the distribution of dentists from urban areas to rural communities is a longer term solution to improve rural access to oral health care. The task of producing more rural dentists is similar to that of producing rural physicians; both depend on a complex combination of admission preferences, curriculum, mentorship, personal lifestyle choices, and incentives (McFarland et al. 2010; Vujicic et al. 2016b). Dental schools could increase the use of a strategy that some medical schools have successfully implemented by creating rural tracks designed to attract, admit, and mentor students who are interested in rural practice and by creating residency programs targeted to the skills required for rural practice (Downey et al. 2010; WWAMI Rural Health Research Center 2012; Deutchman 2013; Suphanchaimat et al. 2016).

Low-Income Populations

Community water fluoridation achieved wide success in the mid-20th century for primary prevention of dental caries (Carstairs 2015). In the 21st century, community water fluoridation has again captured national public health interest, this time for its effects in reducing socioeconomic disparities in dental caries. Not only does water fluoridation confer a protective effect beyond that offered by other sources of fluoride (Slade et al. 2018), it can especially benefit children in low-income families (Sanders et al. 2019). A study compared levels of dental caries in two groups of children: those living in counties where at least 75% of the population received optimally fluoridated drinking water, versus those in counties with a lower percentage of the population with fluoridated drinking water (Sanders et al. 2019). Findings showed that living in a predominantly fluoridated county reduced the magnitude of income disparities in dental caries. The findings are important from a health policy perspective. Efforts to expand population coverage of community water fluoridation that intentionally target counties with high concentrations of families with lower income could yield greater benefits in reducing both dental caries and income disparities in dental caries.

Black or African American Populations

In 2017, 21.2% of non-Hispanic Blacks in the United States lived below the poverty line—the highest of any racial group (Semega et al. 2018a). The median household income of non-Hispanic Blacks in 2017 was $40,258, the lowest of any racial group (Semega et al. 2018b). Thus, the substantial number of non-Hispanic Blacks potentially at risk for oral diseases by income and social pathways alone requires approaches that are geared more towards health equity. Health systems in the United States are starting to incorporate social determinants into health assessment protocols to learn more about which of these may be more influential to health (Gottlieb et al. 2014). In addition, health systems and organizations focused on both disease prevention and care provision are beginning to prioritize oral health through integrated care models and value-based care models (Solomon and Kanter 2018).

Hispanic Populations

Access to new datasets related to Hispanic population health has enabled new research. The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) dataset has several affiliated ancillary studies that explore specific topics in greater depth and have potential to further clarify the role of cultural factors in oral health. The HCHS/SOL has a sociocultural ancillary study with a subset of participants (Gallo et al. 2014) that included more validated cultural measures for a range of psychological stressors and resources than what was available in the main study. Several oral health analyses are underway that will advance the field's understanding of cultural factors among Hispanics in the United States. Advances in genomic studies related to the oral health status of adult Hispanics have been made in recent years, and HCHS/SOL data have been used in genome-wide association studies (GWAS) (Conomos et al. 2016). To date, published HCHS/SOL GWAS studies have focused on temporomandibular disorders (Sanders et al. 2017a), dental caries (Morrison et al. 2015), and chronic periodontitis (Sanders et al. 2017b). This new series of studies based on HCHS/SOL data will advance identification of the biologic/genetic factors associated with oral diseases for Hispanic Americans.

Level of acculturation and the influence of other cultural factors among Hispanic Americans are now being studied in greater depth to advance understanding of their relationships to oral health status and practices. For instance, familism, or *familismo*, is a core cultural concept that describes the importance of immediate and extended family in Latino families (Stein et al. 2014). Exploratory research is emerging on the role of *familismo* in an oral health context (Maupome et al. 2016). In the HCHS/SOL dataset, cultural factors related to ethnic identity (measured by a sense of belongingness) and acculturation were associated with oral health-related quality of life, although overall there were inconsistent patterns of association in adjusted models (Silveira et al. 2020).

American Indian and Alaska Native Populations

New dental care delivery technologies, such as teledentistry, can especially benefit remote-living American Indian and Alaska Native (AI/AN) populations (Glassman et al. 2012). Legislative approaches that address social determinants of health (SDoH) also are being developed. A bipartisan bill, the Social Determinants Accelerator Act of 2019 (H.R. 4004) (116th United States Congress 2019), was introduced in the U.S. House of Representatives (Luthi 2019) and although it was specifically related to Native Americans, it had the potential to benefit many population groups. The legislation would provide technical assistance to local, state, and tribal governments to develop innovative approaches to provide services and improve outcomes (116th United States Congress 2019). A new framework encompassing SDoH in dental education emphasizes a need for reframing the current teaching structure to include health inequities, population health and diversity, and cultural competence (Tiwari and Palatta 2019).

The Indian Health Service (IHS) Loan Repayment Program is available to fund IHS clinicians to repay their eligible health profession education loans in exchange for an initial 2-year service commitment to practice in health facilities serving AI/AN communities. Opportunities are based on Indian health program facilities with the greatest staffing needs in specific health profession disciplines (Indian Health Service 2021c).

The IHS Scholarship Program provides qualified AI/AN health profession students an opportunity to establish an educational foundation for each stage of their preprofessional careers. Since IHS began providing scholarship support to AI/AN students to pursue health profession careers in 1978, the program has grown to support, educate, and place health care professionals within medically underserved Native American health programs throughout the continental United States and Alaska. Today, nearly 7,000 AI/AN students have received scholarship awards, and many have committed to serving their professional careers at IHS.

Oral Health for Those with Special Health Care Needs

There is a growing realization that dental services delivered in the community provide better dental access for vulnerable populations than do traditional brick-and-mortar dental care delivery systems. These services include using mobile and portable equipment, telehealth-connected teams to involve outside dentists, and allied oral health personnel applying aspects of modern prevention science, including minimally invasive treatment techniques. There is growing interest in integration of oral health activities into general health, educational, and social service settings. The integration of general health and oral health care systems will drive incentives to create better oral health for individuals with special needs or complex health conditions. The movement from volume to value will have particular impact on oral health care for this population.

Financing Dental Care

With flexibility built into the current system through Medicaid waivers and the capacity for value-added programs implemented by contracted dental health plans, we may see new initiatives aimed at providing better and more comprehensive oral health through Medicaid and Children's Health Insurance Programs. Moving toward value-based care, where providers are given incentives to improve the oral health of a population, may help to improve dental coverage gaps and increase access, especially for low-income and ethnic minority patients (Riley et al. 2019). There are other policy options available to expand dental insurance for working-age and older adults. Potential options include providing dental coverage for these adults as a mandatory benefit within Medicaid and Medicare, as well as considering dental care services for adults as essential services under the ACA.

Dental Care Delivery Models

Accountable Care Organizations (ACO) are promising models for furthering integrated oral health care. ACOs provide comprehensive medical services through a model that offers incentives for both cost reduction and quality, generally through a capitated mechanism with incentive bonuses for meeting baseline quality measures. ACOs have proliferated since the adoption of the pioneer Medicare ACOs in 2012 (Pham et al. 2014), based on systems developed in 2009 by Blue Cross Blue Shield in Massachusetts. Ten percent of Americans currently receive their care through an ACO utilizing both public and private insurance contracts (Muhlestein et al. 2018).

ACOs represent a seismic shift away from fee-for-service reimbursement in medicine. Given the emphasis on quality of care and the responsibility of the ACO for all member costs, ACOs may be incentivized to pursue innovative models of dental care if they result in cost savings or improved outcomes. Although promising, only about one-fourth of Medicaid ACOs and one-tenth of contract ACOs nationwide were responsible for dental costs and quality in 2015 (Colla et al. 2016). Even when oral health is included in ACO coverage responsibilities, dental care is most often reimbursed with conventional fee-for-service payments to contracted dental providers external to the ACO. A notable exception to this is Oregon's Medicaid ACO, which offers dental providers a per-member per-month (PMPM) fee that is carved out of the global PMPM budget for ACO enrollees (Atchison et al. 2018).

Clinical innovation under the ACO umbrella lags even further—in 2015, only 4% of ACOs had integrated dental clinicians into their care teams. ACOs that have introduced oral health quality measures have been limited to process rather than outcome measures, and those in effect have only been applied to pediatric populations. For example, a quality measure used by the Massachusetts Medicaid ACO is the percent of beneficiaries under age 21 receiving an annual dental visit, and the Oregon Medicaid ACO provides bonuses for increased dental sealant rates among beneficiaries aged 6 to 14 years.

Addressing these concerns—by increasing the numbers of ACOs, fine-tuning reimbursement options, and offering incentives for clinical innovation—could make ACOs a valuable addition to dental care.

Oral Health Literacy

Improving the health literacy of the U.S. population holds great promise to improving utilization and choice of dental care, leading to better oral health outcomes. The foundational skills underlying health literacy, such as reading and math, are typically developed in the context of regular schooling. Consequently, it is likely that health literacy skills of any group will correspond with the overall quality of their education system. Implementing educational strategies shown to effectively enhance reading, numeracy, and verbal communication skills can help individuals better manage their oral health. Incorporating real-world, oral health-related tasks into educational efforts might be particularly valuable, increasing both underlying health literacy skills and oral health knowledge at the same time. A focus on real-world needs often is implemented in adult basic education (Murphy et al. 1996) and could be extended to other levels of the educational system.

Quality of Oral Health Care

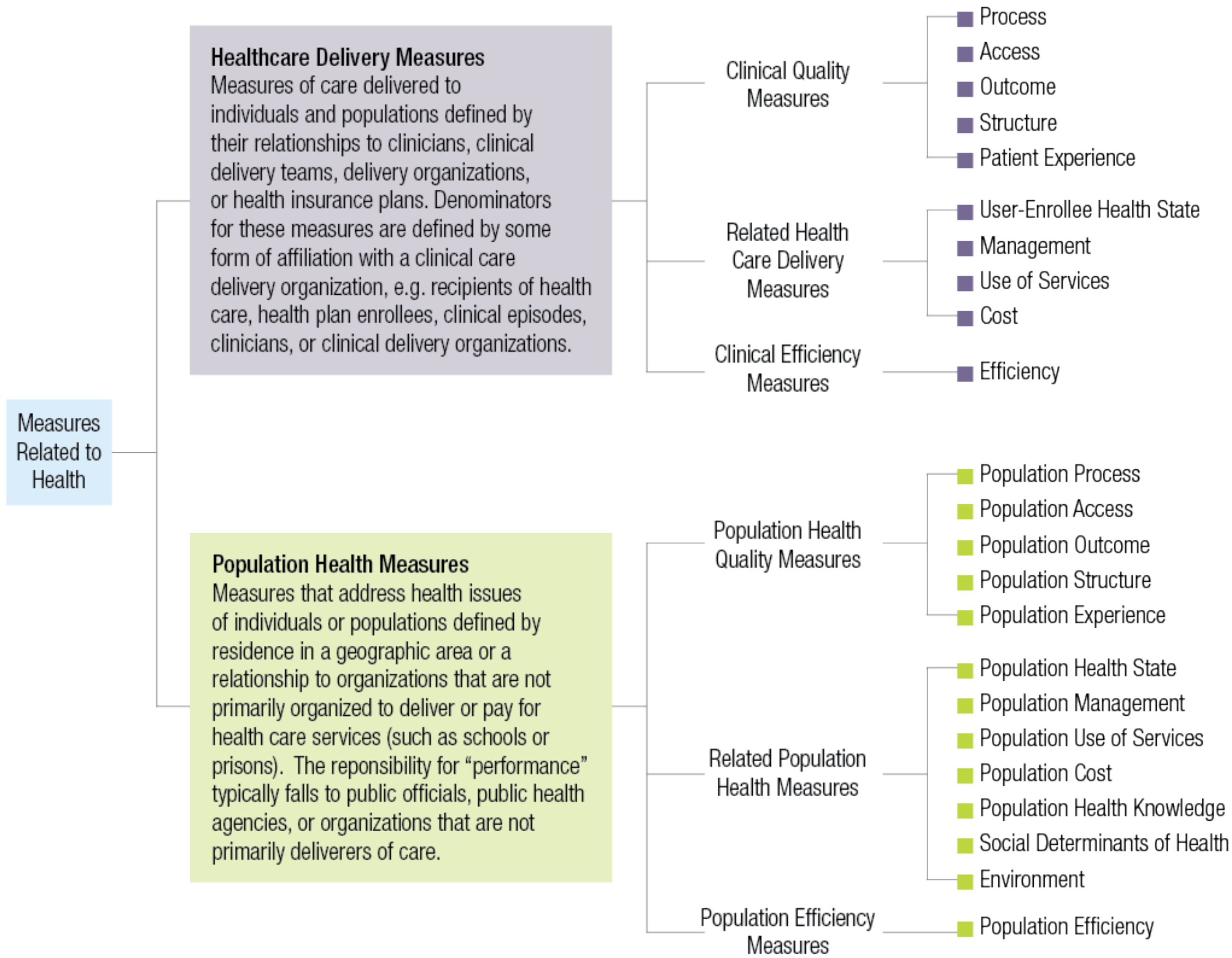
Quality oral health care delivery is advancing on several fronts. There is increased emphasis on the importance of full integration of medical and dental care as integral to a vision of Berwick's Triple Aim, which deploys new patient-centered quality metrics for improved planning and evaluation, better surveillance of population health, and reduced health care costs. Support for integration came from the Institute of Medicine report (2011) that recommended integration of oral health in planning, programming, policies, and research in all U.S. Department of Health and Human Services agencies and programs.

A necessary condition for integration is an interoperable electronic health record (EHR) capable of rapidly updating a patient's clinical status in a way that is accessible to members of the medical and dental teams. Jones and colleagues (2017) provided several examples of organizations that offer promising integration models. These include the U.S. Department of Veterans Affairs (VA), Kaiser Permanente (Permanente Dental Associates), HealthPartners, PACE programs, and some Federally Qualified Health Centers. A highly adaptable model that is not dependent on a unique health care delivery infrastructure is the DentaQuest Medical Oral Expanded Care program (CareQuest Institute for Oral Health 2021), which is both flexible and scalable. These models provide important guidance for others with interest in creating integrated health care.

Another innovation improving EHR effectiveness was motivated by state Medicaid policy requiring use of dental diagnostic codes (ICD-10 codes), now mandated in several states (American Dental Association 2015b). Requirements for diagnostic codes in private insurance are still evolving. Diagnostic codes are central to medical records and provide the foundation for assessing quality of care. As their use in dentistry increases, benefits for care integration and advancement toward the Triple Aim's goals will be supported.

A focus on population health outcomes requires attention to nonclinical determinants of health, as well as clinical determinants. The relevance of SDoH, such as poverty status, is explicitly recognized in the National Quality Measures Clearinghouse framework (Figure 19). Section 1115 of the Social Security Act promotes experimental or demonstration projects likely to forward the objectives of the Medicaid program. Population health outcomes and value are measured separately from health care treatment outcomes. Recognizing this, some states are successfully gaining approval for Centers for Medicare & Medicaid Services' 1115 demonstration projects to address the

Figure 19. National Quality Measures Clearinghouse (NQMC) domain framework



Source: Agency for Healthcare Research and Quality (2019).

SDoH as a pathway to realizing improved outcomes. The North Carolina Department of Health and Human Services is piloting a comprehensive program that targets such social determinants as housing instability, transportation barriers, and food insecurity (North Carolina Department of Health and Human Services 2018). Florida obtained a waiver to pilot the provision of housing support services for adult Medicaid beneficiaries with severe mental illness and substance use disorders who are homeless or at risk for homelessness (Florida Agency for Health Care Administration 2016).

Evidence-based dental practice initiatives aimed at improving the quality of care have grown steadily in recent years. Professional organizations are leading the way in developing clinical practice guidelines aimed at bringing the best evidence into the hands of clinicians in ways that facilitate application in routine clinical practice. The American Dental Association is a leader in this area, having supported development of a number of important guidelines related to prevention, conservative dental caries management, and appropriate antibiotic use, among others. See Section 4, Table 8 for more information.

Oral Health and Public Health Emergencies Planning

Public health emergencies can arise at any time from natural or man-made disasters and could have a serious impact on a community's oral health. Although the magnitude and severity of the impact on oral health can vary greatly, these emergencies often affect the more vulnerable, who already experience poor oral health and who are dependent, to the greatest extent, on the health care safety net. In the United States, preparing for these disasters requires substantial planning, investment, and ongoing discourse at federal, state, and local levels.

Preparedness can take many forms, ranging from addressing financial loss to providing health care (Kim-Farley 2017). A key barrier to health care preparedness typically is a lack of coordination across the spectrum of public health and health care communities and disciplines (Markenson et al. 2005). An example of a community overcoming numerous coordination barriers to include oral health care in emergency preparedness and response is Fulton County, Georgia, where the county health department includes oral health providers in planning for and responding to public health emergencies (Box 3).

The COVID-19 pandemic has revealed the necessity of having health care infrastructure and policy preparedness plans in place to successfully cope with widespread infectious illness across the country. Pandemics reveal inequities in health care access and availability that increase already existing health disparities in vulnerable communities and populations. Just as the HIV/AIDS epidemic forever changed infection control standards and guidelines in dentistry to prevent the spread of bloodborne pathogens (Kohn et al. 2003), COVID-19 may change infection control practices to control the spread of respiratory diseases among dental health care workers and patients. Many dental procedures generate large amounts of droplets and aerosols, which have been shown to be capable of carrying the coronavirus implicated in COVID-19 (Anderson et al. 2020; Ge et al. 2020). Most dental care facilities have not been designed to practice using airborne precautions, and few dental health care workers had prior experience with respirators before the onset of the pandemic. Clinical recommendations and guidelines are rapidly changing to address the new reality, and there is a strong possibility that long-term standards will establish administrative and engineering controls for aerosols. The increasing frequency of disease outbreaks attributable to viruses in recent years suggests that reduction and control of aerosols and droplets may become a permanent practice in the provision of oral health care.

Oral Health and National Security

A promising new direction in military oral health care is being adopted by the Veterans Health Administration, U.S. Coast Guard, and U.S. Department of Defense (DoD). It includes the modernization and integration of EHRs, which will allow service members to maintain the same record when transitioning care from DoD to VA. This will give health care providers a full picture of a patient's history since their start of active duty and will help identify those at increased risk for other issues, such as opioid addiction (U.S. Department of Veterans Affairs 2018).

To facilitate global continuity of care for service members by leveraging telecommunication and information technologies and collaborating with colleagues from the other services and the Defense Health Agency, the Navy is developing and testing a dental virtual health infrastructure (U.S. Department of the Navy 2019).

The Army is exploring incorporation of advanced information technology, such as voice recognition dictation, dental diagnostic coding, and electronic dental records, which could improve efficiency and quality of patient care by allowing rapid creation of a searchable dental record. Advances in nanotechnology could expand the use of salivary diagnostics beyond disease testing to real-time biometric monitoring of soldiers' physiologic function and hydration status (National Institutes of Health 2010).

The greatest impact on soldier wellness and readiness, however, would be accomplished with new methods to prevent or diagnose the root cause of more than half of all dental treatment needs and dental emergencies—dental caries. New technologies that allow for reliable and valid caries detection by nondental personnel would be of great value for screening, particularly in areas where dental professionals are not readily available. This would facilitate triage and referral for prevention or disease management interventions. An antiplaque peptide

Box 3. How does a community include oral health care in emergency preparedness and response?

Hurricanes and other emergency events can create serious challenges to receiving oral health care, particularly for vulnerable individuals. Including oral health professionals in planning for and responding to emergencies has created opportunities to improve access to care for residents of Fulton County, Georgia, and neighboring counties. While assessing the immediate health needs of persons moved to a temporary shelter during a hurricane, a dentist member of the local unit of the Medical Reserve Corps noticed that the health intake questionnaire did not include questions about oral pain or dental problems. Moreover, the membership of the local unit included physicians, nurses, pharmacists, and veterinarians but almost no dentists. Recognizing that dentists, with their advanced knowledge of oral health in the context of overall heath, could play an important role in emergency preparedness and response, the Fulton County Board of Health began recruiting dentists in 2019 to join their local Medical Reserve Corps. During the COVID-19 pandemic in 2020–2021, an additional group of 40 oral surgeons and dentists quickly stepped forward to join the Medical Reserve Corps to develop protocols for swab tests, administer diagnostic tests, and provide vaccinations. In another example of the county's response to an emergency that threatened access to oral health care in an adjacent county, Fulton County and Clayton County entered into a co-location of services agreement. When the Clayton County dental facility had to be closed because of mold, its staff relocated to a dental facility already operating in Fulton County. In the first 6 months of operation, 300 at-risk children from Clayton County received oral health services at the Fulton County facility. This collaboration marks the first time that two districts in Georgia have operated under a co-location of services agreement.

developed by the Army Institute for Surgical Research has demonstrated efficacy against biofilm-producing microorganisms and was recently incorporated into a chewing gum formulation to determine if it can prevent dental caries (Al-Ghananeem et al. 2017). The restoration of deeply cavitated carious lesions using minimally invasive treatment techniques and bioactive materials has the potential to preserve tooth structure, extend the retention and function of soldiers' natural dentition, and possibly help to manage urgent care needs in remote environments (Zhang et al. 2012; Schwendicke 2018; Aro et al. 2019; Pappa et al. 2019).

Chapter 4: Summary

There are several issues that influence oral health beyond the clinical realm in which dentists and their patients typically interact. By considering broad epidemiological, systemic, and policy perspectives and examining the best available data, it can be more clear where oral health is improving and where there is a continued need for concern and action (Box 4).

Many improvements in oral health have occurred in the past 2 decades. The prevalence of major oral diseases is declining. Access to care for low-income children has improved remarkably as a result of Medicaid and Children's Health Insurance Program reform and, more recently, for low-income adults through Medicaid expansion under the Affordable Care Act. Despite ongoing improvements in oral health, poor oral health continues to be highly prevalent and remains a major concern for many Americans. For example, since the release of the last Surgeon General's report on oral health in 2000, the current patchwork of dental care financing continues to create major gaps in access to affordable dental care for many vulnerable groups. These same groups tend to suffer disproportionate levels of dental disease, with little hope of obtaining needed care. Having large segments of society suffer from persistent untreated oral disease creates economic and societal costs that harm individuals, families, communities, and national security.

A new understanding has emerged that the causes of poor oral health are the result of complex interactions of determinants from many levels, including socioeconomic conditions and the food and beverage industries' targeting of vulnerable populations with sugary or low-nutrition food items. The result is unacceptable disparities in oral health among population groups. Although these distal health determinants have previously been recognized in some form or another, they are now identified in the conceptually, empirically, and policy unifying language of the social and commercial determinants of health.

Box 4. Key summary messages for the Effect of Oral Health on the Community, Overall Well-Being, and the Economy

- Good oral health supports overall health and well-being of individuals, families, communities, and the nation.
- Based on economic and social factors, some groups experience more disease and more barriers to care than the general population; the result is unacceptable, but reversible, inequities in oral health.
- Commercial interests play a dual role in affecting oral health, providing excellent products that support oral health, as well as products, such as tobacco and sugar-sweetened foods and beverages, that are detrimental to oral health.
- Lack of access to regular dental care can result in ineffective and expensive overuse of emergency departments.
- Poor oral health reduces the economic productivity of society by limiting participation in the workforce, as well as by increasing health care costs.
- Untreated oral disease can postpone entry to military service or delay deployment of troops to active duty, thus jeopardizing the nation's military readiness.
- Natural disasters, the emergence of novel pathogens, such as COVID-19, and other large-scale emergencies underscore the need for public-private partnerships that plan and ensure the continued delivery of essential oral health care in times of crisis.

Call to Action:

- Policy changes are needed to reduce inequities in oral health status and care, ensuring that all Americans can enjoy the benefits of good oral health.

Lack of access to dental care continues to be a barrier to good oral health, especially among poor and rural communities, and has led to the increased use of emergency departments and urgent care facilities that can only provide palliative, not comprehensive, care.

As a consequence of these developments, policy reform is urgently needed to resolve the structural barriers that allow oral disease and oral disease inequities to persist. This requires that attention be directed toward social and commercial determinants that discourage healthy behavior and nutritional choices and fail to guarantee access to care for all. The benefits of these reforms will more than justify the costs. However, these policy actions will be politically challenging because they are embedded in larger debates about social and economic organization and will require us to engage in highly sensitive conversations about the ways in which historical, and still broadly based, biases create structural racism even in social and health care systems that are intended to support the well-being of all.

Fortunately, compared to 20 years ago, there is better understanding of where remedies are needed. Improved models of disease etiology have identified many new targets for public health and public policy interventions. Increased understanding of the importance of social determinants of health and the common risk factor approach provides a strong rationale for more upstream solutions. There is a broadening consensus that health care practices and patient outcomes would benefit from greater dental and medical integration. The technology infrastructure also is available to support that integration. The growing emphasis on quality metrics and value-based payments is prompting more emphasis on evidence-based practices, health literacy, patient-centered care, and population health outcomes. There also is compelling evidence that was not available 20 years ago that oral health conditions in the population have an economic cost in terms of employability and lost school days.

Looking forward, it is clear that a variety of stakeholders have important roles to play. Policymakers should understand the importance of oral health to individuals, families, and communities and recognize its importance in overall well-being. Significant human suffering and economic costs arise from dental policy neglect. All health care professionals should understand that oral health IS health and that they each have a vital role to play in helping individuals stay healthy. Alongside dental associations and other professional and advocacy groups, all health professions should have the opportunity to advance health promotion and oral health policy.

There is no question that high-quality dental services are routinely delivered in dental offices every day to a majority of Americans. However, significant numbers of Americans are unable to access this care. Approaches that include care outside of the dental office—in places such as nursing homes, schools, and community health centers—should be considered to ensure full access to everyone with oral health care needs. Further, providers and educators must communicate to members of their communities an understanding of the value of oral health and provide incentives for engaging in the healthy behaviors that will help to avoid chronic diseases or to assist in managing them. Most importantly, dentists, other oral health and health care professionals, insurers, and legislators need to understand that healthy behaviors are best achieved by improving social and living conditions and providing equal opportunity to live a good life. None of this is easy, but all of it is necessary to achieve a just and equitable system of health care that provides for everyone's needs, including the experience of good oral health.

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Oral Health in America: Advances and Challenges

Section 2A: Oral Health Across the Lifespan: Children

Chapter 1: Current Knowledge, Practice, and Perspectives

Just as early growth and development predict many aspects of health throughout life, oral health in infancy and early childhood is the precursor to good oral health at later stages of life. Consequently, children have been the primary focus for those involved in promoting good oral health and in developing approaches to prevent oral disease. Substantial resources have been invested in research to better understand the factors that affect oral health in children, particularly among preschool children, mothers, and caregivers. This investment in research has led to interventions promoting health and improving access to dental services for young children with the hope that such interventions will translate into improved health for all children later in adulthood.

Children's oral health has benefited from several advances that have led to better understanding of disease processes and ultimately, to more effective prevention and treatment, especially for preschool children. But despite recent encouraging reductions in tooth decay, particularly among younger children, dental caries remains one of the most common diseases of childhood. A pattern of disparities persists in which children from lower-income and minority racial and ethnic groups generally experience more disease and have less access to treatment. Emerging strategies for addressing these problems focus on innovative models for health care delivery and financing, as well as new, less invasive approaches to treatment and a greater emphasis on prevention.

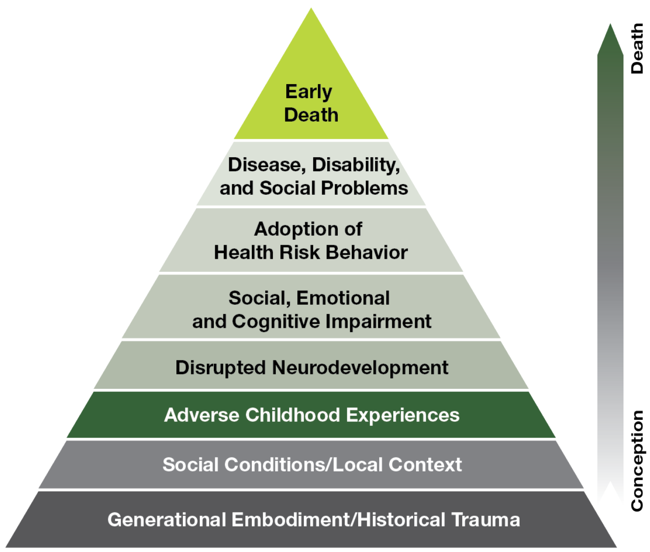
Biology, Growth, and Development

Lifelong health determinants are being established from the moment of conception. As more research sheds light on the effects of early life experiences, leading experts are focusing on prevention and health care, including activities that promote oral health during preconception, pregnancy, and the first 3 years of life. Health promotion activities are a key element for decreasing morbidity and mortality and for improving overall health and well-being.

A baby's size at birth is related more to intrauterine environment—including factors such as maternal health, smoking, and infections—than to genetic potential. Newborns' senses enable them to turn to voices, follow faces, differentiate smells, and become accustomed to repeated stimuli. An infant's experience alters development of the nervous system. During sensitive periods of development, environmental exposures and adverse life experiences have an even greater impact (Figure 1). Maternal smoking and excessive alcohol consumption have consistently been linked to adverse outcomes, such as sudden death in infancy and birth defects, including craniofacial defects (American College of Obstetricians and Gynecologists 2021). Children with vitamin D deficiency are at risk for rickets, dental caries, and other poor health outcomes (Schroth et al. 2013). Vitamin D supplements are recommended for all infants during the first year of life to support healthy teeth and bones (Wagner and Greer 2008).

Multiple influences at the family and community levels engender poor oral health outcomes in children (Fisher-Owens et al. 2007). Maternal oral health status (Weintraub et al. 2010; Dye et al. 2011; Chaffee et al. 2014) and maternal intake of sugar and fat in pregnancy (Wigen and Wang 2011) have been associated with or found to strongly predict caries in children.

Figure 1. Mechanisms by which adverse childhood experiences influence health and well-being throughout the lifespan: The ACE Pyramid



Sources: Centers for Disease Control and Prevention (2020a); Felitti et al. (1998).

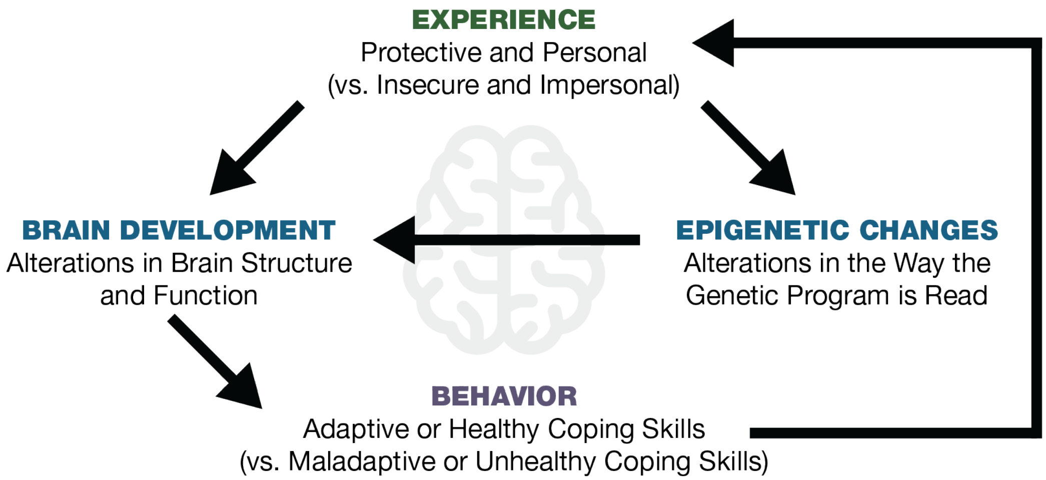
Lower income, lack of health insurance, and poorer maternal mental health status were strong factors in seeking preventive dental care for children (Iida and Rozier 2013). In addition, although some studies have shown an association between maternal periodontal disease and adverse pregnancy outcomes, such as preterm birth and low birth weight (Corbella et al. 2016; Vivares-Builes et al. 2018), others have not (Wagle et al. 2018). Nevertheless, a 2018 umbrella review of existing systematic reviews found associations indicating that pregnant women with periodontal disease have increased risk of developing preeclampsia and delivering a baby that is preterm or has low birth weight or both (Daalderop et al. 2018). However, whether periodontal treatment during pregnancy can avert these adverse outcomes is unclear (Iheozor-Ejiofor et al. 2017). The inconsistencies reported across studies suggest the need for additional research using standardized methodologies and outcome measures, with follow-up studies to determine whether periodontal disease treatment in pregnant women might result in improved pregnancy outcomes.

A variety of early cognitive and behavioral deficits in children may be attributable to maternal prenatal substance use. For example, fetal alcohol syndrome is a condition affecting infants exposed to alcohol during the mother's pregnancy and can cause serious oral and craniofacial abnormalities, as well as a broad range of other physical and cognitive problems. Although individual genetic makeup is the foundation for brain development, ongoing interactions with the environment and life experiences alter brain architecture and ultimately affect behavior (Figure 2). Poor nutrition and environmental toxins, for example, may lead to changes in cognition, language development, and behavior (Bornehag et al. 2018; East et al. 2018). Some of these environmental toxins—for example, environmental lead—not only negatively affect cognitive development, but also are associated with dental caries in children (Moss et al. 1999).

Fluorine, particularly in its anionic form, fluoride, is among the most common environmental elements on earth. For nearly 75 years, most individuals in the United States have been drinking water with added or natural fluoride and brushing their teeth with fluoride toothpaste to help keep their teeth strong and reduce cavities. Although low levels of fluoride generally do not negatively affect human health, acute high levels of ingestion or chronic exposure to high fluoride concentrations can have toxic effects. Recent concerns related to fluoride safety have emerged around neurotoxicity affecting cognition in young children as a result of prenatal exposure to higher maternal levels of fluoride (National Toxicology Program 2020). Although a National Toxicology Program monograph summarizing available science about fluoride exposure and cognitive health effects raised these concerns, a review of the monograph by the National Academies of Sciences, Engineering, and Medicine (2020) does not support classifying fluoride as a cognitive neurodevelopmental hazard in humans and suggests that additional analyses should be conducted.

Cortisol and other hormone levels normally rise and may persist in the body, although these states can reflect extreme responses. Chronic high levels in response to stress, for example, represent a chronic state of hypervigilance and can disrupt the developing brain, with potentially lifelong effects on learning, behavior, and health (Figure 3). Although children are resilient, they can better weather stress when it is short-lived and trusted adults are available for support (Shonkoff and Garner 2012).

Figure 2. Development results from an ongoing, reiterative, and cumulative dance between nurture and nature



Source: American Academy of Pediatrics (2015). © American Academy of Pediatrics and Dave Thomas Foundation for Adoption. Reprinted with permission.

But adverse childhood experiences—such as the loss of a parent, neglect, or abuse—can have significant negative effects. Such experiences in childhood trauma also may interfere with a child's receipt of preventive care or dental services (Crouch et al. 2019). Although it has been suggested that dental caries may occur at a higher level in children with a combination of elevated salivary cortisol and high counts of cariogenic bacteria (Boyce et al. 2010), this relationship remains inconclusive (Tikhonova et al. 2018).

Craniofacial and Tooth Development

Most of our knowledge about mammalian tooth development comes from animal studies. These studies, primarily in mice, show that teeth are formed through a series of interactions between the epithelium (tissues that line the outer surfaces of organs and blood vessels and the inner surfaces of cavities in many internal organs) and the mesenchyme (a type of connective tissue found during embryonic development). As the epithelium and mesenchyme interact, the developing tooth progresses through several stages, eventually leading to the differentiation of cells that secrete tissues of the crown, dentin, and enamel.

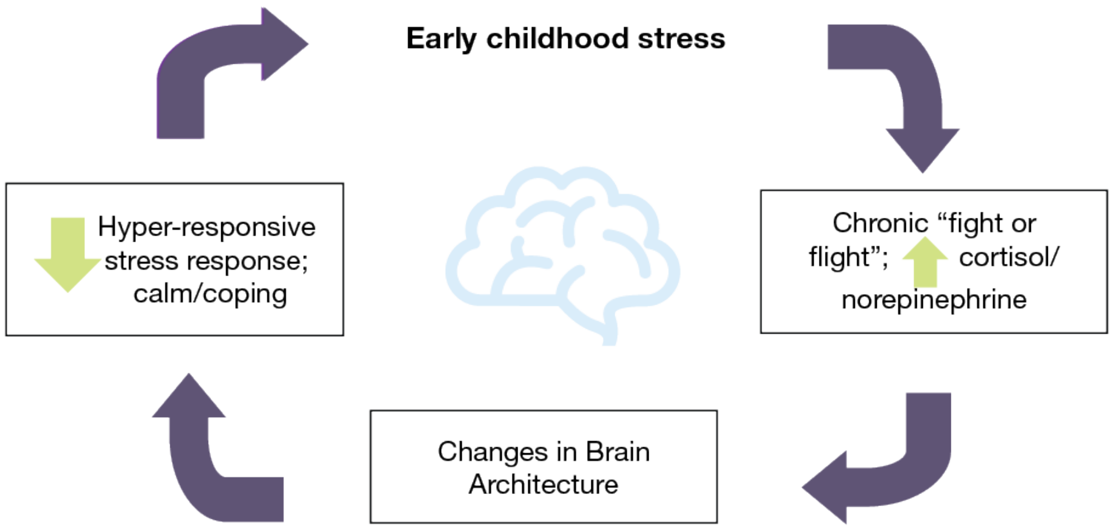
Odontoblasts, cells that are part of the dental pulp, produce dentin—the substance beneath the tooth enamel on the crown. Ameloblasts, cells present only during tooth development, produce enamel, the protective surface covering each tooth. Enamel, the hardest substance in the human body, serves as the tooth crown's wear-resistant outer layer. Half of the ameloblasts die during enamel formation; the rest die after this process ends. Consequently, no secondary or regenerative enamel is produced (Bartlett and Simmer 2015; Lacruz et al. 2017). The tooth root starts to form after the crown takes its biological shape and is not fully formed until after the tooth has erupted into place. At this point, the tooth's anatomic structures are complete (Figure 4). Most infants get their first teeth (incisors) within a few months after birth, usually starting around 6 months of age. Rarely, some infants are born with one or more teeth, but by 3 years of age, all 20 primary teeth should have erupted (Figure 5). Normal in utero development of the teeth, mouth, and supporting structures sets the stage for craniofacial and tooth development during early life and the beginnings of any oral diseases and conditions that may appear later.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Of all the dental and craniofacial disorders that affect children, dental caries—the disease that causes tooth decay—remains the most prevalent.

Figure 3. Chronic stress and effect on brain development in childhood

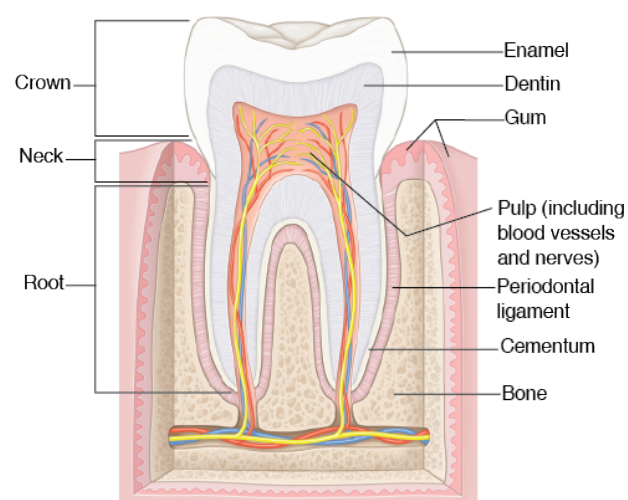


Source: American Academy of Pediatrics (2018). Reproduced with permission.

It is one of the most common chronic diseases of childhood, with about 1 in 4 preschool children having experienced caries in their primary teeth (Figure 6) and at least 1 in 6 children aged 6 to 11 years experiencing dental caries in their permanent (adult) teeth (Figure 7). Globally, it remains one of the most common chronic diseases in people of all ages (Kassebaum et al. 2017). Health care agencies, such as the World Health Organization (WHO), have identified dental caries in children as a major public health problem and have issued reports characterizing the condition and strategies to prevent it in children. More than 530 million children worldwide have untreated caries in primary (baby) teeth, with the prevalence of disease increasing with age (World Health Organization 2020). In the United States, significant disparities in the prevalence and severity of dental caries continue to persist among low-income populations and certain race/ethnic groups (Dye et al. 2017).

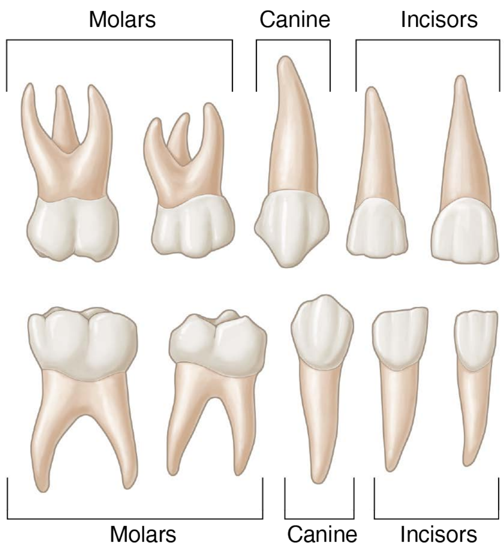
Dental caries is a multifactorial disease process that begins with an imbalance in microbial biofilms that cover tooth surfaces. Decay-causing bacteria in the mouth come into contact with sugars from food and drink, producing acids that attack the tooth's enamel and cause mineral loss. Early in the stage of mineral loss, a noncavitated lesion arises within the enamel that can be reversed. During this early period of demineralization, the process can be reversed with exposure to calcium and other minerals from saliva, and fluoride from toothpaste or other sources. If remineralization is insufficient, over time the enamel is weakened and then destroyed, forming a cavity that, if left untreated, can cause pain, infection, and even tooth loss (Figure 8). If allowed to progress, caries can result in infection of tissues beyond the tooth itself (Divaris 2016; Pitts et al. 2017).

Figure 4. Tooth anatomy



Source: Created by Jonathan Dimes for this NIH Report.

Figure 5. Primary teeth



Source: Created by Jonathan Dimes for this NIH Report.

Today, about 1 in 10 preschool children and 1 in 5 children aged 6 to 11 have some form of tooth decay that requires treatment (Dye et al. 2017; Centers for Disease Control and Prevention 2019). Globally, 9% of children have untreated dental caries in their primary teeth, representing the 10th most prevalent health-related condition worldwide (Frencken et al. 2017). Dental caries can begin as soon as the first teeth erupt and is influenced by a host of biological, environmental, and behavioral factors (Seow et al. 2009; Fontana 2015).

Although genetic factors can affect susceptibility to dental caries, their interactions with environmental factors appear to be more highly predictive of dental caries in children (Shaffer et al. 2012; Silva et al. 2019). These environmental factors include increased exposure to cariogenic bacteria, high frequency of sugar consumption, inadequate salivary composition or flow, delayed or insufficient fluoride exposure, and poor oral hygiene. Other risk factors for dental caries include poverty, race and ethnicity, and maternal oral health status (Fontana 2015; Garcia et al. 2015; Fontana and Gonzalez-Cabezas 2019). Childhood dental caries and untreated caries are more prevalent and more severe among racial and ethnic minorities and in lower-income households (Dye et al. 2017; Rozier et al. 2017; Slade and Sanders 2018; Centers for Disease Control and Prevention 2019).

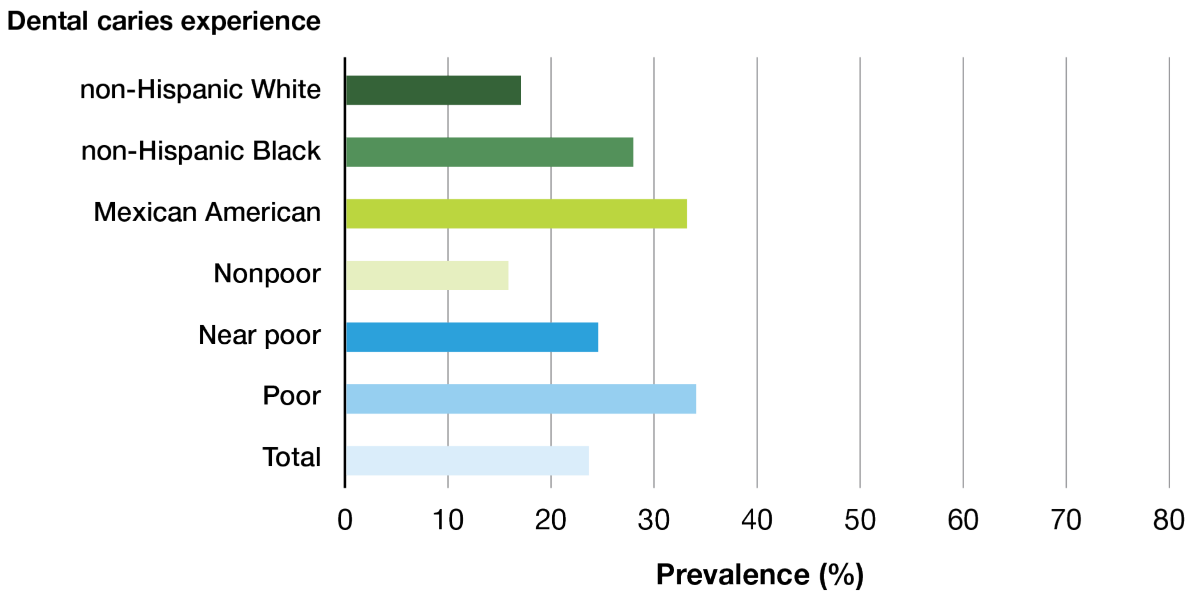
Research shows sociodemographic disparities in dental caries affecting permanent teeth. These disparities begin to appear soon after adult teeth emerge. More than 1 in 5 Mexican American and non-Hispanic Black children aged 6 to 11 years experience tooth decay, whereas fewer than 1 in 7 non-Hispanic White children have such decay (Figure 7). For children living in poverty, nearly 1 in 4 experience tooth decay, compared to about 1 in 8 children living in households at twice the federal poverty guideline level or higher (Figure 7). Dental caries has a higher prevalence in other minority racial and ethnic groups too. American Indian and Alaska Native (AI/AN) children aged 6 to 8 years are twice as likely to have untreated dental caries in their primary teeth, and five times more likely to have untreated caries in their permanent teeth than U.S. children overall (Phipps and Ricks 2017).

Untreated caries can lead to pain, inflammation, and spread of infection to bone and soft tissue (Figure 8). As a result, children may suffer from difficulty eating, poor nutrition, poor physical development, and poor self-image and socialization (Casamassimo et al. 2009). Academic performance also can be affected by the presence of dental caries (Ruff et al. 2019). In rare cases, lack of treatment or postoperative complications from treatment have even resulted in death (Otto 2007; 2017). In many cases, caries significantly diminishes the quality of children's lives (Egerton 2015). Without appropriate preventive and disease-management interventions, dental caries that persists throughout the life course will have negative lifelong consequences. These conditions disproportionately affect some population groups, creating patterns of oral health inequity.

Early Childhood Caries

In children younger than 6 years, dental caries is referred to as early childhood caries (ECC), a condition defined as one or more decayed, missing, or filled surfaces attributable to caries in any primary tooth (Drury et al. 1999; Pitts et al. 2019; Tinanoff et al. 2019). Once referred to as "baby bottle tooth decay" or "nursing bottle caries," ECC spurred epidemiologic research on dental caries in young children (Dye et al. 2015). According to the American Academy of Pediatric Dentistry (AAPD) (2020a), any sign of smooth-surface caries in a child younger than 3 years of age indicates severe ECC (S-ECC).

Figure 6. Percentage of children ages 2–5 with dental caries in primary teeth by poverty status and race/ethnicity: United States, 2011–2016



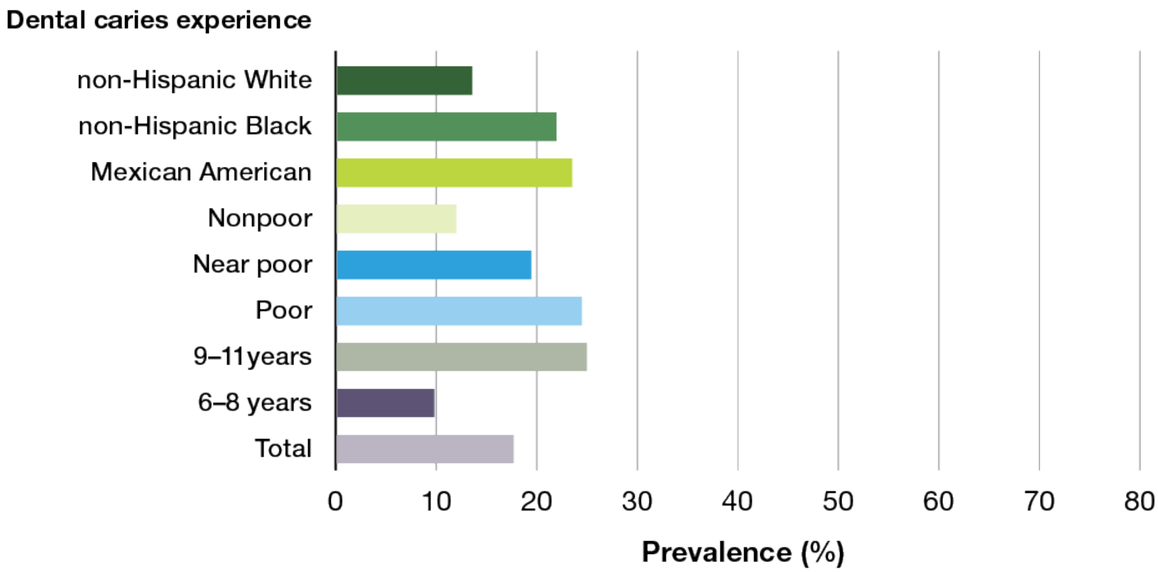
Notes: Dental caries experience (dft > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: Centers for Disease Control and Prevention (2019).

From 3 to 5 years of age, one or more decayed, missing, or filled smooth surfaces attributable to caries in primary maxillary anterior teeth or a decayed, missing, or filled score of at least four, five, or six surfaces (by 3, 4, and 5 years of age, respectively) also is considered to be S-ECC.

Disparities in the prevalence and severity of dental caries continue to persist in the United States, with Hispanic and non-Hispanic Black preschool children having higher average levels of dental decay than non-Hispanic White children (Dye et al. 2017; Centers for Disease Control and Prevention 2019). Poverty also remains as one of the most important indicators of early childhood dental caries experience, with about 1 in 3 preschoolers living in poverty having some form of ECC (Figure 6). The concurrence of poverty and race/ethnicity is associated with dental caries in preschool children. More Mexican American children and non-Hispanic Black children living in poverty experience caries than do poor non-Hispanic White children (Figure 9). However, for preschool children living in non-poor families, the prevalence of dental caries is the same regardless of race/ethnic status. This relationship between poverty and race/ethnicity exemplifies an important oral health inequity experienced by preschool children. Untreated dental caries affects about 10% of children aged 2 to 5 in the United States, with the highest prevalence in children living in poverty (17%) (Centers for Disease Control and Prevention 2019a). Mexican American and non-Hispanic Black children are more than twice as likely to have untreated dental caries than non-Hispanic White children (15% vs. 7%) (Centers for Disease Control and Prevention 2019a).

Of all racial and ethnic groups, AI/AN children have the highest prevalence of ECC (Ricks et al. 2015). More than half (52%) of young AI/AN children aged 1 to 5 experience ECC, and the prevalence increases to 71% for those aged 3 to 5 (Phipps et al. 2019). The prevalence of ECC increases with age. For example, one study found a prevalence of caries in AI/AN children of 7–9% at 2 years, 35–36% at 3 years, and 55–56% at 4 years (Batliner et al. 2018). An estimated 1 in 3 young AI/AN children aged 1 to 5 have untreated ECC (Phipps et al. 2019).

Figure 7. Percentage of children ages 6–11 with dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 2011–2016

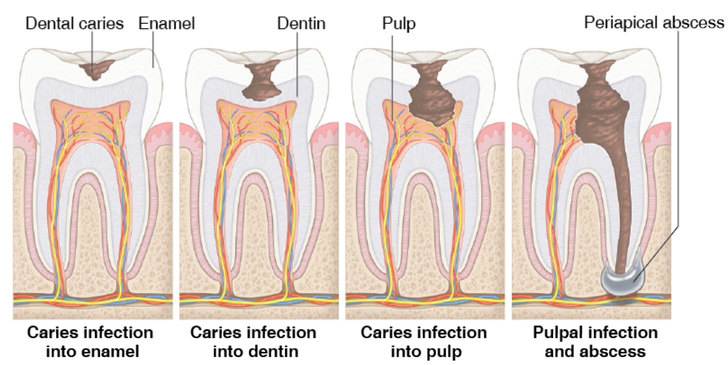


Notes: Dental caries experience (DMFT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: Centers for Disease Control and Prevention (2019).

ECC can have negative consequences for preschool children (Tinanoff et al. 2019), including oral pain, chewing and sleeping difficulties, changes in behavior, and poorer school performance (Tinanoff and O'Sullivan 1997; Casamassimo et al. 2009). Pain not only causes suffering, but also can compromise food intake, leading to weight loss and delayed growth and development (Sheiham 2006; Phantumvanit et al. 2018).

Among the contributors to the prevalence of ECC, a key factor is free sugar—all the monosaccharides and disaccharides that food manufacturers, cooks, and consumers add to foods—plus sugars naturally present in a variety of foods and beverages, such as honey, syrups, fruit juices, and milk (Moynihan and Kelly 2014; Sheiham and James 2015). The dental caries chain of causality can be broken by eliminating the use of free sugars, such as those offered in the form of sugary drinks between meals or at night (Chaffee et al. 2015). Delaying the introduction of free sugar into a child's diet and promoting healthful eating practices could contribute significantly to future health status and could prevent, or at least delay, the onset of dental caries (Feldens et al. 2010; Vitolo et al. 2010).

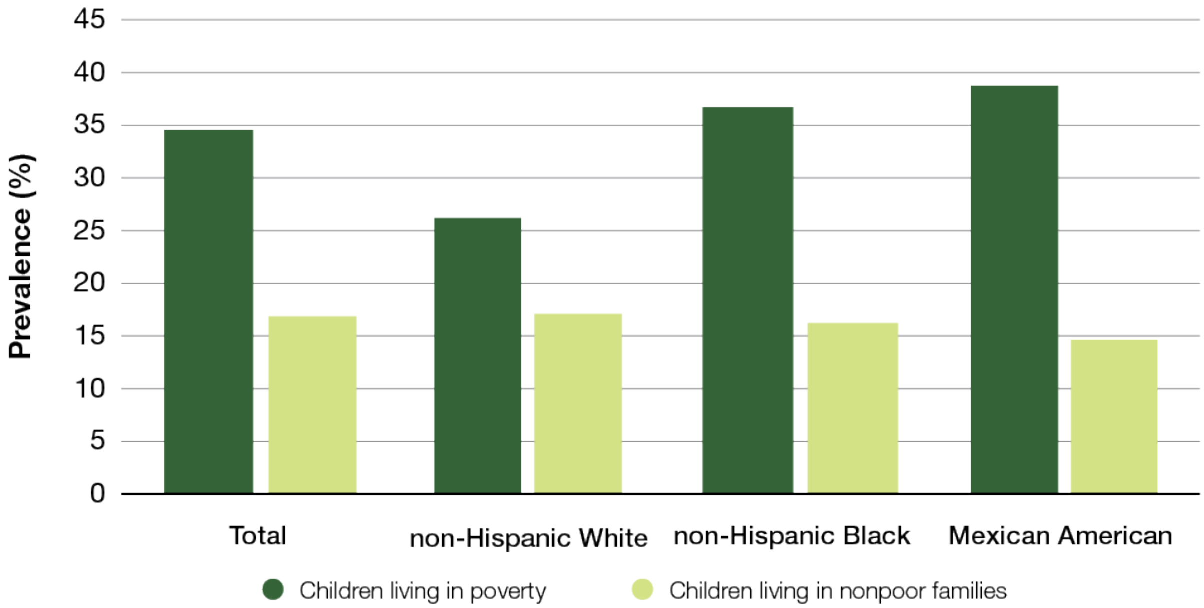
Figure 8. Important changes associated with dental caries progression



Source: Created by Jonathan Dimes for this NIH Report.

The first clinical sign of ECC is noncavitated lesions, which appear as white or brown spots on teeth. Early recognition of these lesions can lead to using interventions such as fluoride, fluoride varnish, or fluoride-releasing glass ionomers, depending upon the tooth surface area affected to encourage remineralization and arrest further lesion development. However, if risk factors, such as poor oral hygiene or frequent exposure to free sugars persist, these lesions can progress to cavities and ultimately to tooth destruction (Figure 10).

Figure 9. Percentage of children ages 2–5 with dental caries in primary teeth by race/ethnicity and poverty status: United States, 2011–2014



Notes: Dental caries experience (dft > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor and ≥ 200% FPG = nonpoor.
Source: Dye et al. (2017).

Without an early diagnosis, ECC treatment often requires restorative procedures or tooth extraction, both of which can be technically, financially, and emotionally complex in young children. Depending on the child's age, as well as the number and extent of the cavities, safe and effective treatment may require hospitalization and general anesthesia, which involve additional costs and risks (Casamassimo et al. 2009; Tinanoff and Reisine 2009). Cost estimates to treat dental caries for young children under general anesthesia in a hospital can vary widely, but the United States Indian Health Service estimates these costs to be as much as $9,350 per child (Atkins et al. 2016; Phipps et al. 2019). ECC treatment involves formidable complexity and cost. Along with incorrect perceptions that primary teeth don't need to be treated because they eventually will be replaced, this could explain why in many parts of the world almost no children with ECC are treated (Phantumvanit et al. 2018).

Craniofacial Anomalies

Craniofacial anomalies result from variations in the growth pattern of the head and the face. These congenital conditions have multiple causes, including genetics and environmental exposures (WHO Registry Meeting on Craniofacial Anomalies et al. 2003; Parker et al. 2010), as well as a combination of these two factors. Most craniofacial anomalies are serious lifelong disabilities that require extensive treatment and have an impact on oral function, appearance, and quality of life across the lifespan (Sischo et al. 2017).

Figure 10. Early childhood caries (ECC) in preschool children

Source: Carlos Feldens

Serious birth defects are estimated to occur in 6% of births worldwide, or about 7.9 million infants (Christianson et al. 2006). Most of these birth defects are associated with a wide variety of craniofacial anomalies, including orofacial clefts, skull deformities, malformation and malalignment of the jaws, missing and malformed teeth, and premature tooth loss arising as a result of complications from the anomalies. Craniofacial birth defects, and in particular, cleft lip and/or palate, occur as often as 1 in 700 live births and represent the most common congenital disorder, after Down syndrome (Mai et al. 2019). Craniofacial disorders also can directly influence risk for and resistance to common oral diseases such as dental caries and periodontal disease (Gaggl et al. 1999; Mucci et al. 2005; Huynh-Ba et al. 2009; Antonarakis et al. 2013; Vieira et al. 2014).

Cleft lip, cleft palate, or both (CL/CP), a separation of the lip, palate, or both, are the most common of all craniofacial anomalies in children. These anomalies include alterations in tooth size, shape, and number, as well as malocclusions and nasal deformities. Clefts are the second most common birth defect in children (Parker et al. 2010), after Down syndrome. The Centers for Disease Control and Prevention (CDC) estimates that each year in the United States, about 2,650 babies are born with a CP (1 in 1,574 newborns) and 4,440 babies are born with a CL, with or without a CP (1 in 1,000 newborns). These birth defects occur more often in Asians and AI/ANs and less often in African Americans. CP seems to be slightly more common in females, whereas CL, with or without CP, is more common in males (Michalski et al. 2015).

The separation seen in CL/CP occurs when the medial nasal process and the maxillary process fail to fuse early in fetal development. Although 70% of both cleft types result from unknown causes, other cases involve known risk factors, including genetics, exposure to toxic or environmental substances, and nutritional deficiencies during fetal development. Among persons with both CL and CP, about 30% have an associated genetic defect (see Figure 9 – Section 6 in this monograph for more detailed information on genetic syndromes). Genes associated with clefting include *IRF6*, *MSX1*, *FGF*, and *BMP4* (Twigg and Wilkie 2015). Other factors known to increase the risk for CL/CP malformations include maternal smoking, insufficient folic acid, family cleft history, child's gender, maternal education, and maternal race and ethnicity (Raut et al. 2019).

Besides CL and CP, other, rare craniofacial anomalies can impact a child's quality of life. Osteogenesis imperfecta had an incidence of 4.54 per 100,000 live births in Texas from 1999 to 2006; less severe cases may be identified later in childhood (Moffitt et al. 2011). The recessive dystrophic type of epidermolysis bullosa, which has oral manifestations, had an incidence of 3.05 per 1 million live births in 1986–2002 (Fine 2016). The incidence of craniosynostosis from 1989 to 2003 in metropolitan Atlanta was estimated at 4.3 per 10,000 live births (Boulet et al. 2008), with the anomaly occurring twice as often in males as in females (Michalski et al. 2015).

Other craniofacial anomalies in children that can strongly influence a child's oral health and overall well-being include:

- Pierre Robin sequence (PRS), defined by an undersized lower jaw (micrognathia), posterior CP, and downward displacement of the tongue (glossoptosis), affects 1 in 8,500–14,000 persons (Mackay 2011). It can cause life-threatening eating and breathing difficulties in infants. Genetic mutations near the *SOX9* gene are the most common cause of nonsyndromic PRS. Environmental conditions in utero, such as abnormal pressures on developing tissues, also can contribute to the characteristic small jaw (Benko et al. 2009; Amarillo et al. 2013; Tan and Farlie 2013).
- Treacher Collins syndrome (TCS), or mandibulofacial dysostosis, is associated with underdeveloped facial bones, particularly the cheekbones, with a small lower jaw. The maxilla and zygoma can be affected as well. Key characteristics include abnormalities of the external- and middle-ear ossicles, downward-slanting openings between the eyelids (palpebral fissures) with notching of the lower eyelid, and CP. A mutation in the *TCOF1* gene encoding treacle 4–7 is associated with TCS. This particular gene mutation (*TCOF1)* is only one of multiple known gene mutations that can cause TCS. Neural crest-cell formation and proliferation also appear to play a role (Jones et al. 2008).
- A genetic defect on chromosome 22 causes 22q11.2 deletion syndrome, also known as DiGeorge or velocardiofacial syndrome. The clinical manifestations vary but include congenital heart defects, palatal defects, and leakage of air into the

nasal passages during speech (velopharyngeal dysfunction), which can contribute to feeding difficulties (Robin and Shprintzen 2005; Bassett et al. 2011).

- Lack of development in the size and shape of facial structures on one side of the face characterizes craniofacial microsomia, also known as hemifacial microsomia. Affected children typically are described as having maxillary and mandibular jaw underdevelopment, contributing to difficulties with feeding, speech, and breathing. Children also may have ear abnormalities or an absent external ear, which leads to hearing loss (Gougoutas et al. 2007; Werler et al. 2009).
- Craniosynostosis, the premature fusion of the sutures (joints of the skull), causes increased intracranial pressure and leads to restricted brain and skull growth. Treatment often involves surgery early in infancy to relieve the pressure and allow the brain to grow. Future studies are needed to understand suture stem cell behavior, the mechanisms behind premature suture closure, and possible therapeutic interventions.

Children born with craniofacial anomalies may have significant psychosocial, as well as physical, issues and consequently may experience some reduction in quality of life. A variety of instruments are used to determine how a child's oral conditions affect them in terms of physical symptoms, emotional well-being, peer interactions, school experience, and functional well-being (Tapia et al. 2016). Among the few reports on children with craniofacial anomalies, one found that high-functioning patients with TCS had quality-of-life scores comparable to those of children without such anomalies (de Oliveira et al. 2018). More often, though, studies indicate that craniofacial anomalies significantly affect a child's social development. By 9 years of age, children with CL/CP have greater anxiety and behavioral inhibition. Self-ratings of popularity are below average, and girls with clefts of the lip and palate experience a decrease in self-worth during adolescence (Leonard et al. 1991). These children may need support for developing resilience, social skills, and emotional resources to prevent social isolation and low self-esteem (Lewis et al. 2017).

Developmental Tooth Defects

Developmental tooth defects are irregularities in tooth formation that occur at 6 weeks of fetal development for primary dentition and continue through formation of the third permanent molars in late adolescence (Wright 2000). Several types of defects involve tooth development, but the main three are dental fluorosis, enamel hypoplasia, and amelogenesis imperfecta. All three result from factors affecting tooth enamel mineralization. Amelogenesis imperfecta is a genetic disorder that affects the developing structure and appearance of tooth enamel, whereas enamel hypoplasia is caused by either hereditary or environmental factors that lead to inadequately formed tooth enamel. Amelogenesis imperfecta affects 1 in 14,000 persons (Crawford et al. 2007). Other types of developmental tooth disorders include congenitally missing teeth (hypodontia), which is rare in primary teeth, although the prevalence of hypodontia in permanent teeth in North America is 3.7% (Polder et al. 2004). Extra (supernumerary) teeth may be found in up to 2.0% of the population (Russell and Folwarczna 2003).

Dental fluorosis is a form of hypomineralization of enamel that can occur as a result of ingestion of too much fluoride during enamel formation. Dental fluorosis can range from barely visible white spots or lines in teeth in milder cases to converged opaque areas and pitting in severe forms. Dental fluorosis is common in the United States, affecting at least 33% of children aged 6 to 11 and 41% of youth aged 12 to 15 (Beltrán-Aguilar et al. 2010), with most of these being the mild or less severe forms, which are typically considered not an aesthetic issue by many.

Genetic, environmental, and nutritional factors, as well as injury, illness, and birth weight can influence developmental tooth defects (Wright 2000; Thesleff 2006). The most common developmental abnormalities of the teeth relate to changes in the number of teeth, such as missing teeth; supernumerary, fused, and geminated (double) teeth; changes in the size and shape of teeth, such as peg or small lateral teeth; and changes in position because of ectopic or out-of-place tooth eruption (American Academy of Pediatric Dentistry 2021). In addition, developmental defects of enamel can affect dental caries susceptibility (Vargas-Ferreira et al. 2015; Costa et al. 2017; Foulds 2017). Dental and medical teams working together to provide ongoing health care maintenance, anticipatory guidance, and acute care are more likely to ensure timely diagnosis and referral. In this way, members of interprofessional health care teams can function as advocates for children, providing necessary liaisons for needed services (Lewis et al. 2017).

Orofacial Pain

Pain is an unpleasant sensory and emotional experience usually associated with actual or potential tissue damage. Reactions to pain are highly individualized (International Association for the Study of Pain 1994). Dental pain in children most often stems from dental caries. Untreated dental caries can result in urgent and costly visits to the dentist or hospital emergency department. It disproportionately affects individuals with inadequate access to care, especially children who are members of racial and ethnic minority groups or living in poverty.

Dental pain is not an uncommon event, yet an accurate assessment of the prevalence of dental pain among children is largely unknown. In a survey of Maryland elementary school-age children, nearly 12% of all children surveyed reported experiencing some lifetime dental pain, and this increased to 28% among those who had dental caries (Vargas et al. 2005). A review conducted 2 decades ago estimated lifetime prevalence of oral pain among youth ranging from 5% to 33% globally (Slade 2001). Both of these studies reported that children of lower socio-economic status were more likely to experience dental pain in their lifetimes, suggesting that dental pain in childhood is a health disparity accentuated by poverty.

In the pediatric population, it is important to examine two aspects of dental pain: pain resulting from oral diseases and problems associated with pain management such as sedation, hospital admission, or general anesthesia. The first aspect acknowledges dental pain as one of five vital signs and further recognizes its effects on daily life including learning, growth and development, socializing, and use of dental services (Casamassimo et al. 2009). The second aspect has an influence on care system utilization and an impact on the costs associated with pain management and treatment of underlying dental disease. For example, dental pain shifts the care pattern from primary preventive care to emergency care, often in hospital emergency departments.

A report examining emergency room visits for dental complaints in children and adolescents noted that for 1,081 such visits during a 5-year period, the most common complaint was pain (51% of patients) (Friedman et al. 2018). A study examining 769 children 5 years of age, noted that difficulty eating and speaking because of oral problems was associated with a history of dental pain (Gomes et al. 2020). Yet another study examining self-reported dental pain in 8- to 10-year-old children in Brazil noted that 51.5% of 819 children reported episodes of dental pain in the month before the study. In addition, the presence of dental pain was significantly associated with trouble sleeping, difficulty eating, school absenteeism, difficulty paying attention in class and doing homework, and avoidance of recreational activities (Santos et al. 2019). Examining U.S. populations, one study noted that among children receiving treatment at a tertiary care children's hospital, the mean duration of pain was 17.7 days (Thikkurissy et al. 2012). In addition, 26% of these children described their pain as severe. Finally, it has been reported that one-third of all dental treatments result in pain or discomfort. For example, dental extractions were painful in 62.4% of cases, with injection of local anesthesia reported as the major source of pain. Operative treatments were painful in 38.8% of procedures, with preparing the tooth with dental drills cited as the most common reason for pain and discomfort (Ghanei et al. 2018).

Dental Erosion

Dental erosion is the irreversible, acid-induced loss of dental hard tissues, not involving the bacterial-secreted acids associated with dental caries (Ganss 2014). It may be caused by extrinsic acids, such as acids from juice, soda, fresh fruit, and sour candies; hypochlorous acid from chlorine used in swimming pools (Lussi 2006; Lussi and Jaeggi 2006; Taji and Seow 2010); and intrinsic, gastric acid as a result of reflux (Lussi 2006; Lussi and Jaeggi 2006).

A systematic review on dental erosion in children and adolescents' permanent teeth estimated a global prevalence of 30.4% (Salas et al. 2015), which is lower than a separate estimate of 39.8% among U.S. children (Okunseri et al. 2011). Dental erosion in children most often affects occlusal (chewing) surfaces of first primary molars, followed by occlusal surfaces of second primary molars and then mesial-cusp tips of permanent first molars. The first sign of erosion on first primary molars is on cusp tips; the erosion then progresses to encompass the entire occlusal surface. The lingual (next-to-the-tongue) surfaces of maxillary incisors may display erosion if a child has a tongue-thrust swallow (when the tongue presses too far forward in the mouth), which propels acidic liquid forward during swallowing.

Gastroesophageal reflux disease (GERD) is suspected if severe erosion is associated with loss of primary molar occlusal-surface anatomy (Pace et al. 2008; Ranjitkar et al. 2012). Identifying GERD is important because the risk of developing esophageal adenocarcinoma later in life is estimated to be 43 times greater in individuals with untreated GERD than in those without GERD (Lagergren et al. 1999).

Dental Trauma

Dental traumatic injuries can be classified as avulsion, or complete loss of the tooth; luxation, or displacement within the bone but still in the mouth; or fracture, in which the tooth is broken. In preschool children, teeth are most commonly luxated (displaced) or avulsed (knocked out) as a result of reduced bone density (Andersson 2013). Accidental, or unintentional trauma, is the greatest source of dental trauma. In preschool-age children, dental trauma is one of the more common injuries, accounting for almost 20% of all bodily injuries among young children (Malmgren et al. 2012). The highest incidence of trauma affects primary maxillary incisors in children 2 to 3 years of age, when motor skills are developing (Flores 2002; Avşar and Topaloglu 2009). More information on dental trauma is located in Section 2B.

High-Risk Behaviors

Caregiver Oral Health Behaviors

Parental oral health behaviors affect children's oral health (Case and Paxson 2002; Isong et al. 2010). Parents who have poor oral hygiene, who do not get dental care, and whose diets promote tooth decay are more likely to have caries, untreated decay, and high levels of oral cariogenic bacteria. These behaviors also affect their children (Chaffee et al. 2014). Children of mothers with high levels of untreated tooth decay are more than three times as likely to have treated or untreated dental caries as children of mothers who have no untreated decay. Similarly, children of mothers with greater tooth loss are more than three times as likely to have higher levels of caries experience as children of mothers with no tooth loss (Dye et al. 2011).

Rural parents are less likely to utilize preventive health care visits or preventive dental care visits for their children than urban parents (Probst et al. 2018). Like other rural children, AI children living on reservations have less access to these prevention measures and also experience unusually high levels of dental caries (Batliner et al. 2013; Wilson et al. 2014; Batliner et al. 2018). Moreover, fluoridated water supplies often are not available in rural areas. For some parents, fear of environmental, chemical, and pesticide contamination, including in well-water sources, increases the consumption of bottled water, which reduces the preventive effects of community water fluoridation even when it is available (Scherzer et al. 2010; VanDerslice 2011).

Dietary Behaviors

Diet during the formative years affects children's immediate risk for caries and their development of taste and food preferences that influence the risk for caries throughout their lives (Hooley et al. 2012). An association between tooth decay and obesity has been shown in children living in high-income countries, but not in those living in low- and middle-income countries (Hayden et al. 2013; Chen et al. 2018). This relationship is likely attributable to shared societal and environmental risk factors, including poor-quality diets and other socioeconomic factors. For example, children of low socioeconomic status are at increased risk for food insecurity, which is associated with lower vegetable intake and higher sugar intake (Eicher-Miller and Zhao 2018).

Oral bacteria ferment carbohydrates, including sugars and ultra-processed starches, to produce acids, which demineralize enamel and dentin during the caries process. Soda, fruit juice, and some infant formulas contain added sugars that can lead to caries. These added sugars are concentrated in ultra-processed foods with limited nutritional value. Many children, irrespective of age, race, ethnicity, or family income, consume too much sugar. About 60% of children aged 2 to 5 years and 58% of older children consume more added sugars than recommended by U.S. Dietary Guidelines for Americans (U.S. Department of Health and Human Services and U.S. Department of Agriculture 2015). The American Heart Association recommends that sugar in foods and drink should be avoided in children under 2 years (Vos et al. 2017). In addition, the American Academy of Pediatrics (AAP) recommends that 100% fruit juice should not be introduced before 12 months of age, and should be limited to no more than 4 ounces a day for children aged 1 to 3 years (Heyman and Abrams 2017). Although milk consumption by children has historically received wide support from professional organizations, AAP and others now are recommending that flavored milk be avoided in preschool children as a strategy to reduce added sugar intake (Muth 2019; Lott et al. 2019).

The top two sources of added sugars for children aged 2 to 18 years are sugar-sweetened beverages (SSBs) and baked goods with added sugars. Children aged 2 to 8 years and 9 to 19 years in the top decile of added-sugar consumption consume more than 50% and 64%, respectively, of their added sugars from these two categories (Bailey et al. 2018). Among children and adolescents aged 2 to 18, 11.5% of boys and 9.5% of girls consume three or more SSBs per day. Whereas energy intakes from SSBs do not differ by race among boys, non-Hispanic Black girls consumed more energy from SSBs than Hispanic girls, according to the 2011–2014 National Health and Nutrition Examination Survey (Rosinger et al. 2017).

Behaviors that increase either frequency or length of exposure to sugars and ultra-processed starches increase caries risk (Marshall et al. 2003; Palmer et al. 2010). Skipped meals, prolonged snacking or sipping, and freely available food outside of mealtimes or adult supervision are associated with increased caries risk (Dye et al. 2004; Bruno-Ambrosius et al. 2005). Nighttime bottle feeding; prolonged use of a sippy or no-spill cup with sugary beverages, including fruit juices; and frequent between-meal consumption of sugar-added snacks or drinks also increase caries risk, because these behaviors prolong tooth exposure to sugars (Tinanoff and Palmer 2000). In particular, nighttime exposure of teeth to SSBs is an important risk factor for ECC because salivary flow, which protects against caries, decreases during sleep. A study of more than 2,500 California children from diverse backgrounds showed that those with a history of falling asleep while sipping SSBs at 1 year of age had a risk of ECC that was four times higher (95% confidence interval = 1.9, 8.5) than children who had not gone to sleep with SSBs. It has been recommended that fluoride toothpaste should always be the last thing to touch a child's teeth before sleep (Silva et al. 2016).

Social Determinants of Health

Social and environmental forces, including those imposed by families, communities, and society, profoundly affect children and youth. These forces can act in a positive direction, providing the potential for success and good health, or they can act in an opposing direction, with unintended consequences that often manifest as inequities in oral health and well-being (Lee and Divaris 2014; Albino and Tiwari 2016). Social determinants of health (SDoH) are recognized as predictors of oral disease in children (Patrick et al. 2006; Fisher-Owens et al. 2007; Kim Seow 2012). They play an important role in establishing and perpetuating oral health disparities in children, particularly among ethnic minorities and those with lower socioeconomic status, who experience a higher burden of disease (Do 2012; Schwendicke et al. 2015). For instance, AI/AN and Hispanic children have the highest rates of dental caries and untreated caries among children in the general U.S. population (Dye et al. 2015; Phipps and Ricks 2017).

A considerable body of evidence illustrates the role of social determinants on oral health disparities (Lee and Divaris 2014). Factors contributing to these disparities include perceived social capital, insurance coverage, the paucity of dentists who treat publicly-insured children, and the impact of life stresses and allostatic load (via chronic exposure to fluctuating stress-related hormones, including adrenaline and cortisol) on oral health behaviors (McEwen 2000). Parent education, household income, and social status (Patrick et al. 2006) can influence health beliefs, literacy, and behaviors related to oral health, including dietary and oral hygiene habits (Schwendicke et al. 2015). These social determinants have varying relative impact across the life course and transitions from birth to adolescence (Patrick et al. 2006; Ramos-Gomez 2019).

Socioeconomic inequities in health have widened during the past several decades in the United States (Berkman 2009). Interventions and policies focused on social, behavioral, and environmental conditions have improved general population health, but have not been as effective in reducing health inequities (Berkman 2009). In the past 20 years, nonmedical influences on health have garnered greater attention. In fact, only 10–30% of the variation in health among individuals can be attributed to clinical care

(McGinnis et al. 2002; Booske et al. 2010; Hood et al. 2016). SDoH can account for much of the remainder of this variation (Viner et al. 2012). See Section 1 for more information on SDoH.

Cultural and economic factors have been shown to affect care-seeking behaviors, which, in turn, affect oral health. These factors include the high cost of dental care, lack of insurance, and trouble accessing dentists who accept Medicaid (Bramlett et al. 2010). Although few studies have examined how cultural factors affect care seeking, it is generally understood that not all groups view health and the need for health care similarly (U.S. Department of Health and Human Services 2000a). For example, some cultural groups believe that primary teeth are unimportant, whereas others seek medical or dental care only to address an obvious problem, such as severe pain (Butani et al. 2008). For some, preventive care may be an unfamiliar concept, and visits to a doctor or oral health professional for routine care are less likely. In addition, some groups use different methods of tooth cleaning. For example, a *miswak* stick is sometimes used in Muslim cultures instead of a toothbrush. If oral health providers lack cultural knowledge and sensitivity when interacting with these children and parents, clashes in values and beliefs could affect future care-seeking behaviors (Garcia et al. 2008).

Prevention and Management of Oral Diseases and Conditions

Efforts to prevent and control oral diseases in children have been focused most often on dental caries. Preventive health care typically comprises three levels of prevention. When applied to activities aimed at preventing dental caries, the first level (primary) focuses on intervening before tooth decay occurs. Activities associated with primary prevention often include health promotion, such as encouraging better dietary habits; the use of fluoride, including fluoridated toothpaste, receiving fluoride varnish, or drinking fluoridated water; and the use of dental sealants on teeth.

Secondary prevention efforts are intended to reduce the impact of early disease and include the detection of early signs of disease or even those at high risk for disease. For example, a caries risk assessment (CRA) could help determine who would benefit from dental sealants, fluoride varnish, or more regular follow-up. Controlling disease after diagnosis to prevent progression to tooth loss and rehabilitation to restore some function is the focus of tertiary prevention. For controlling caries progression in children, this could range from non-invasive or conservative restorative approaches using silver diamine fluoride (SDF) to more complex restorative procedures. When considering orofacial birth defects, tertiary prevention is generally the only preventive health care approach available utilizing oral surgery and other therapies with the goal of restoring function and improving overall well-being. The objective of any of these preventive efforts is to implement an intervention early enough to preserve as much of the natural tooth structure as possible, reduce orofacial disabilities, and improve overall health through childhood.

Management of Craniofacial Disorders

Management and treatment of craniofacial disorders have improved the lives of thousands of children and their families. Contemporary approaches to care address function (speech therapy and nutrition), psychosocial aspects (psychology and social work), and developmental and related issues (orthodontics and otolaryngology). Surgical treatment for children with craniofacial anomalies typically involves an interdisciplinary team of specialists, including oral and medical surgical specialists, pediatric dentists, orthodontists, and prosthodontists to achieve an optimal aesthetic and functional result. Some surgical procedures are carried out in infancy; others are best done after growth is complete. Temporary anchorage devices (screws and miniplates) now aid orthodontists and reduce surgical interventions. Surgery performed on the jaws and procedures on soft tissues often are important for facial aesthetics and speech.

Most children with craniofacial disorders are identified early, cared for by a primary care physician and a range of specialists, and receive care at a health center that provides treatment specific to their disorder. Such children often have oral issues that may involve a range of dental professionals, with primary care by a pediatric dentist, craniofacial orthopedics by an orthodontist, bone grafting and orthognathic care by an oral and maxillofacial surgeon, and transitional restoration and prosthetics from a prosthodontist. Fortunately, effective measures to correct craniofacial disorders are advancing and can reduce disability and improve overall health through adulthood. Craniofacial disorders have complex and often unknown or multifactorial causes. Genetic research and advances in genome science may lead to preventive strategies.

Management of Dental Caries

Contemporary management of dental caries in children typically begins with a caries management plan that includes a strong focus on prevention, assessment of a child's risk, surveillance to evaluate disease progression, and preventive and nonrestorative treatment for carious lesions, along with restorative treatment when indicated (Slayton 2015). An accurate assessment of caries risk is an important first step in managing tooth decay and monitoring oral health improvement over time. A CRA helps in formulating an individualized treatment plan that identifies factors (biological, environmental, and social) that contribute to the development and progression of dental caries. Contemporary CRA approaches usually incorporate several if not all concepts originating from Caries Management by Risk Assessment protocols, which were developed in the late 1990s (California Dental Association 2019). Some young children and children with special health care needs (SHCN) require more active prevention and management of caries. These strategies may include comprehensive restorative care, which can require the use of sedation and general anesthesia, which carry possible health risks (Sinner et al. 2014). This approach is expensive (Berkowitz et al. 2011) and may not prevent the recurrence of caries (American Academy of Pediatric Dentistry 2020b). Alternatively, more active prevention and management may include a chronic disease management (CDM) approach (Ramos-Gomez et al. 2010; Edelstein and Ng 2015), interim therapeutic restorations (American Academy of Pediatric Dentistry 2020c), and active surveillance (American Academy of Pediatric Dentistry 2020d). CDM is a patient- and family-centered, risk-based approach to achieve individualized behavioral and treatment goals. Care providers use techniques such as self-management goals and encouraging parent engagement through coaching, role modeling, positive reinforcement, and motivational interviewing (MI) (Edelstein and Ng 2015) to try to reduce dental caries risk (Featherstone 2006). Providers may need to recall high-risk patients on a more frequent basis to monitor their caries disease.

A major component of dental caries management involves limiting the consumption of foods and drinks with free sugars, which are aggressively marketed to children and adolescents. The WHO (2015) suggests limiting intake of free sugars to 5% of total calories to minimize the risk of dental caries and other oral health conditions (FDI World Dental Federation 2016). Steps can be taken to regulate the amount of sugar in food and drink and to educate families on how to limit dietary sugar. These steps can include efforts to promote healthy eating, such as avoiding added sugar before 2 years of age and restricting sugar intake during childhood and adolescence, as well as broader social and policy changes, such as reducing sugar availability at school, establishing labeling rules that make products less attractive to children, and reducing the affordability of sugary drinks. It is important that these steps be taken early in children's lives because they benefit not only oral health, but overall health, as well.

The importance of establishing good oral health behaviors early in childhood underlies recommendations by the American Dental Association (ADA), AAPD, and AAP that children establish an ongoing relationship with a dentist (that is, a dental home) between 6 and 12 months of age to ensure that the first dental visit occurs during a child's first year of life (American Academy of Pediatric Dentistry 2020e). This initial visit includes an early assessment and appropriate preventive strategies to help promote the eruption of healthy primary teeth and overall oral health. It also should include advice to brush the child's teeth twice daily with the correct amount of fluoride toothpaste, reduce the consumption of sugar, and prevent injuries (American Academy of Pediatric Dentistry 2020f). Professionally applied fluoride varnish should be considered for all infants and children younger than 5 years of age (U.S. Preventive Services Task Force Draft Recommendations 2021).

Fluorides for Dental Caries Prevention and Management

Systemic exposure to fluoride occurs as the result of dietary intake of natural substances, including water and food, through inadvertent ingestion of fluoride from dental products such as fluoride toothpaste, and other sources in which fluoride is purposefully added at the community levels as a public health benefit. The use of fluoride-containing products is one of the most important strategies for the prevention of dental caries. Evidence-based fluoride strategies, which can prevent the development of lesions, also have the potential to arrest and remineralize noncavitated dental caries lesions (Slayton 2015). Present in saliva and plaque, fluoride works to prevent early caries by inhibiting the demineralization of sound enamel and enhancing the remineralization (recovery) of demineralized enamel (Featherstone 1999). Fluoride also inhibits dental caries by affecting the metabolic activity of cariogenic bacteria (Buzalaf et al. 2011). There are many safe and effective ways to use fluoride, from community water fluoridation to toothpaste, mouth rinses, and professionally applied products such as gels and varnishes (Marinho et al. 2013; Wright et al. 2014).

Fluoride and the mechanisms that promote dental fluorosis were widely studied in the 1930s and 1940s by H. Trendly Dean and others (Centers for Disease Control and Prevention 1999a). As a result of that landmark research, an epidemiologic relationship between fluoride concentration in water supplies, dental fluorosis, and dental caries began to materialize from information collected across 21 cities in four states (Centers for Disease Control and Prevention 2021). This understanding ultimately formed the justification for supporting an original fluoride concentration of 1 milligram per liter (mg/L) in water supplies to reduce dental caries incidence, while maintaining a very low risk for the more severe forms of dental fluorosis. Community water fluoridation, a cost-effective community-based mode of prevention, benefits everyone, including children in low-income families (O'Connell et al. 2016; Slade and Sanders 2018; Sanders et al. 2019). Given the benefits most Americans have experienced with reduced severity of tooth decay as a result of water fluoridation, CDC (1999b) named community water fluoridation 1 of 10 great public health achievements of the 20th century. For these reasons, *Healthy People 2030* has as an objective to increase the percentage of the U.S. population served by community water systems with optimally fluoridated water to 77.1% (U.S. Department of Health and Human Services 2020). As of 2018, 73% of the U.S. population on community water systems received optimally fluoridated water compared to 65% of the population in 2000 (Centers for Disease Control and Prevention 2020b).

Although the efficacy of water fluoridation to prevent caries is well known, the number of people with access to this preventive measure remains low in some areas of the country. In fact, some communities have discontinued optimal water fluoridation. While budgetary concerns may contribute to these decisions, community water fluoridation has been discontinued in some locations as the result of organized opposition based on false and unscientific arguments. Unfortunately, communities not fluoridating their water supplies will usually have higher rates of dental caries (McLaren et al. 2016; Meyer et al. 2018). The original recommendation for the optimum level of fluoride in drinking water ranged from 0.7 mg/L to 1.2 mg/L (U.S. Department of Health, Education, and Welfare 1962), depending on children's estimated water intake and the area's mean maximum air temperature. Because Americans now have access to more sources of fluoride than they did when water fluoridation was first introduced, and national surveillance data was indicating higher levels of dental fluorosis, among other reasons, the U.S. Department of Health and Human Services updated its recommendation for the fluoride concentration in drinking water to 0.7 mg/L in 2015 (U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation 2015). Efforts are underway to align the level of fluoride added to bottled water with this recommendation (U.S. Food and Drug Administration 2019).

In addition to the systemic caries-preventive effects of community water fluoridation, fluorides also are applied topically to increase the concentration of fluoride ion at the enamel surface. Fluoride varnish has a high concentration of fluoride ion—typically 2.6%—in a natural or synthetic resin base and is applied to the surface of primary and permanent teeth to help prevent caries lesions or arrest noncavitated caries lesions (Slayton et al. 2018). It was developed in the 1960s and gradually became widely used as an anticaries agent in Europe and Canada by the 1990s for children and adults (Seppä 2004). The U.S. Food and Drug Administration cleared fluoride varnishes in 1994 for use as cavity liners and as desensitizers for hypersensitive teeth. However, fluoride varnish is primarily used today as a caries-prevention agent, an "off-label" use ADA has endorsed (Weyant et al. 2013), and varnish recently has been used to treat noncavitated lesions (Slayton et al. 2018). Given the risk of nausea and vomiting associated with unintentional swallowing, only medical and dental providers should apply fluoride varnish to children younger than 6 years (Weyant et al. 2013; Garcia et al. 2017). Because application is recommended beginning at 1 year of age, some concern about an effect on developing teeth or on other possible adverse events has been raised but is not supported by evidence (Garcia et al. 2017).

The 2000 Surgeon General's report on oral health confirmed that fluoride varnish effectively prevented carious lesions, but questions remained concerning the optimal number and interval of applications of varnish (U.S. Department of Health and Human Services 2000a). In 2006, the ADA Council on Scientific Affairs released clinical recommendations focused strictly on prevention of caries in primary and permanent teeth, depending on a patient's caries-risk status. It concluded that children with a low risk for caries may not benefit from fluoride varnish applications, although the Council recommended that children younger than 18 years and at moderate risk receive varnish applications every 6 months. For high-risk children younger than 18 years, varnish applications were recommended at 3- or 6-month intervals (American Dental Association 2006). A 2013 ADA systematic review of these recommendations streamlined moderate and severe caries risk into one category of elevated risk. The previous application schedule was revised slightly to recommend applications at least every 3–6 months. Other than supervised brushing with an over-the-counter fluoride-containing dentifrice, fluoride varnish is the only topical fluoride recommended for children younger than 6 years (Weyant et al. 2013). In 2014, the U.S. Preventive Services Task Force recommended a schedule for fluoride varnish application specifically by non-dental personnel (U.S. Preventive Services Task Force 2014 (May)), supporting the unique opportunity to provide this preventive strategy to children in medical settings, especially in the early years of life when they are more likely to regularly see a medical provider than a dental provider.

Clear evidence supports fluoride toothpaste's effectiveness in preventing and controlling dental caries (Walsh et al. 2019). An age-appropriate amount of toothpaste—a small "smear" (approximately 0.1 mg fluoride or the size of a grain of rice) for children under 3 years and a "pea-sized" amount (approximately 0.25 mg fluoride) for children aged 3 to 6 years—has been recommended to minimize the risk of fluorosis because of inadvertent toothpaste swallowing (Wright et al. 2014). A recent systematic review found that toothbrushing without fluoride toothpaste only reduces plaque accumulation; it offers no protection from dental caries (Hujoel et al. 2018). Brushing twice a day with fluoride toothpaste has been suggested as a reasonable goal for imparting caries prevention. To control the amount of toothpaste used and the risk for fluorosis, parents or caregivers should help brush the teeth of preschool children 2 years of age and older twice a day, beginning with eruption of the first tooth, with a fluoride toothpaste containing between 850 to 1150 parts per million of fluoride (U.S. Food and Drug Administration 2020).

In terms of overall safety, several systematic reviews have found that fluoride is safe for use in various forms and is indicated for both self-care (Marinho et al. 2003; Wright et al. 2014) and professional use (Beltrán-Aguilar et al. 2000; Crystal et al. 2017). No acute adverse effects were found in a large study investigating fluoride varnish's short-term safety (Garcia et al. 2017). Some reviews also support the home use of prescription-strength fluoride mouth rinse (0.09%) and fluoride gel or paste (0.5%) for children aged 6 and older, plus professionally applied fluoride varnish (2.26%) and fluoride gel (1.23% acidulated phosphate fluoride) at least every 3 to 6 months for all children at risk for developing caries (Weyant et al. 2013). Only 2.26% fluoride varnish is recommended for children younger than 6 years, applied by medical or oral health professionals beginning with eruption of the first tooth (Weyant et al. 2013; Garcia et al. 2017). Another product, containing 38% SDF (discussed in more detail in Chapter 4) recently has become commercially available in the United States for the arresting of cavitated carious lesions.

Dental Sealants for Caries Prevention and Management

Dental sealants, thin plastic coatings that protect the tooth, are placed on the occlusal (chewing) surfaces of posterior teeth to prevent caries initiation and to stop the progression of noncavitated lesions to a point where damage to dental enamel is irreversible. Sealants provide a physical barrier that inhibits microorganisms and food particles from collecting in pits and fissures (Wright et al. 2016; Slayton et al. 2018). In addition to being provided directly in dental practices, they also can be provided through school-based community programs or by dental hygienists embedded in medical practices. Sealant programs in elementary and middle schools, which serve children who otherwise would not receive preventive dental care, have been highly cost-effective. Each tooth sealed saves more than $11 in dental treatment costs (Griffin et al. 2016). According to the CDC (2016), applying sealants in schools to the teeth of the nearly 7 million low-income children who do not already have them would prevent more than 3 million cavities and save up to $300 million in dental treatment among these children.

The effectiveness of dental sealants, particularly resin-composite materials, depends on long-term retention. Nevertheless, sealants typically protect against 80% of cavities for 2 years and continue to protect against 50% of cavities for up to 4 years (Community Preventive Services Task Force 2013). About 2 in 5 children aged 6 to 11 years have at least one dental sealant applied to a permanent tooth, but children living in lower-income families are less likely to have access to dental sealants (Centers for Disease Control and Prevention 2016). Although the use of sealants in children continues to increase, dental sealants are generally underused and differences between low- and high-income groups persist (Centers for Disease Control and Prevention 2019a). Parents' lack of awareness of the benefits of dental sealants continues to influence this underutilization. Only 55% of parents of children younger than 18 years have knowledge of dental sealants, and the level of awareness is even lower among low-income and racial- and ethnic-minority parents (Junger et al. 2019).

Prevention and Management of Dental Trauma

Prevention and management of trauma to the primary dentition of younger children is highly dependent on their activities and the supervision of parents, who may benefit from anticipatory guidance from dental professionals. Active involvement in contact sports puts children at greater risk for dental injury, and protective gear for sports, including mouth guards to reduce the likelihood of injury, should be used (American Academy of Pediatric Dentistry 2020g). Reinsertion of avulsed primary teeth is not recommended because of the difficulty in treatment, poor prognosis, and eventuality of a succedaneous tooth in its place. Additional discussion of prevention of injury in adolescents can be found in Section 2B.

Behavior Change and Oral Health Literacy

Parents and children, as well as health professionals, play key roles in health promotion for caries prevention. Some research suggests that dental and medical providers may be able to optimize children's diets and home care practices through nutritional counseling (Feldens et al. 2010) and case management, using MI techniques (Borrelli et al. 2015; Wu et al. 2017).

Some communities, including AI/AN and Latino communities, have readily accepted MI approaches, when used to elicit behavior change in primary caregivers (Borrelli et al. 2010; McNeil et al. 2017; Batliner et al. 2018; Henshaw et al. 2018; Randall 2018). MI is a style of patient-centered communication specifically designed to resolve ambivalence about change and build intrinsic motivation for it. MI has been used to successfully promote behavior change in brief encounters (Borrelli et al. 2007).

Weinstein and colleagues (2004) provided early evidence of potential for improving oral health behaviors. Since then, however, studies have produced mixed results, and reductions in caries have only rarely been found. A systematic review and meta-analysis of parent-level MI studies aimed to improve pediatric health behavior and outcomes found that, relative to comparison groups, MI was associated with significant improvements in diet including SSB consumption, physical activity, smoking cessation, reduced screen time, oral health, secondhand smoke, and body mass index (Borrelli et al. 2015). Only a few studies have directly assessed the effects of MI on dental caries, and although Harrison and colleagues' (2007) and Weinstein's studies showed promising trends, two large-scale clinical trials of MI have demonstrated no impact on dental caries (Batliner et al. 2018; Henshaw et al. 2018). In some cases, it appears that familial and community histories of poor oral health may lead to parental lack of confidence in the ability to influence their children's oral health outcomes, perhaps also dampening responses to prevention interventions (Petti 2010; Batliner et al. 2018).

Health promotion that focuses on behavior may lead to positive changes, including dietary choices that are increasingly considered necessary for optimal oral health. Sugar consumption has an undeniable influence on dental caries (Sheiham and James 2015), with frequency of consumption having the most impact. Professionals can help children and families set goals to limit sugar consumption and shift toward a more healthful diet (van Loveren 2019). This includes reducing the use of bottles or sippy cups for extended periods of time, such as in bed.

Another approach to promoting oral health in children focuses on using early education and childcare programs to provide preventive oral health services, such as brushing children's teeth with fluoride toothpaste during the school day and facilitating their visits with a dentist. Integrating preventive oral health services into early education, particularly in combination with community dental resources, can greatly improve children's access to care (Burgette et al. 2018). For example, children who participated in Early Head Start received more preventive dental care than peers who were not in the program (Burgette et al. 2017).

An important factor in health promotion is health literacy. Oral health literacy (OHL) is "the degree to which individuals have the capacity to obtain, process, and understand basic oral and craniofacial information and services needed to make appropriate health decisions" (National Institute of Dental and Craniofacial Research and National Institutes of Health 2005, p. 176). Caregivers' OHL affects children's ability to navigate the dental and medical system to obtain care (Divaris et al. 2014). Caregivers with low OHL were more likely to engage in unhealthy oral health behaviors involving their children, including nighttime bottle use and no daily brushing or cleaning (Vann et al. 2010). In addition, their children had lower oral health knowledge (Vann et al. 2010) and were more likely to have high emergency dental care expenditures (Vann et al. 2013). Finally, caregiver literacy is associated with children's dental disease status (Miller et al. 2010; Vann et al. 2010).

Children with Disabilities and Special Health Care Needs

The number of children with disabilities and SHCNs is increasing, largely because of advances in both prevention and treatment of a variety of health conditions that previously limited survival. Today almost 10% of children live with medical conditions that affect their daily lives (Perrin et al. 2014), and nearly 20% of U.S. children have SHCNs (Child and Adolescent Health Measurement Initiative 2012). Parents and other caregivers play an important role in promoting the oral health of children with SHCNs, especially those with severe or debilitating needs (Phillips et al. 2011). For example, many children with SHCNs depend on caregivers to participate in activities of daily living, including daily toothbrushing, eating healthy meals and snacks, and accessing dental care services. Caregiver burden—the extent to which a child's health condition affects a caregiver's work, time spent on health management, and finances—also is a barrier to oral health (Chi et al. 2014; Wiener et al. 2016). Support services and respite care for caregivers can help improve the oral health of children with SHCNs.

Dental treatment continues to be one of the most common unmet health care needs for children with SHCNs (Lewis 2009). Most dental research on oral health needs of children with SHCNs since 2000 has focused on dental utilization. Some state-level studies show higher dental care utilization rates for children with SHCNs enrolled in Medicaid compared with other children, although other studies indicate lower rates (Chi et al. 2011; Craig et al. 2019). In addition, the data do not indicate whether the amount of care received meets children's oral health care needs. Finally, no research has been conducted on two other important behavioral determinants of oral health for children with SHCNs: fluoride-based hygiene practices and dietary intake of added sugars (Chi 2018).

Addressing the complex, long-term treatment needs of patients with SHCNs frequently involves teams of health care providers (Angle and Rebellato 2005; Mandal et al. 2014). For example, managing the health care of infants with CL/CP begins at birth, with habilitation approaches lasting many years and involving the expertise of specialized health care providers, including surgeons, orthodontists, and speech therapists, among others. Finding and accessing experts to provide good oral health care for children with SHCNs can be daunting for their parents, especially in rural or other underserved areas.

Oral Health and Quality of Life

It has long been evident that oral health is related to well-being and quality of life; impaired oral health affects diet, nutrition, sleep, psychological status, social interaction, school, and employment. Today, scientific understanding of the important relationship of oral health to overall well-being, particularly for children, continues to expand. It is well known that oral health behaviors and disparities early in life may have serious consequences for children's well-being throughout childhood. The consequences of children's impaired oral health include the following:

1. Impact on general health. Poor oral health can result in failure to thrive if the negative effects on nutrition cause insufficient weight gain (Ayhan et al. 1996; Thomas and Primosch 2002; Narksawat et al. 2009; Gaur and Nayak 2011; Koksal et al. 2011; van Gemert-Schriks et al. 2011; Boeira et al. 2012; Abanto et al. 2014; Clementino et al. 2015) and stunted height (Freire et al. 2002; Nicolau et al. 2005).
2. Impact on longer-term oral health. Caries experience in the primary teeth is a significant predictor of future caries experience in the permanent teeth. In addition, the premature loss of primary teeth as a result of caries can result in misalignment of teeth (Gray et al. 1991; Grindefjord et al. 1995; O'Sullivan and Tinanoff 1996; al-Shalan et al. 1997).
3. Impact on need for emergency dental care, most often attributable to dental caries (Blumenshine et al. 2008; Abanto et al. 2014; Braun et al. 2014; Sun et al. 2015), and even hospitalizations (Wadhawan et al. 2003; Abanto et al. 2014). In addition, children's urgent needs for dental visits can result in parental work loss and children's days off from school (Foster Page et al. 2005; Goes et al. 2007; Barbosa and Gaviao 2008; Blumenshine et al. 2008; Jackson et al. 2011; Braun et al. 2014; Clementino et al. 2015).

A systematic review and meta-analysis have identified improvements in oral health-related quality of life (OHRQoL) following dental treatment under general anesthesia in children in all studies, and an overall large magnitude of improvement (Tinanoff et al. 2019).

Assessments of school-age children (kindergarten through fifth grade) using face-to-face interviews found clear relationships between their own OHRQoL responses and their objectively assessed oral health (Inglehart et al. 2006; Inglehart et al. 2016).

Dental Insurance Coverage and Utilization of Dental Services

Dental care is delivered in a wide variety of locations and facilities. Traditionally, private and public sites have functioned "almost completely separately; they use different financing systems, serve different clientele, and provide care in different settings" (Institute of Medicine 2011, p. 82). The private sector encompasses all privately-owned dental practices. As a group, these practices serve mostly individuals with private insurance or the ability to fund their own care, as well as some publicly-funded patients. The contemporary dental safety net includes the facilities, providers, and payment programs, such as Medicaid and the Children's Health Insurance Program (CHIP), that support dental care for underserved populations, including people disadvantaged by a variety of social, economic, and health conditions (Edelstein 2010). Safety net locations include dental schools, a variety of health centers—public clinics, Federally Qualified Health Centers, school-based health centers, Indian Health Services clinics, and rural health centers—hospital clinics and emergency rooms, free-care programs, and increasingly, private dental practices that care for patients covered by Medicaid and CHIP. In 2019, 43% of dentists accepted Medicaid or CHIP. See Section 4 for more information on workforce and practice models.

In general, one or more of four sources pay for pediatric dental care: private dental benefit plans (typically called "dental insurance"), such as those offered by employers; private benefit plans with state subsidies, offered in state marketplaces under the Affordable Care Act (ACA); public insurance programs, such as Medicaid and CHIP; and out-of-pocket payments by families. Almost all private health plans require some amount of copayment for all but preventive services. The availability of employer-sponsored insurance plans depends in large part on parents' jobs, and the plans vary in quality. Parents whose employers do not offer dental insurance or do not extend it to dependent children and adolescents have been able to purchase state subsidized dental coverage in the insurance marketplaces established in each state as a result of the ACA. Lower-wage jobs tend not to offer health insurance, are less likely to allow dependent children to enroll in their parents' health plans when they do, or offer health insurance that does not include a dental plan. This puts lower-income families at higher risk of incurring out-of-pocket costs for their children's oral health care unless their children qualify for Medicaid or CHIP.

Although financial eligibility for Medicaid and CHIP varies by state, insurance coverage is available to low-income families and supports access to care by eliminating or limiting out-of-pocket costs. Since 1967, Medicaid's Early and Periodic Screening, Diagnostic, and Treatment benefit has covered all services deemed medically necessary, including comprehensive dental and qualifying orthodontic care. Since 2010, CHIP plans also have provided a wide range of essential dental services. States may administer CHIP in one of three ways: they may enroll CHIP-eligible beneficiaries in their Medicaid program, with its expansive dental benefits and cost-sharing prohibition; establish a separate CHIP program with somewhat different dental benefits and limited cost sharing; or combine these two approaches. As of May 2015, nine states had elected to integrate their CHIP programs into Medicaid, 13 had CHIP as a separate insurance program, and 29 had some combination (Hinton and Paradise 2016). Whether a parent can enroll a child in Medicaid or CHIP depends on family income, the child's age, and the family's state of residence.

Medicaid provides comprehensive dental benefits to children in every state, but whether children obtain care seems to depend, in part, on their parents' own Medicaid dental benefits. Children whose parents have comprehensive Medicaid dental benefits are more likely to have attended a dental visit in the preceding year than are children whose parents have only Medicaid emergency dental benefits or none at all. However, children of parents with no Medicaid adult dental coverage were seven times more likely to have no dental utilization, compared with children of parents with some dental coverage (Children's Dental Health Project 2012).

Although Medicaid, CHIP, and the ACA all mandate dental coverage for children, none of these programs assures dental coverage for adults who have no employer-sponsored dental plan. It has been suggested that when Medicaid expands benefits to adults, there is some additional utilization of preventive services by their children (Venkataramani et al. 2017). Moreover, there have been some studies that have demonstrated that when low-income caregivers have dental insurance, their children are more likely to receive dental care (Lipton 2019). Expansion of dental benefits to the parents of children living in low-income families could improve these children's access to dental care.

Provision of Pediatric Oral Health Care in Alternative Settings

Dental Educational Settings

Comprehensive, low-cost dental care for children is provided in a wide variety of settings, including 300 dental hygiene training programs (American Dental Hygienists' Association 2021), 76 North American dental schools, 82 pediatric dentistry residency programs in universities and hospitals, and many of the 259 hospital-based general practice residencies and university-based advanced education in general dentistry programs (Commission on Dental Accreditation 2021). Because these programs' primary mission is provider education, rather than patient services, these sites typically provide lower volumes of care than other components of the safety net. Pediatric dentistry training programs may constitute a particularly valuable part of the dental safety net for young children, as demonstrated by one program in which one-third of children younger than 6 years of age were treated for emergency relief of nontraumatic pain or infection, often on referral from other dental providers (Meyer et al. 2017).

Early Childhood Oral Health Programs

Oral health programs and policies for children typically come from the Centers for Medicare & Medicaid Services, the Health Resources and Services Administration (HRSA), and CDC. These public agencies develop policy and funding mechanisms that affect pediatric oral health and, in turn, state Medicaid and CHIP programs, Head Start, and state and local health departments (Mandal et al. 2014; Orynich et al. 2015; Edelstein 2018).

Professional organizations, such as AAPD, AAP, and ADA have a long history of supporting and improving oral health policies for children. These organizations bring together stakeholders from diverse backgrounds to develop smarter strategies for America's children to achieve optimal oral health. They produce policy and technical briefs related to issues such as the workforce, oral health in primary care, Medicaid and CHIP reform, and water fluoridation. They also monitor federal and state health insurance exchanges and offer guidance on cost-effective ways for states to strengthen their programs. Other advocacy organizations of this type include AAPD's Pediatric Oral Health Research and Policy Center, the Children's Dental Health Project (as of January 2020, its activities have moved to Community Catalyst), and ADA's Health Policy Institute. In addition, the HRSA-funded National Maternal and Child Oral Health Resource Center, a resource library, serves the maternal and child health community with high-quality oral health technical assistance, training, and resources.

School-Based Oral Health Programs and School-Based Health Centers

Using schools to provide oral health care has a long and successful history for some communities. Some U.S. schools have dental operatories or portable dental operatory equipment set up in multipurpose rooms, or mobile dental clinics that travel from school to school. For example, Cincinnati, Ohio, city schools have a brick-and-mortar dental clinic serving children enrolled at that school and elsewhere (Delta Dental of Ohio 2018). Delivering oral health care in school settings has the potential to reach many students who are at risk for oral disease and in need of care. Untreated oral disease affects students' success in school and in life. Schools are logical places to educate students and families about the importance of oral health and to deliver a continuum of oral health services aimed at preventing oral disease and connecting students to ongoing community-based oral health care. School-based programs may stand alone or are integrated with other services, such as school-based health centers. They improve access to oral health care for students at high risk for oral disease; deliver preventive services, such as topical fluoride and dental sealants; improve OHL; connect students and families to a dental home; and build knowledge, skills, and habits for achieving lifelong oral health while helping families navigate community services.

In 2017, the Oral Health 2020 Network and the School-Based Health Alliance proposed a framework for organizing the partners, policies, programs, services, and curricula necessary to achieve better and more equitable oral health outcomes for people of all ages. The framework has five elements: oral health education, oral health screening, oral health preventive care, care coordination and linkage to community-based oral health care, and oral health treatment in schools (School-Based Health Alliance 2018). Schools with many low-income students now offer programs to prevent dental caries by using pit and fissure sealants to prevent dental caries in permanent teeth. These programs usually target students in the second and sixth grades to place sealants on first and second permanent molars, respectively. An effective school-based oral health program ensures that students who need treatment are referred to an oral health professional, receive services in a timely fashion, and establish an ongoing relationship with a dentist (that is, a dental home). Parents' and caregivers' OHL also play a major role in their ability to provide effective oral care for their children.

Oral health screenings conducted in schools can effectively identify students at risk for oral disease. Because parents and guardians are not present at the screening, screeners later provide them with information about their children's oral health and any recommendations for follow-up. Ideally, school screening programs should follow up and track all referrals for further care by dental professionals (Association of State and Territorial Dental Directors 2008). Providing oral health education, screenings, preventive services, case management, and limited treatment in schools meets students and families where they are in a familiar setting. Although supervised toothbrushing programs have been successfully incorporated into preschool programs, such as Head Start, and have helped reduce caries (Kanellis 2000), such programs are not common in elementary schools, which means that a high-risk child whose risk was reduced in a Head Start brushing program could return to a higher caries-risk status upon entering elementary school. The long-term benefit in caries reduction attributable to these programs needs further study.

Interprofessional Care

Collaboration among health care providers can enable such providers to better serve many children affected by pediatric dental diseases and comorbid chronic health conditions. Interprofessional care (IPC) helps address a child's comprehensive care—medical and dental—by involving the child, family members, caregivers, and providers from at least two disciplines in coordinated, patient-centered care that improves health outcomes (Mitchell et al. 2012; Graffunder and Sakurada 2016).

IPC models have been shown to reduce cost and errors, improve health outcomes, and decrease disparities while increasing access (Mitchell et al. 2012; Bambini et al. 2016; Navickis and Mathieson 2016; West and King 2019). They differ from traditional health care models in that they use innovative delivery approaches to coordinate care for patients with significant challenges. Health care providers, including dental professionals, must be trained to practice on IPC teams and to address some conditions outside their disciplines. Oral health educators on IPC teams are frequently safety net providers who support non-dental providers' ability to recognize and monitor common dental diseases, such as tooth decay (Maxey et al. 2017). To date, evidence on effectiveness of some IPC care in terms of prevention and caries reduction remains limited (Chou et al. 2021).

Chapter 2: Advances and Challenges

Much progress has been made during the past 20 years in children's oral health, from reduced prevalence of untreated dental caries to new and more effective treatments and interventions. However, many challenges remain. A new emphasis on understanding and translating social determinants of health (SDoH) into oral health promotion strategies has emerged along with disease management approaches that emphasize risk assessment and the involvement of a variety of health care professionals in managing children's oral health. The remaining challenge is to identify still more effective ways of decreasing the experience of tooth decay for children that address disparities in the prevalence of caries and inequities in access to oral health care. Progress has lagged in some areas, such as understanding and managing dental erosion and in the development of treatments for a variety of craniofacial anomalies that affect many thousands of children each year.

Biology, Growth, and Development

Epigenetics Related to Growth and Development

Enormous recent advances in the field of genetics include mapping of the human genome, new technologies to identify and replicate genetic material, and the use of gene therapy to treat disease. A related field, epigenetics, deals with DNA modifications that lead to changes in gene expression but that are not part of the DNA sequence. Some DNA modifications are inherited, whereas others are influenced by environmental factors. The immediate effects of epigenetics in children are relevant to tooth development and craniofacial disorders with genetic causes and risks because of the importance of gene regulation during different developmental stages (Seo et al. 2015). One of the most exciting discoveries involves understanding how epigenetic regulation can control tooth-root patterning and development (Jing et al. 2019). Although the discoveries in this field generally arise from animal models, learning about the mechanisms and interactions of key proteins during tooth development could one day lead to the ability to regenerate a whole tooth.

Environmental Influences Related to Growth and Development

Epidemiologic and experimental data have suggested that teratogens—agents, such as cigarettes, alcohol, household and workplace products, and medications such as thalidomide and Dilantin—that can cause developmental malformations also can contribute to craniofacial anomalies (Wickstrom 2007; Murthy and Bhaskar 2009; Oginni and Adenekan 2012). In the past 20 years, awareness of per- and polyfluoroalkyl substances (PFASs) and their potential for negative health outcomes, including low birth weight and cancer, has been growing. These substances are synthetic chemicals used in manufacturing that leach into drinking water and accumulate.

Although many of these substances were phased out in 2002, the U.S. Environmental Protection Agency (2020) is developing a maximum-contaminant-level approach to help communities protect public health (Winkens et al. 2017; U.S. Environmental Protection Agency 2020). The most pronounced negative health effects from PFASs occur during exposure in pregnancy, infancy, and childhood

(Winkens et al. 2017; Gyllenhammar et al. 2019), although preliminary research found no link between childhood PFAS exposure and dental caries (Puttige Ramesh et al. 2019). Environmental lead is another toxin with well-known adverse health outcomes as a result of exposure. Several studies (Gil et al. 1996; Moss et al. 1999; Gemmel et al. 2002; Kim Seow 2012) have suggested an association between lead levels and dental caries. However, other information suggests that dietary factors may confound this relationship and an independent association may not exist (Wu et al. 2019).

Our understanding of environmental and disease effects on tooth development has advanced, but our knowledge regarding the mechanisms through which these effects occur is still emerging, largely through advances in basic science (see Section 6). Trauma to the face and mouth is common, especially in children and young adults. Systemic and local disease and radiation (both therapeutic and environmental) have the potential to modify craniofacial development. Respiratory function also can affect facial development, but the relationship is not well understood. Similarly, jaw function or its absence can affect craniofacial development.

Gene Regulatory Network

Since 2000, new methods to document facial morphology, along with faster, less-expensive gene sequencing, have helped explain the contributions of genetic and environmental factors to normal craniofacial development and craniofacial anomalies. Genome-wide association studies have investigated the relationship between normal facial variation and single-nucleotide polymorphisms. The new methods have direct application to the oral-facial complex. For example, the *PRDM16* gene is associated with *Pax* genes and plays a role in nose length and shape (Shaffer et al. 2016). The *Hox* family of genes represents an evolutionarily conserved group of transcription factors that are important in specifying regional identity and craniofacial patterning within the embryo (Deschamps and van Nes 2005). In addition, several well-characterized signaling pathways are involved in patterning of the jaw and the facial skeleton and in differentiation of neural crest cells. These include Sonic hedgehog, wingless-related, bone morphogenetic protein, and fibroblast growth factor (Ruiz i Altaba et al. 2002; Helms and Schneider 2003; Kimelman 2006; Minoux and Rijli 2010; Marcucio et al. 2011).

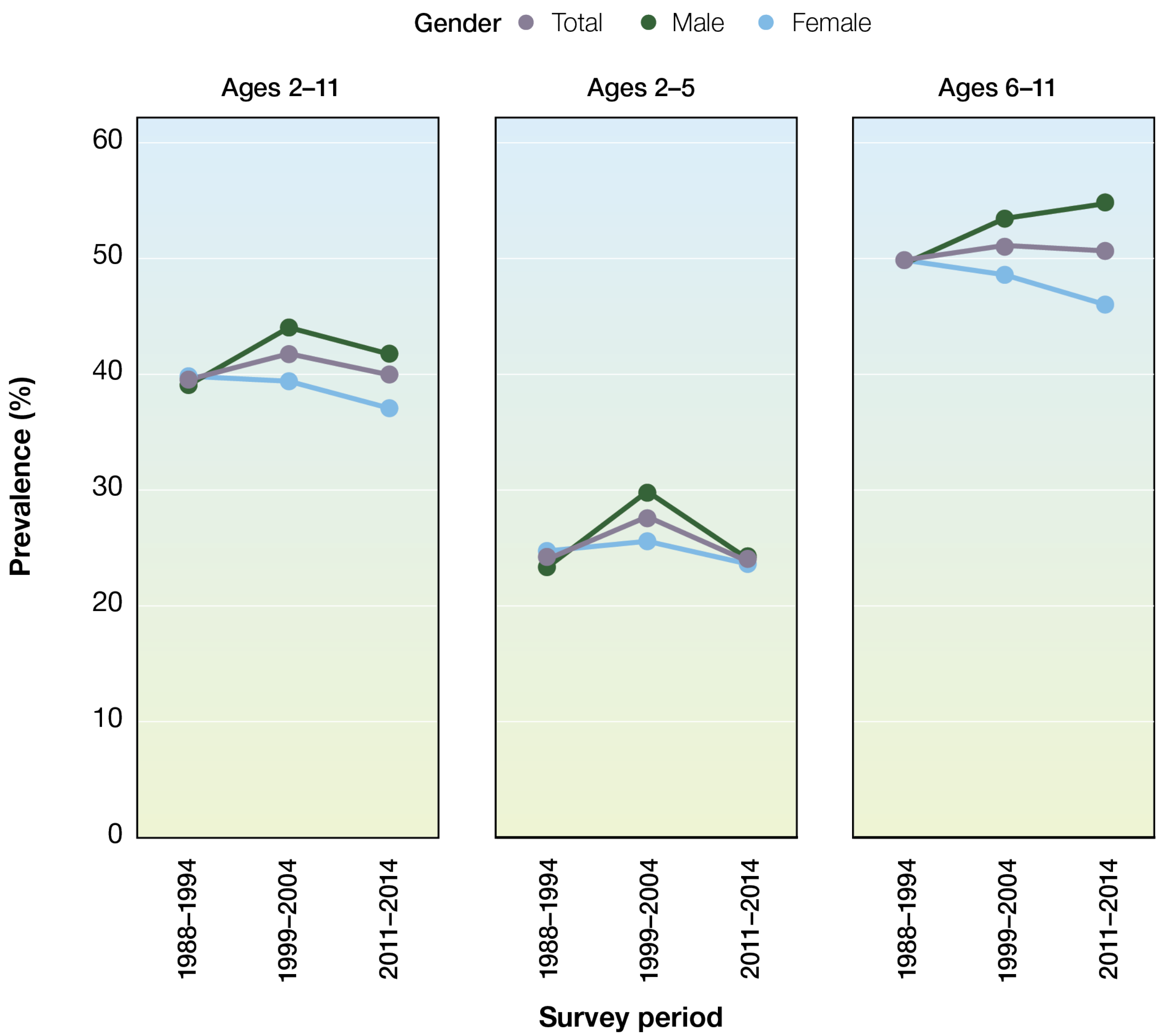
Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Compared to previous generations, many children now experience improved oral health, but this picture is complicated. Among preschool-age children, the prevalence of dental caries increased from about 24% to 28% between 1988–1994 and 1999–2004, but returned to 24% in 2011–2014 (Figure 11). Although the prevalence of dental caries in preschool children appears unchanged since the 1999–2004 survey, digging deeper into the data reveals that this relatively flat trend was really an inverted “V-shaped” trend driven by boys. This unusual pattern of caries experience in primary teeth among children 2 to 11, has produced a cohort of children in which boys are experiencing significantly more dental caries than girls.

However, there is some good news: a decade ago, the prevalence of dental caries in children aged 2 to 5 years living in lower-income households appeared to be on an upward trajectory, but recent data indicates that it has now declined (Figure 12). The most significant improvement in oral health status for preschool children in the past 20 years is the substantial decline in untreated dental caries. Overall, nearly 10% of children aged 2 to 5 years have untreated caries, whereas 19% had untreated caries 20 years ago (Figure 13). More important, these improvements are seen in preschool children across all racial and ethnic groups and family income levels, with larger declines in untreated caries benefiting minority and low-income children the most. This reduces long-established health disparities for this important oral health metric (Figures 14 and 15). American Indian and Alaska Native (AI/AN) preschool children also have experienced a small reduction in the prevalence of dental caries (55% to 52%) during the past decade (Phipps et al. 2019) and have experienced fewer untreated dental caries (39% to 34%). Indian Health Service (IHS) has attributed this improvement to the IHS Early Childhood Caries Collaborative, which focused on early access to care (first tooth, first exam), applying fluoride

Figure 11. Percentage of children ages 2–11 with dental caries in primary teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



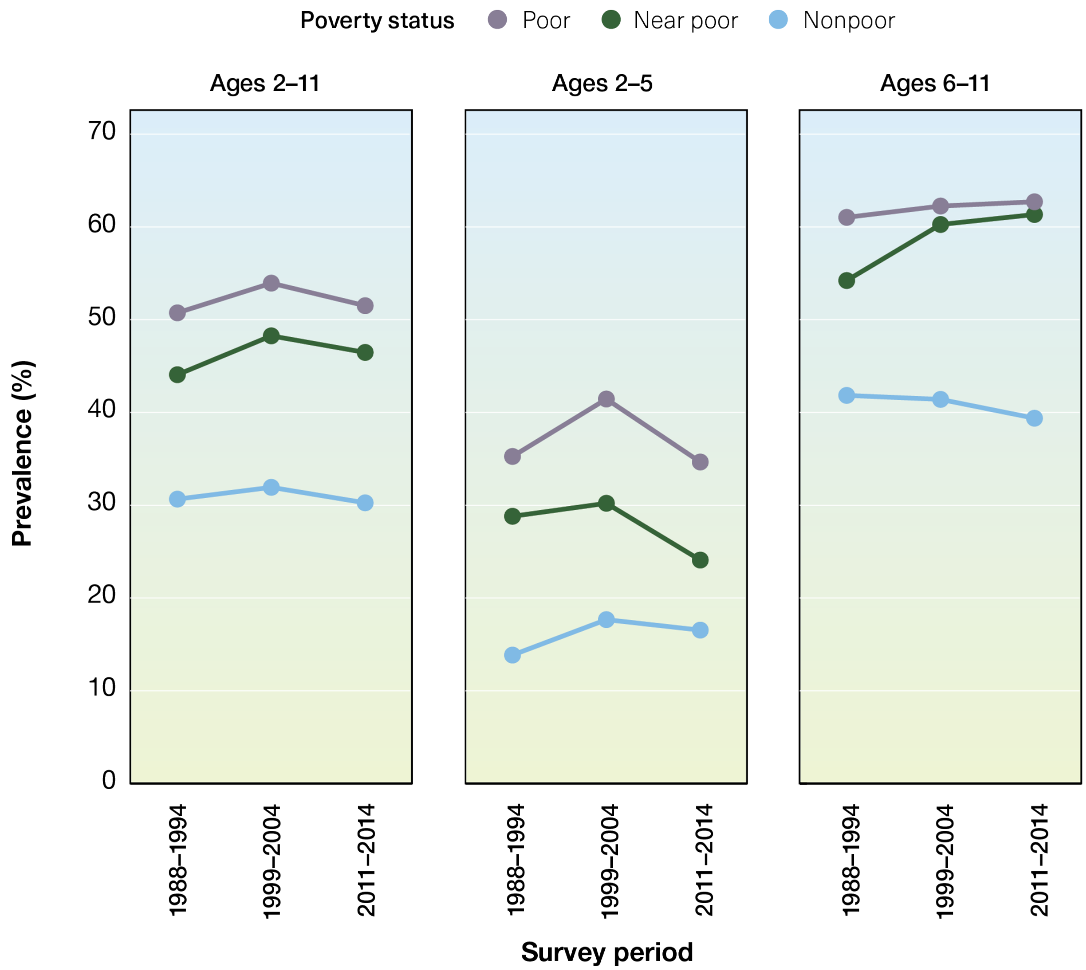
Note: Prevalence of dental caries in primary teeth (dft > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

varnish four times per year, providing dental sealants to the very young, and implementing noninvasive restorative dentistry as early as possible.

For children aged 6 to 11 years, the prevalence of dental cavities in permanent teeth has declined significantly in the past 20 years, from 25% to 18%, irrespective of gender (Figure 16). This decline has mostly benefited children not living in poverty and those who are non-Hispanic White (Figures 17 and 18). For Mexican American children aged 9 to 11 years, a significant decline in dental cavities has occurred within the past decade as well (from 45% to 33%). Children living in higher-income households have seen significant decreases in caries experience, whereas those living in poverty have not (22% to 13% vs. 28% to 24%). This decrease in overall caries rates during the past 20 years disguises an increasing health disparity between children who live in poverty and those who do not.

Overall, untreated caries in permanent teeth has declined in the past 20 years; girls aged 6 to 11 years have experienced a steeper decline than boys (Figure 19).

Figure 12. Percentage of children ages 2–11 with dental caries in primary teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



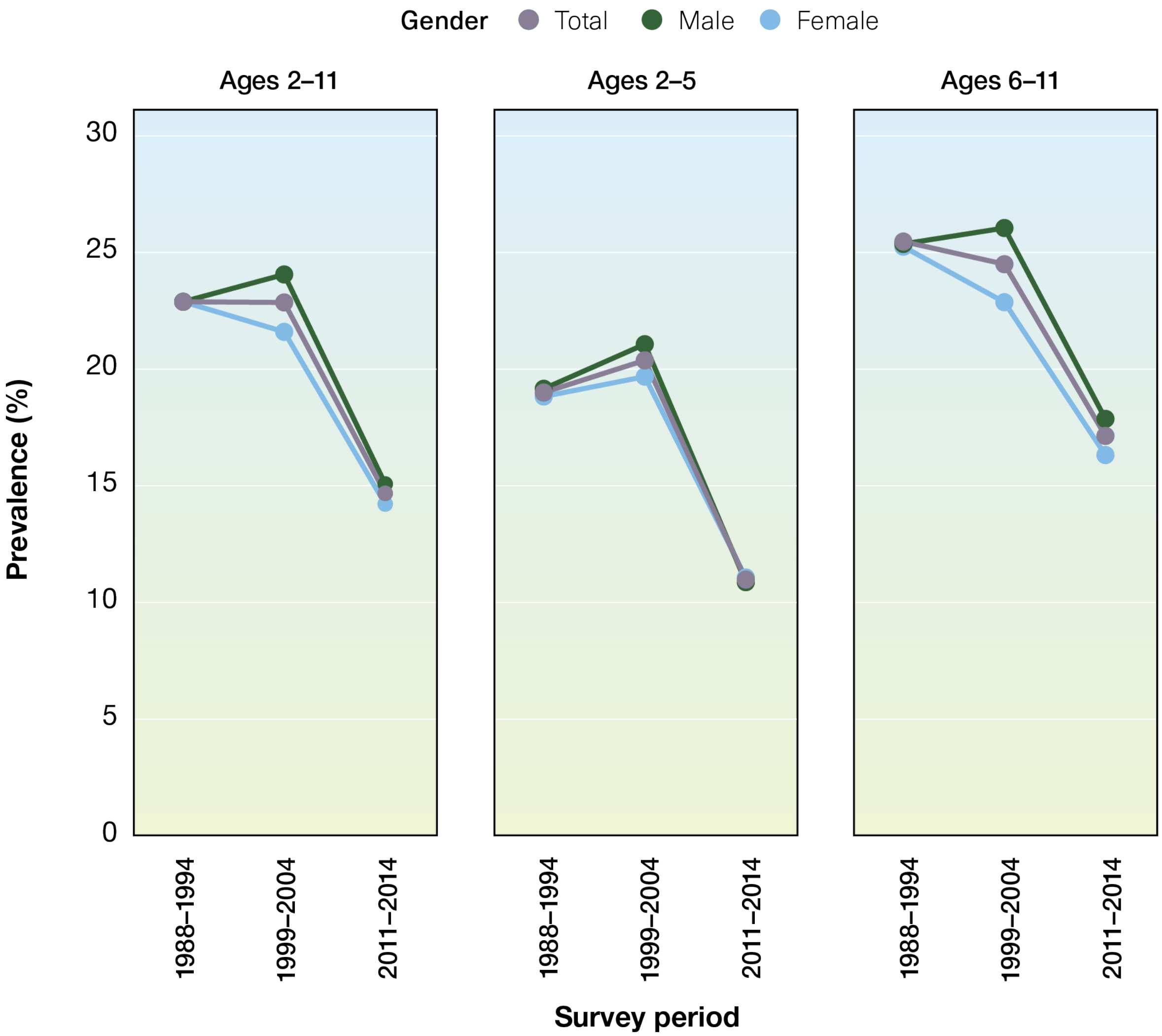
Notes: Prevalence of dental caries in primary teeth (dft > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

A decline in untreated caries among children aged 6 to 11 years living in less affluent homes has been substantial, especially since 2004 (Figure 20). Untreated dental caries among Mexican American and non-Hispanic Black children aged 6 to 11 years has also declined during this time period, and this decrease is most pronounced among those aged 9 to 11 years (Figure 21). Overall, this decline in untreated dental caries for children aged 6 to 11 years, like that in preschool children, indicates a reduction in some children's oral health disparities.

The decline in the number of children with untreated dental caries has dramatically affected the proportion of untreated and filled tooth surfaces. Although the percentage of children aged 2 to 11 years with untreated dental caries in their primary teeth has decreased substantially in the past 20 years (from 23% to 15%), the mean number of dental surfaces in primary teeth affected by dental cavities has increased from 2.9 to 4.2 (Figure 22). This increase in decayed primary teeth surfaces has had a greater impact on boys than girls, and the difference is significant in boys and girls aged 6 to 11 (6.0 vs. 4.3 surfaces) (Figure 22). This relationship between decayed and filled tooth surfaces has become more evident among traditionally underserved or minority children during the past 20 years.

Figure 13. Percentage of children ages 2–11 with untreated dental caries in primary teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



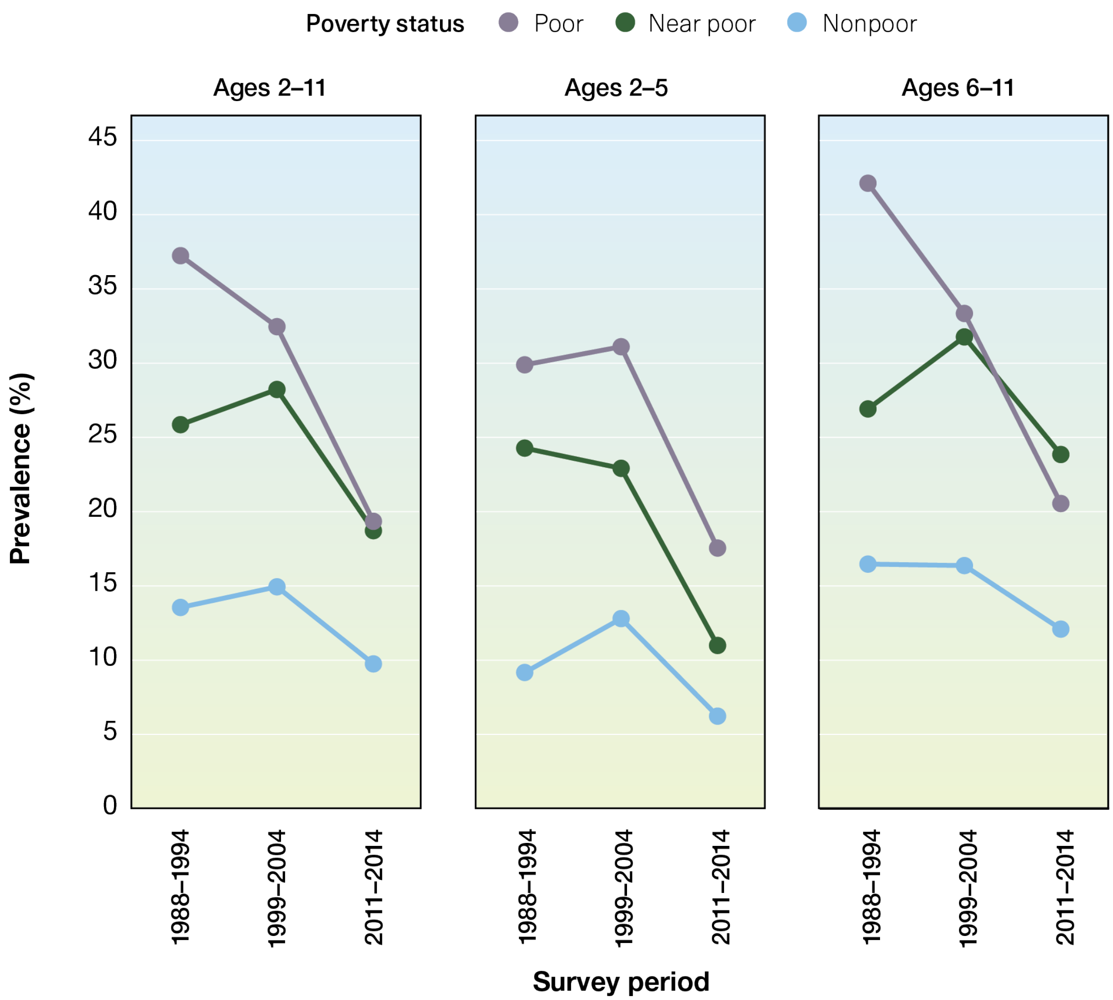
Note: Prevalence of dental caries in primary teeth (dt > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

As the mean number of untreated tooth surfaces has declined significantly among children from low-income families and those of color, the mean number of treated surfaces has increased substantially in those same groups, suggesting improved access to care but also greater tooth decay experience (Figures 23 and 24). Although great strides have been made in reducing both the prevalence of untreated tooth decay and the number of tooth surfaces with untreated decay, these children still experience tooth decay in primary teeth at higher levels than non-Hispanic White children or those living in higher-income families.

Two decades ago, the proportions of untreated and filled primary tooth surfaces were approximately equal among children age 2–11; currently though, about 2 out of 3 tooth surfaces are now restored (Figure 25). Although this decline in untreated caries in primary tooth surfaces during the past 20 years has affected all children, regardless of gender, race and ethnicity, and family income, it has had a greater impact among preschool

Figure 14. Percentage of children ages 2–11 with untreated dental caries in primary teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



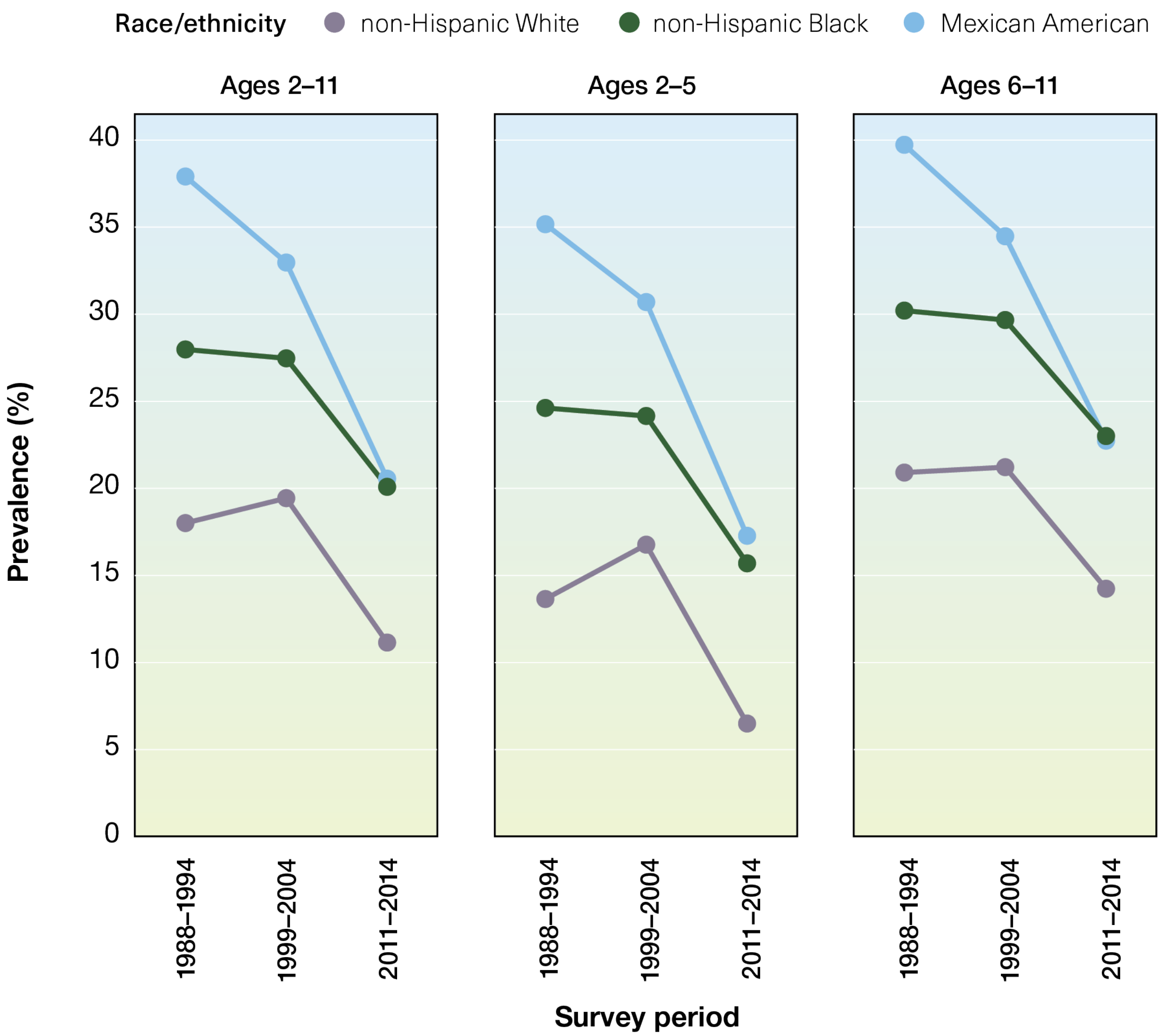
Notes: Prevalence of dental caries in primary teeth (dt > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

children (Figures 26 and 27). Two decades ago, 3 out of 4 tooth surfaces were untreated in children aged 2 to 5 years; currently among children in this age group, at least half of all tooth surfaces are restored (Figure 25). This improvement in the proportion of filled tooth surfaces has substantially benefited lower-income preschool children, essentially eliminating the disparity between this group and children living in higher-income households for this aspect of oral health (Figure 26). This proportional change indicates that children are receiving more dental treatment than 2 decades ago. However, it also suggests that efforts during the same time period to prevent new tooth decay have not yielded any promising results regarding children's primary teeth.

During the past 2 decades, the mean number of tooth surfaces in the permanent dentition affected by tooth decay has changed little among children 6 to 8 years of age, and the proportion of surfaces untreated or filled has remained consistent as well (Figure 28). However, the mean number of dental surfaces affected by tooth decay has decreased significantly among children aged 9 to 11 years, especially for girls. When examining differences by poverty status, children aged 6 to 11 years living in households at 200% or higher of the federal poverty level

Figure 15. Percentage of children ages 2–11 with untreated dental caries in primary teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



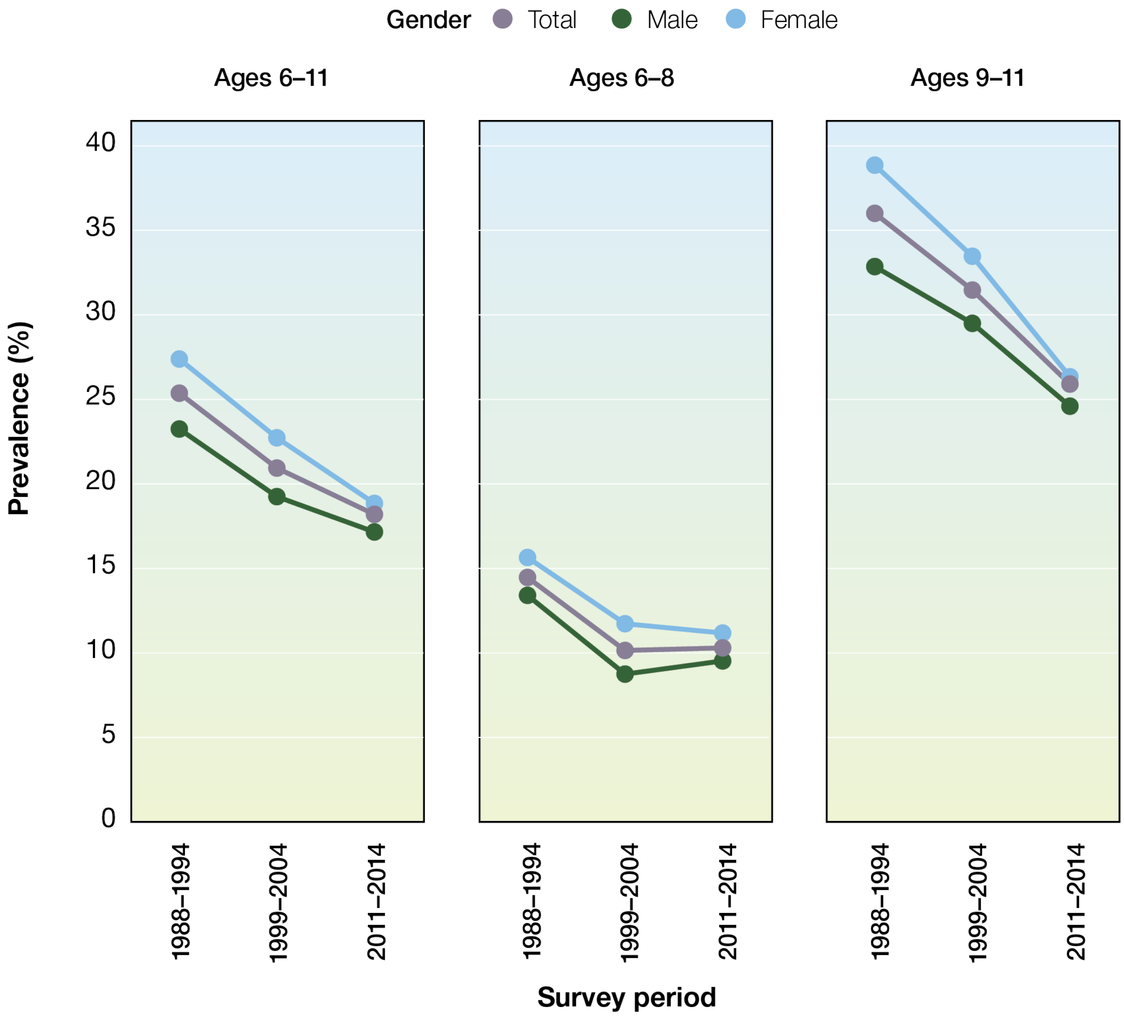
Note: Prevalence of dental caries in primary teeth (dt > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

experienced a decline in mean number of tooth surfaces affected by dental caries, whereas those living in poverty have experienced no change (Figure 29). Moreover, the proportion of untreated and filled tooth surfaces has remained fairly constant for these children. This outcome has increased the observed disparities in dental caries experience among children in the past 2 decades, and suggests that efforts to prevent tooth decay in newly erupted permanent teeth among children living in or near poverty are falling short and reflect an ongoing challenge.

Craniofacial Anomalies

In 1997, the National Birth Defects Prevention Network (NBDPN), a nationwide network of programs to facilitate birth defects surveillance and research, was founded. The establishment of this network has led to the first systematic collection, analysis, and dissemination of population-based birth defect information using surveillance data. Since the early 2000s, surveillance information has been used to produce national estimates of prevalence for orofacial defects.

Figure 16. Percentage of children ages 6–11 with dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



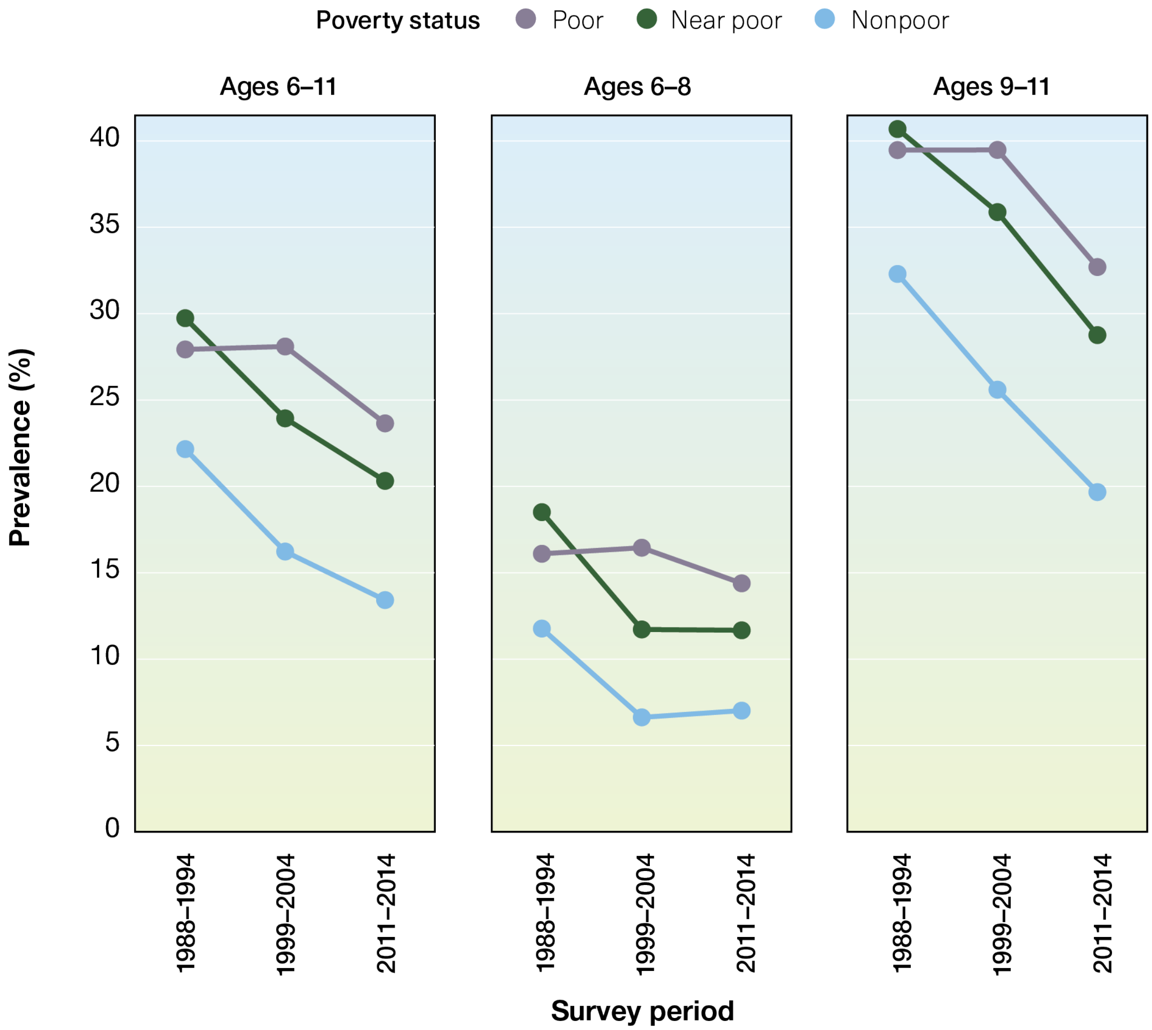
Note: Prevalence of dental caries in permanent teeth (DMFT > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

In 2006, data pooled from 11 states showed that the national prevalence of cleft palate was 6.4 per 100,000 live births; that for cleft lip (with or without cleft palate) was 10.5 per 100,000 live births (Canfield et al. 2006). Similarly, in 2010, according to national estimates using 2004–2006 NBDPN data pooled from 14 state programs, the prevalence of cleft palate and cleft lip (with or without cleft palate) was 6.4 per 100,000 live births and 10.6 per 100,000 live births, respectively (Parker et al. 2010). Race/ethnic differences in craniofacial abnormalities continue, with the highest rates in non-Hispanic White and AI/AN babies. The rates of cleft palate without cleft lip per 100,000 live births were 6.4 for non-Hispanic White, 4.2 for non-Hispanic Black, 5.2 for Hispanic, and 6.5 for AI/AN babies from 1999–2007 (Canfield et al. 2014). Similarly, the rates of cleft lip, with and without cleft palate, per 100,000 live births were 9.7 for non-Hispanic White, 6.0 for non-Hispanic Black, 10.2 for Hispanic, and 20.1 for AI/AN births in that same time period (Canfield et al. 2014).

Orofacial developmental disorders also continue to be a challenge. Despite advances in understanding their causes, particularly their genetic basis, new approaches to

Figure 17. Percentage of children ages 6–11 with dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental caries in permanent teeth (DMFT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

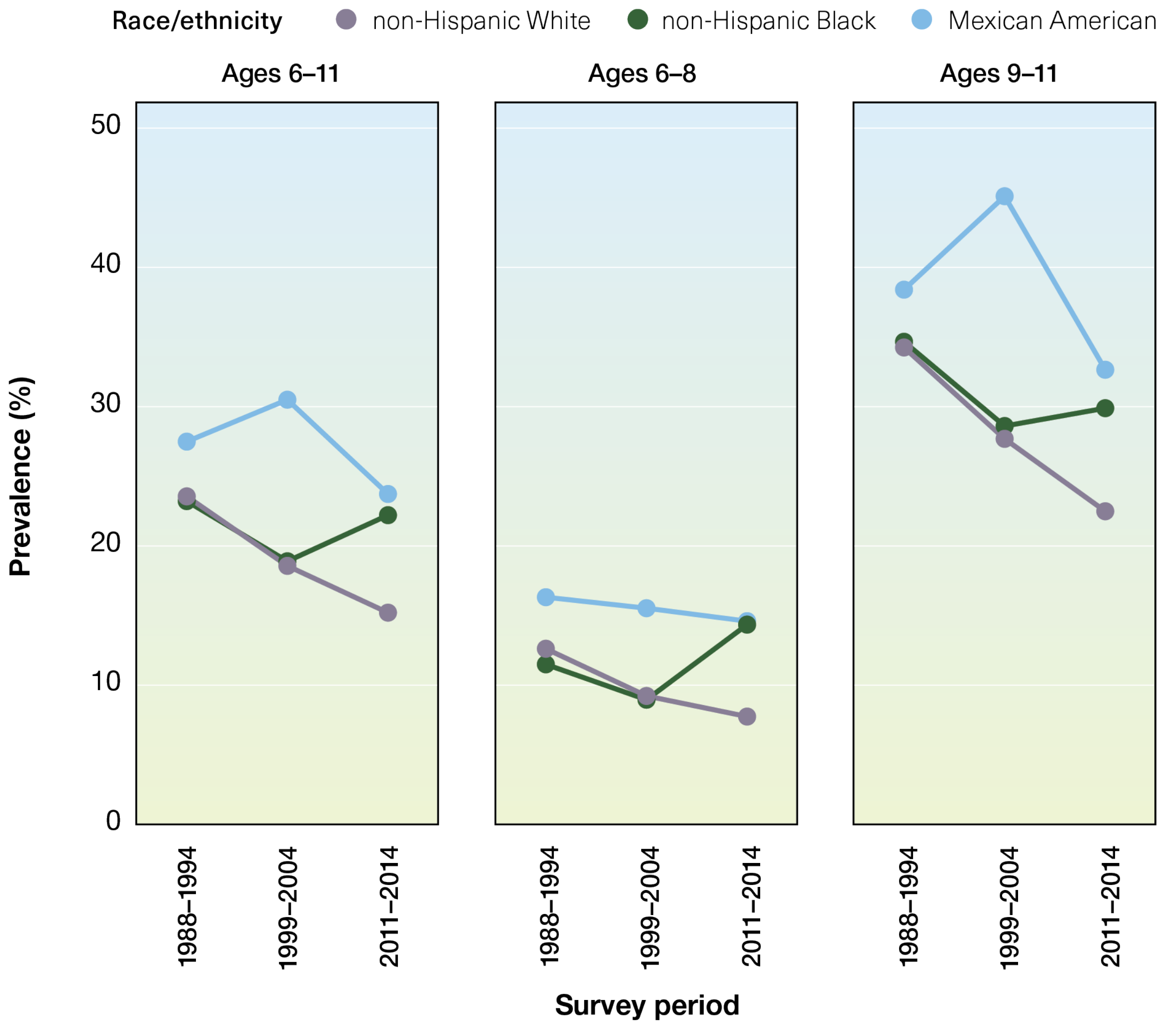
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

treatment continue to lag. Tissue engineering, prenatal interventions, and microsurgery techniques remain underutilized in the care of children with these disorders. Thirty years ago, the lack of prospective studies hindered advancement of surgical innovation in this area (Roberts et al. 1991). In addition, techniques available today, such as three-dimensional imaging and microsurgery, were not available or sufficiently refined (Gattani et al. 2020). The need persists for ethical, well-designed prospective studies to validate these innovations. Nevertheless, as surveillance systems continue to improve with better reporting, our understanding of the epidemiology of craniofacial defects expands, and more targeted research can be implemented to identify areas for improvement in prevention and health services planning, which will improve quality of life for children affected by craniofacial disorders.

Developmental Tooth Defects (Dental Fluorosis and Other Defects)

A major challenge affecting our understanding of a range of developmental tooth defects and their impact on U.S.

Figure 18. Percentage of children ages 6–11 with dental caries in permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



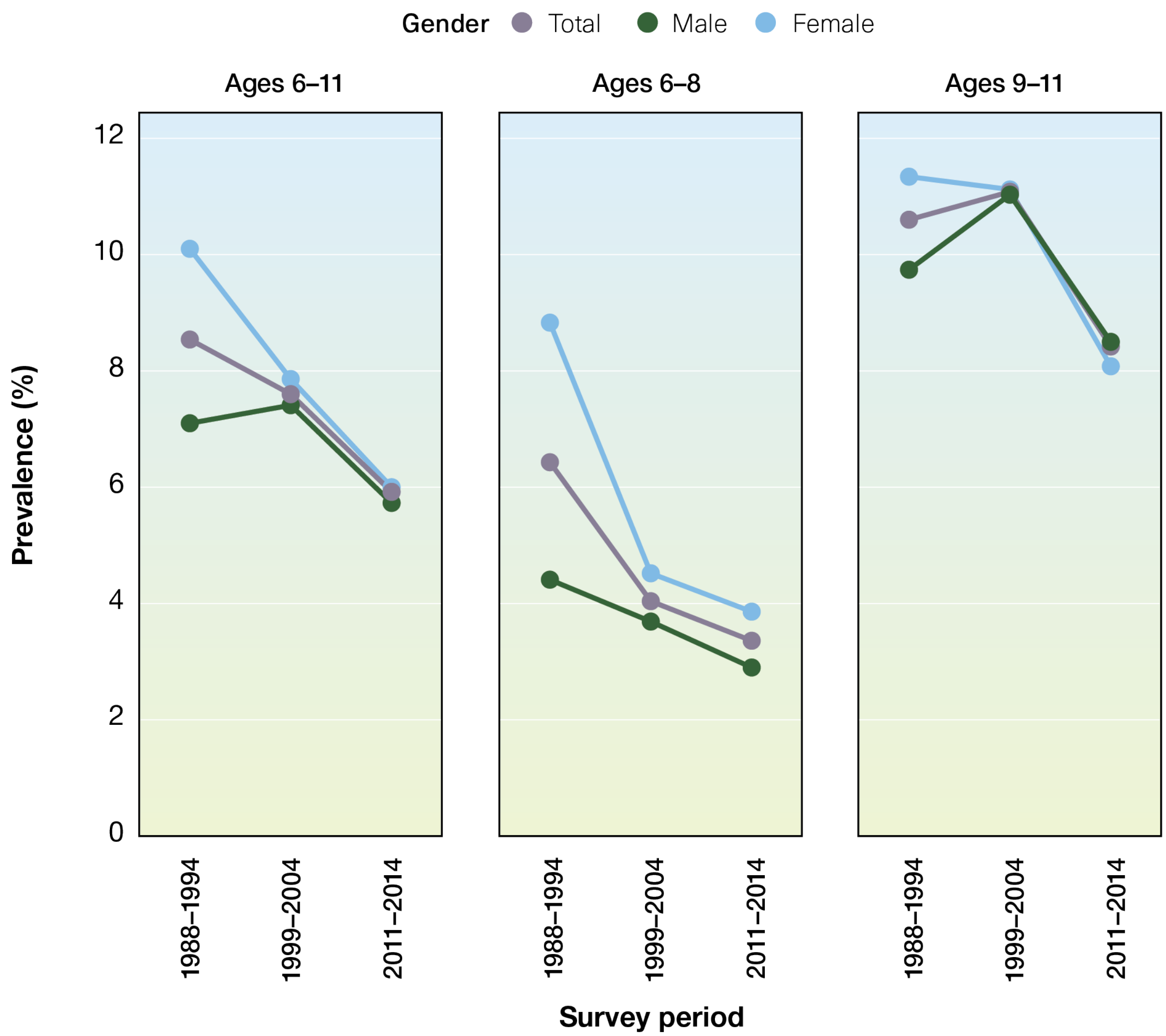
Note: Prevalence of dental caries in permanent teeth (DMFT > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

children is the paucity of recent epidemiological data regarding these conditions. Consequently, there is no accurate estimate of recent prevalence of developmental tooth defects in the United States.

Although the use of various fluoride modalities to prevent and control dental caries has been a topic of popular controversy for decades, new concerns involving the assessment of dental fluorosis have emerged since the 2000 Surgeon General's Report on Oral Health. Efforts at measuring dental fluorosis have been inconsistent at the national level. Published findings from the 1999–2004 National Health and Nutrition Examination Survey (NHANES) reported an increase in dental fluorosis from the previous national assessment conducted in 1986–1987 (Beltrán-Aguilar et al. 2010). Later studies evaluating the 2011–2012 NHANES data suggested that the prevalence of dental fluorosis increased further (Wiener et al. 2018; Neurath et al. 2019), but subsequent analyses of examiner performance questioned this increase and suggested that the 2011–2016 NHANES fluorosis data may not be suitable for trends analyses (National Center for Health Statistics 2019).

Figure 19. Percentage of children ages 6–11 years with untreated dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).

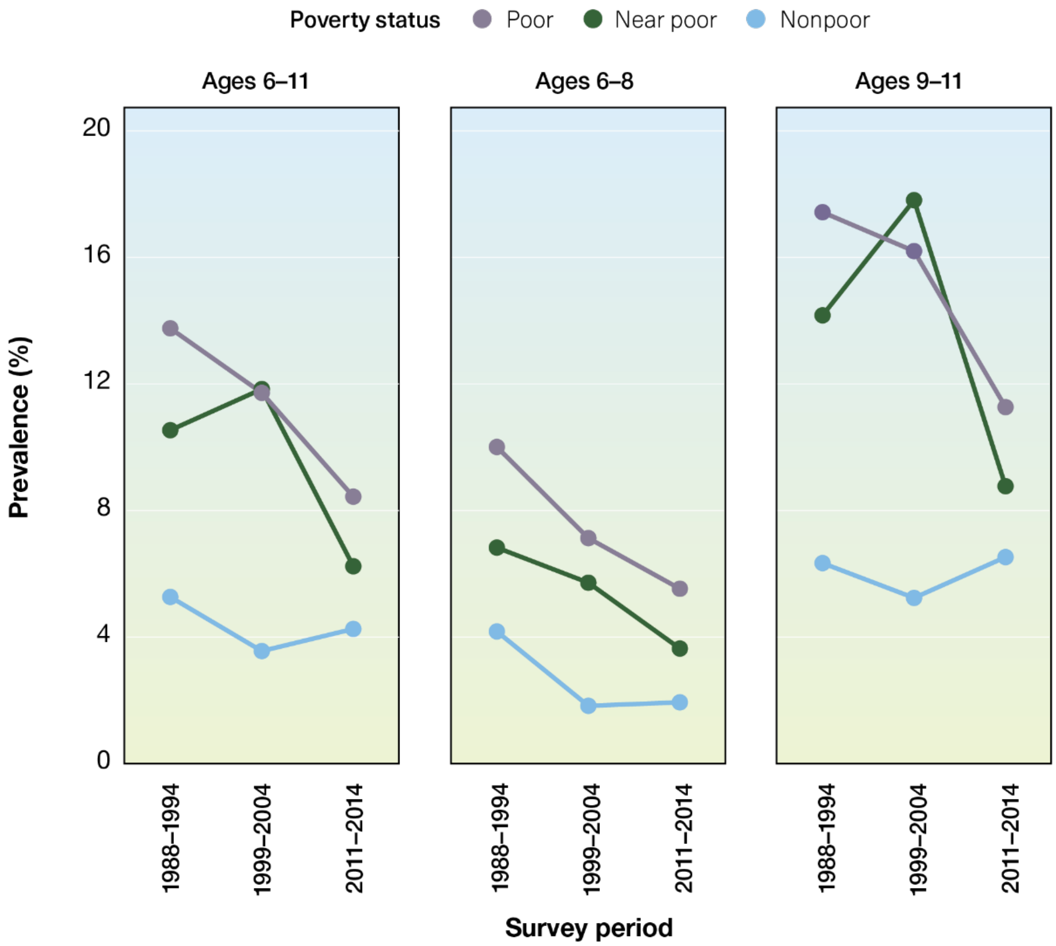
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Consequently, an ongoing challenge is that contemporary policy making around this topic is dependent on data that are more than two decades old and with little consensus on how this condition should be assessed in the future.

Other Orofacial Conditions (Dental Erosion)

Dental erosion and tooth wear in children typically receive far less attention in the United States than in other countries. In the United States, dentists are incentivized to restore rather than monitor nonsensitive dental-erosive lesions for progression, which is important in managing acid exposure reduction. This relative lack of attention has led to knowledge gaps that have an impact on our understanding of the condition. Although other countries have developed consensus guidelines addressing diagnosis and management of dental erosion (O'Sullivan and Milosevic 2008; Loomans et al. 2017), and there is widespread adoption in Europe of the Basic Erosive Wear Examination Scale (Bartlett et al. 2008), there has been a lack of consensus in the United States about how to recognize, measure, and document dental erosion (American Dental Association 2018).

Figure 20. Percentage of children ages 6–11 with untreated dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of untreated dental caries in permanent teeth (DT > 0). **FPG** = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Although trend data regarding erosion are sparse, there is concern that erosive tooth wear is increasing among children and adolescents (Lussi 2006). The status of dental erosion in children, and its management, have remained essentially unchanged during the past 2 decades. This likely can be attributed to the focus on pediatric dental caries, which has a far more widespread impact on tooth destruction in youngsters.

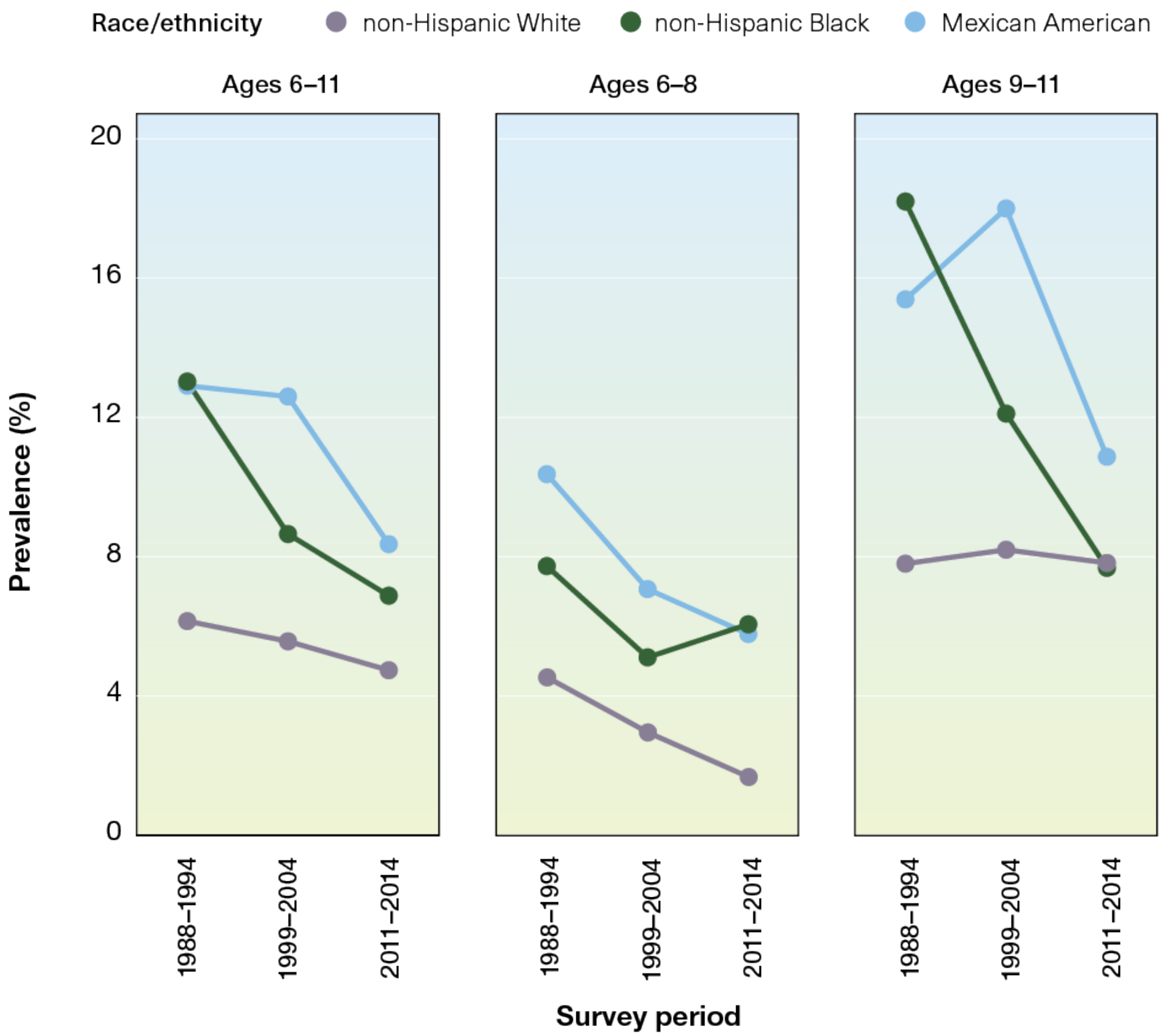
High-Risk Behaviors

Caregiver Oral Health Behaviors

Only a few interventions have been shown to exert a positive impact on parents' attitudes, beliefs, and behaviors regarding their children's oral health (Ismail et al. 2011; Wagner et al. 2014). Even when parents know what is best, this knowledge does not necessarily translate into practice. Almost 80% of parents and caregivers reported engaging in behaviors they knew were harmful to their children's teeth, such as giving them juice or putting them to bed with a bottle of milk or juice (Hill et al. 2019).

Studies show that parental motivation and self-efficacy are associated with better child toothbrushing habits and healthier diets (Finlayson et al. 2007; Knowlden and Sharma 2015). However, despite early successes, clinical trials designed to increase parental motivation and self-efficacy to reduce the risk of early childhood caries (ECC)

Figure 21. Percentage of children ages 6–11 years with untreated dental caries in permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



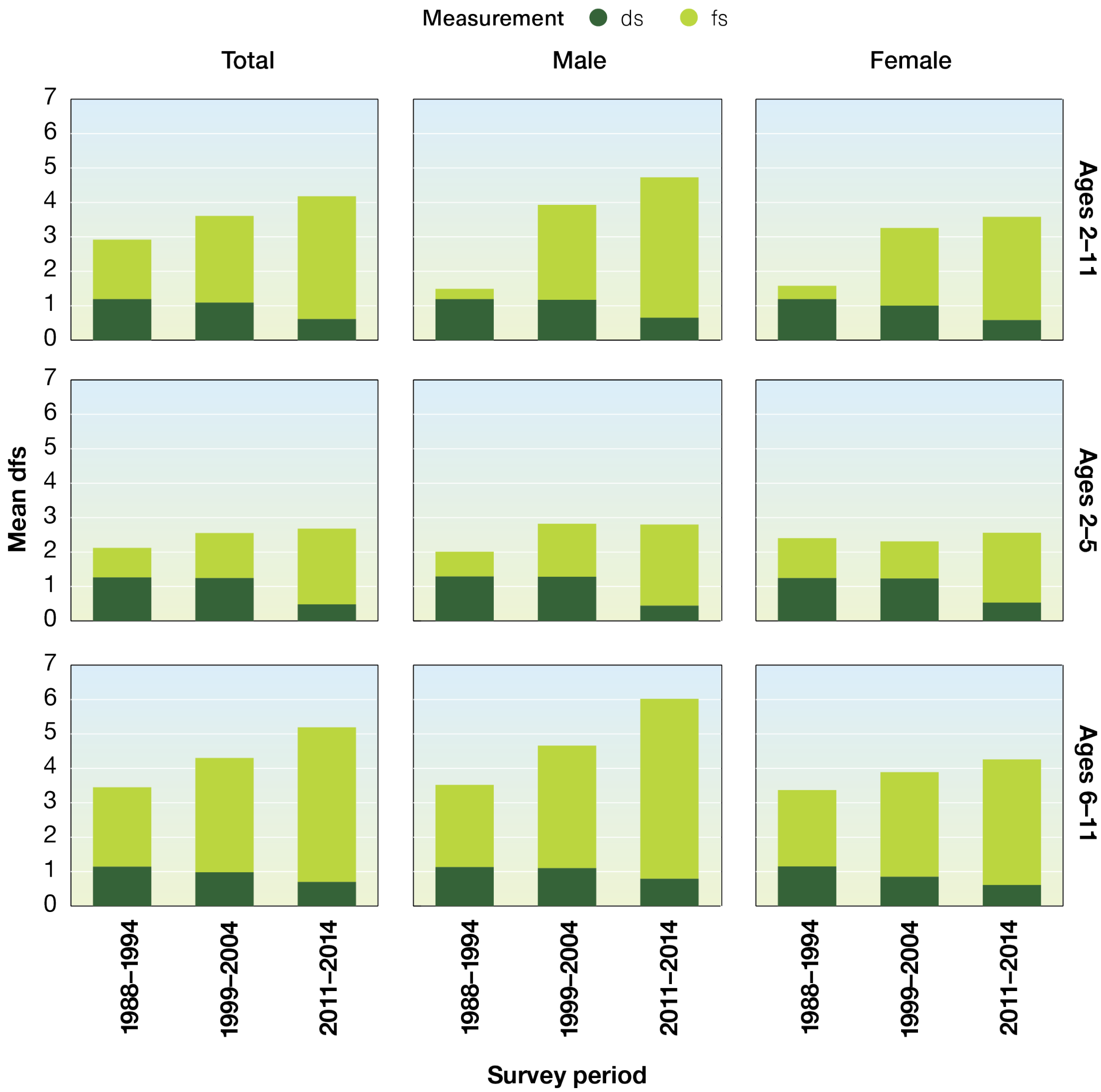
Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

in high-risk children failed to reduce the incidence of caries (Batliner et al. 2018; Henshaw et al. 2018). Challenges remain for motivating parents to participate in caries-preventive behaviors (Bryant et al. 2016).

Dietary Behaviors

Our understanding about the adverse health effects of obesity and sugar-sweetened beverage (SSB) consumption in children has evolved substantially in recent years. New guidelines and policies have been implemented to help reduce the incidence of obesity, hypertension, diabetes, and tooth decay, all of which have a strong dietary component. Mentioned previously, these include guidelines from the American Academy of Pediatrics (AAP) on SSBs, including minimizing use of bottles and sippy cups for beverage consumption, not introducing 100% fruit juice before 12 months of age, and limiting juice to no more than 4 ounces a day for children aged 1 to 3 years (Heyman and Abrams 2017; Lott et al. 2019). Significant policy changes at the local, state, and national levels have restricted the availability of low-nutrient, high-sugar food and beverages at school as a consequence of

Figure 22. Mean number of decayed (ds) or filled surfaces (fs) of primary teeth in children ages 2–11 by gender and age group: United States, 1988–1994, 1999–2004, 2011–2014

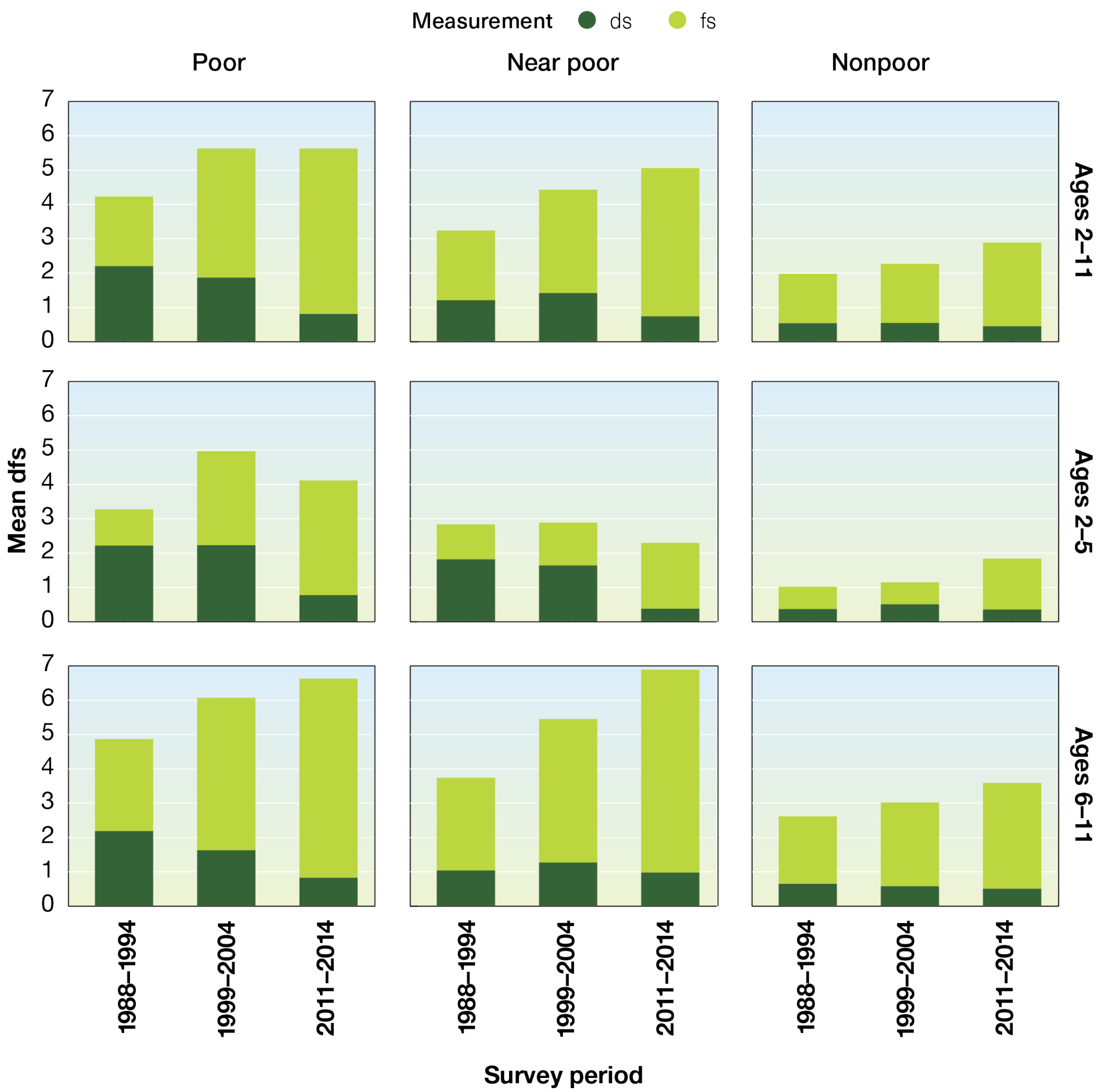


Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

the National School Lunch Program, the Supplemental Nutrition Assistance Program (SNAP), the Summer Food Service program, and the Afterschool Snack program, even though some of these programs have been cut (Roy and Stretch 2018).

Although the oral health workforce is trained to assess patient intake of added sugars and to recommend against it, they are generally not equipped to identify the complex factors influencing dietary behaviors and cannot recommend changes in a child's overall dietary plan. In addition, dental providers generally are unfamiliar with programs that provide access to healthier foods. The U.S. Dietary Guidelines outline a model in which the education, health care, and industry sectors can help individuals with varying social and cultural norms learn how to make healthier food choices (U.S. Department of Health and Human Services and U.S. Department of Agriculture 2015). Although participation in interprofessional health care teams that include registered dietitians, psychologists, social workers, and pediatricians has the potential to change health behaviors and improve

Figure 23. Mean number of decayed (ds) or filled surfaces (fs) of primary teeth in children ages 2–11 by poverty status and age group: United States, 1988–1994, 1999–2004, 2011–2014



Note: **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

oral health outcomes, most pediatric oral health providers continue to provide dental care independent of collaborative care.

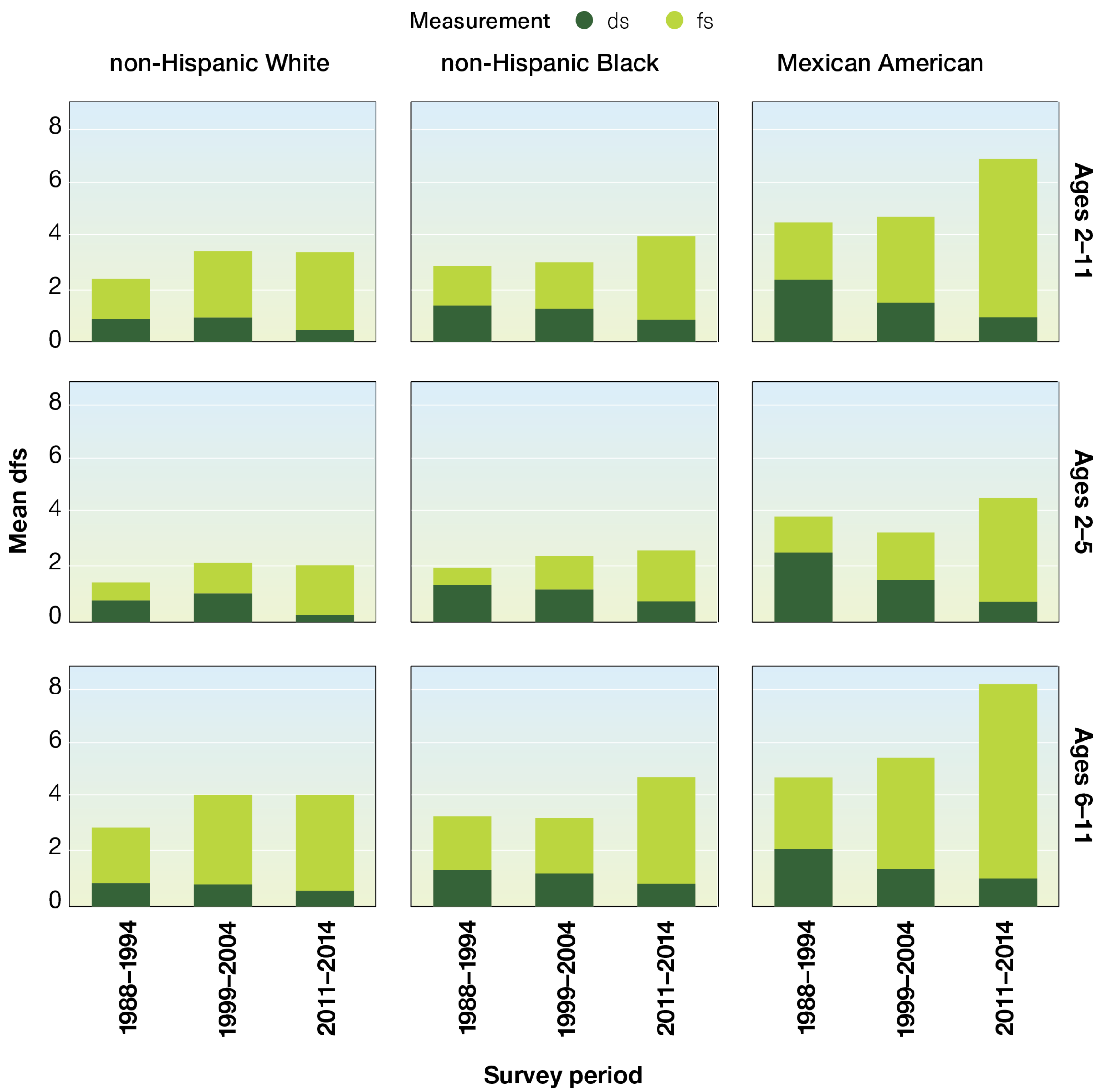
Social Determinants of Health

Multilevel Influences

During the past 2 decades, SDoH have been recognized as major contributors to oral disease, especially in children (Patrick et al. 2006; Fisher-Owens et al. 2007; Kim Seow 2012). This recognition has led, in part, to better understanding of numerous factors in a child's background that can shape a child's biology and behaviors related to oral health.

Much research on SDoH has focused on individual determinants of oral health, such as sociodemographic characteristics or behaviors (Link and Phelan 1995;

Figure 24. Mean number of decayed (ds) or filled surfaces (fs) of primary teeth in children ages 2–11 years by race/ethnicity and age group: United States, 1988–1994, 1999–2004, 2011–2014



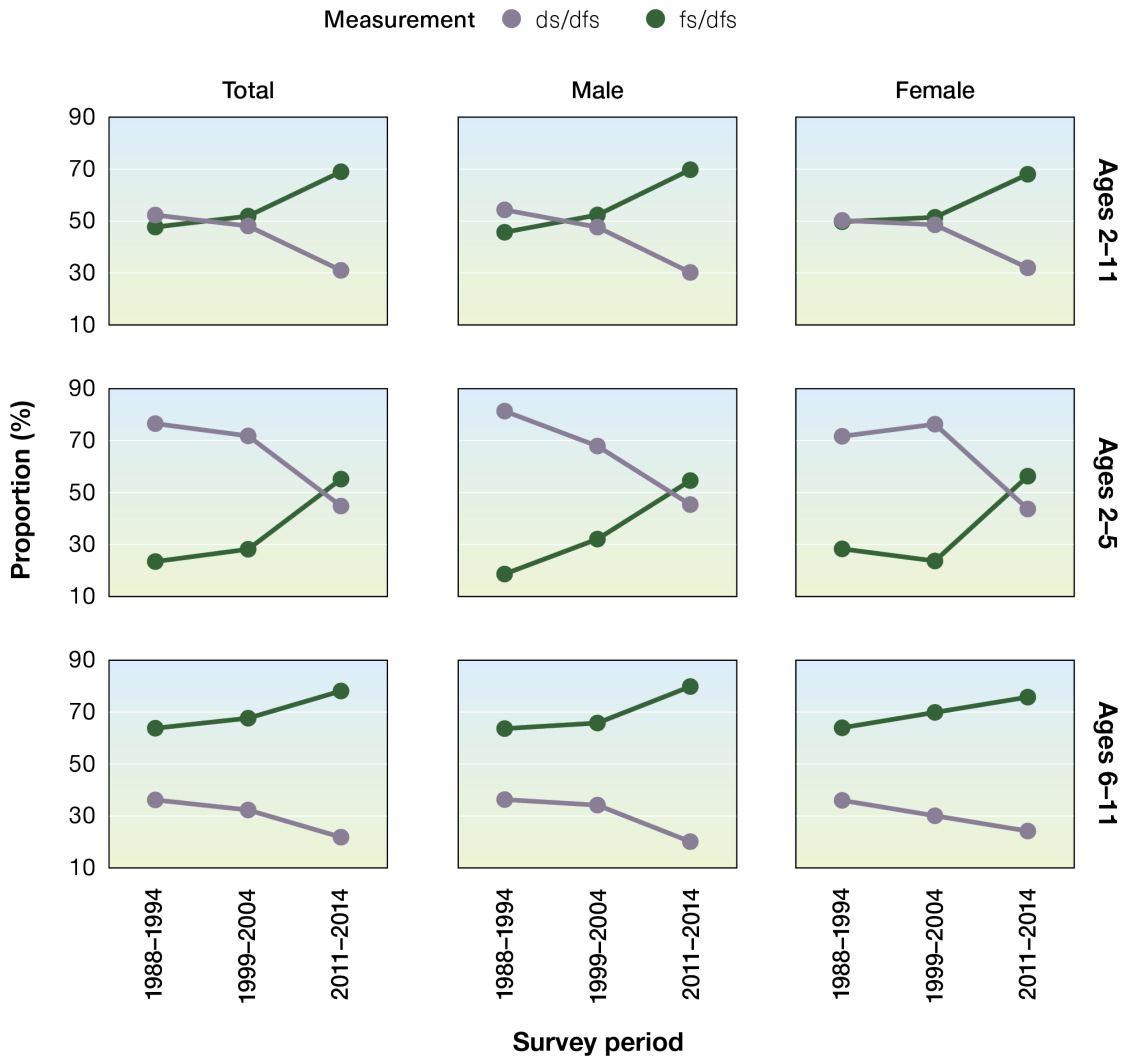
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

Solar and Irwin 2010; Petersen and Kwan 2011). Although individual-based approaches to assessment and intervention are important, they are limited because they do not address variations in oral disease at the population level or the underlying causes of disease (Duijster et al. 2014; Fontanini et al. 2015; Singh et al. 2018). Population-level approaches can help to explain the complex and interactive causes of children's health and oral health outcomes (Fisher-Owens et al. 2007; Lee and Divaris 2014), and emerging multilevel studies also can explicate the influence of different levels of social organization on oral health outcomes (Singh et al. 2018).

Child-Level Influences

A growing body of research during the past 20 years is showing that poor health and social circumstances can affect children for a lifetime. The damage can occur as early as the prenatal period. For example, gene transcription during fetal development in a mother under stress can

Figure 25. Contribution of decayed (ds) or filled surfaces (fs) to the number of decayed and filled surfaces (dfs) of primary teeth in children ages 2–11 by gender and age group: United States, 1988–1994, 1999–2004, 2011–2014

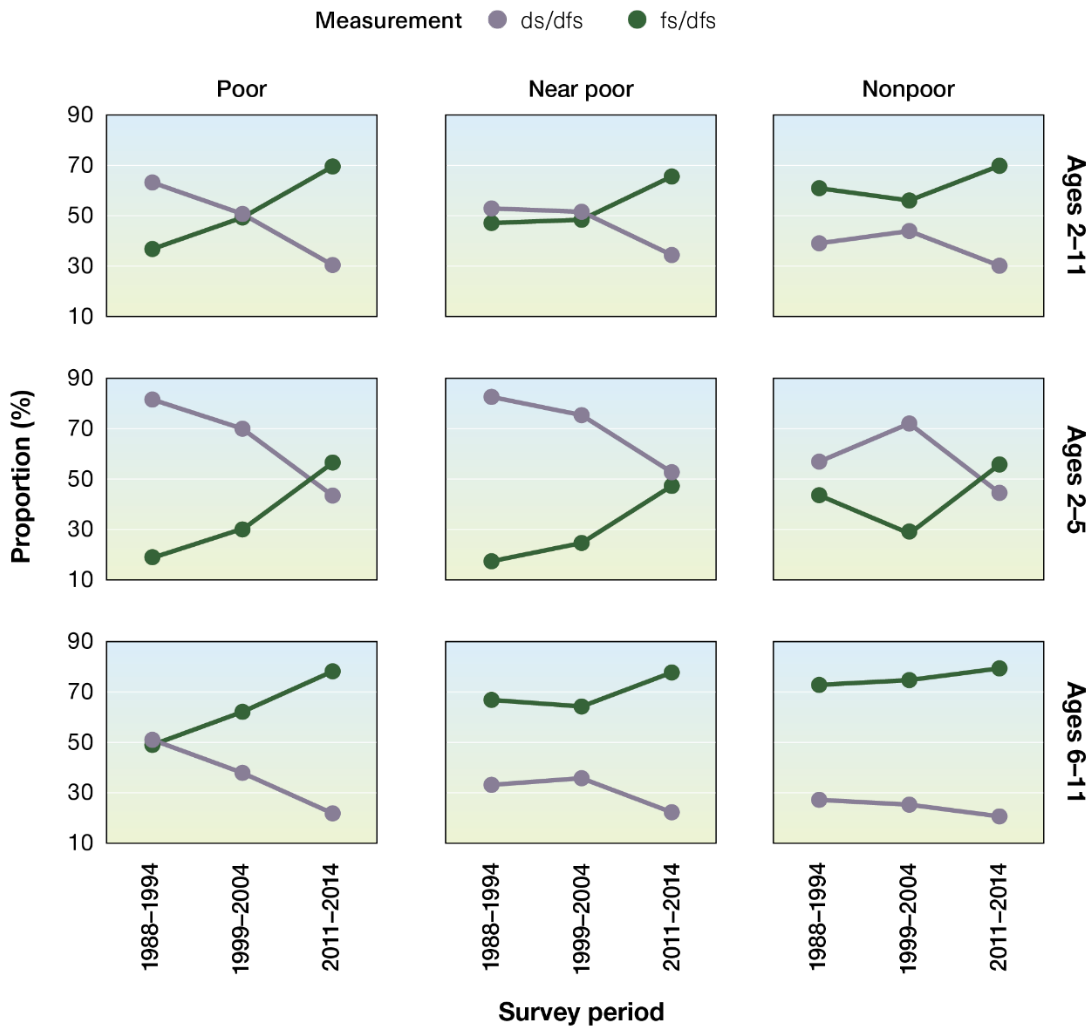


Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

produce lifelong negative outcomes (Kanherkar et al. 2014; Tiffon 2018). For preverbal children, too, exposure to adverse childhood experiences has a lifelong impact in ways as diverse as depression and suicide, interpersonal violence, sexually transmitted diseases, smoking and vaping, substance abuse, cancer, heart disease, and respiratory disease (Felitti et al. 1998; Hughes et al. 2017). The Commission on Social Determinants of Health regarded minimizing such challenges as an "ethical imperative" (Commission on Social Determinants of Health 2008).

In addition, intrinsic risk factors in children's genetic makeup may require extra attention from the health system and family caregivers. Children with special health care needs (SHCN) often are at greater risk for oral health problems (Newacheck et al. 2000; Lewis 2009; Iida and Lewis 2012; Chi 2018) because of medication-related reduced salivary flow, behavioral challenges, muscle rigidity, poor access to care, and other factors (Newacheck et al. 2000).

Figure 26. Contribution of decayed (ds) or filled surfaces (fs) to the number of decayed and filled surfaces (dfs) of primary teeth in children ages 2–11 by poverty status and age group: United States, 1988–1994, 1999–2004, 2011–2014



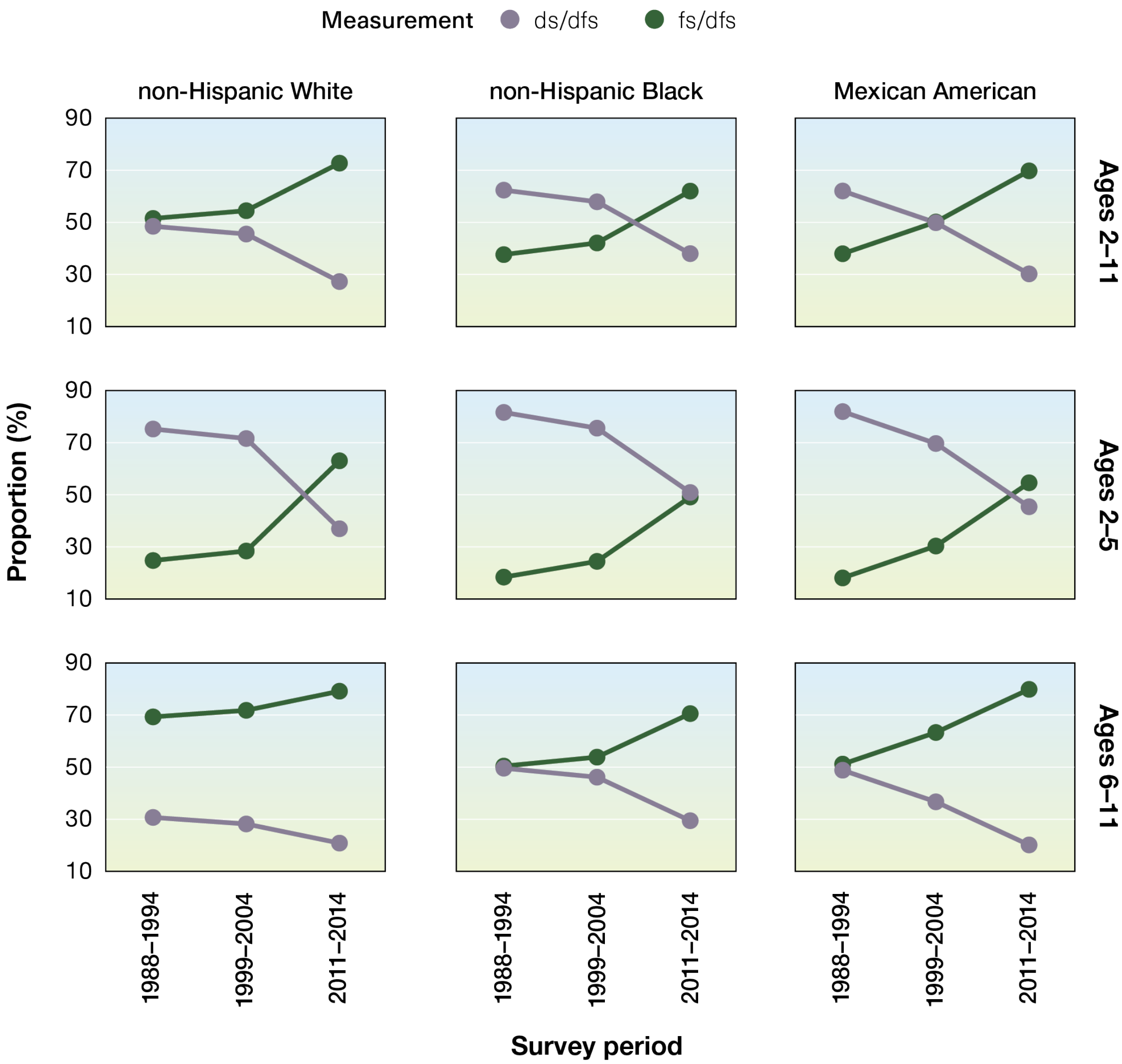
Note: **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

Parent- and Family-Level Influences

Social structure and social environments influence parental behaviors, determining positive or negative oral health behaviors for parents themselves, as well as their children (Albino and Tiwari 2016). For example, studies have shown that in parents, better oral health is correlated with higher maternal education attainment and maternal self-care (Shearer et al. 2011; Heima et al. 2015; Phillips et al. 2016). Conversely, worse oral health is correlated with greater maternal stress, maternal smoking, unhealthy eating, and lack of clinical dental care (Masterson and Sabbah 2015; Phillips et al. 2016).

Parents can create an environment that directly influences children's oral health behaviors by establishing and supervising toothbrushing, providing a healthy diet, and ensuring early visits to dental professionals (de Castilho et al. 2013). For example, children whose mothers supervise their toothbrushing have better oral health outcomes (Saied-Moallemi et al. 2008). Psychosocial constructs, such as attitudes, beliefs, and culture, also influence parental

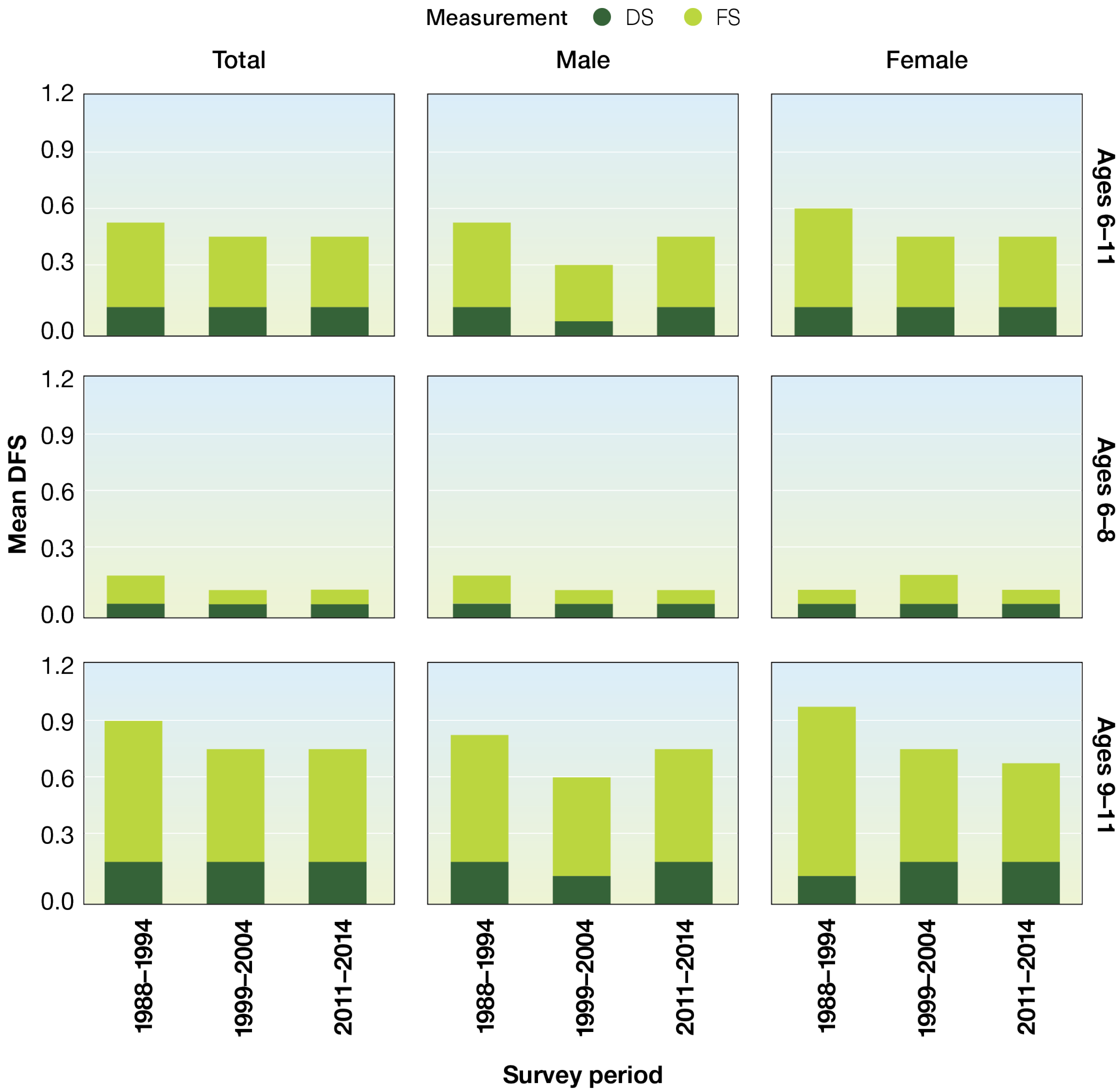
Figure 27. Contribution of decayed (ds) or filled surfaces (fs) to the number of decayed and filled surfaces (dfs) of primary teeth in children ages 2–11 by race/ethnicity and age group: United States, 1988–1994, 1999–2004, 2011–2014



Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

behaviors that, in turn, may affect parents' oral health and that of their children (Reisine and Douglass 1998). Research has shown that parents who perceived fewer barriers and greater benefits to maintaining their children's oral health and who understood susceptibility to caries have children with less caries experience (Kim Seow 2012; Tiwari and Albino 2017; Wilson et al. 2017; Batliner et al. 2018). Other psychosocial factors recognized as protective for pediatric oral health include higher maternal sense of optimism, positive coping strategies, resiliency, and confidence in one's ability to self-control. These factors have been associated with increased parental participation in oral health promotion events, higher utilization of dental services, and caries-free status of children (Freire et al. 2002; Finlayson et al. 2007; Lindmark et al. 2011; Albino et al. 2014; Gururatana et al. 2014; Bryant et al. 2016; da Silva et al. 2018). Although numerous studies have assessed how SDoH affect children's oral health, far fewer studies have examined how interventions can successfully ameliorate the oral health disparities related to economic and social inequalities in the United States.

Figure 28. Mean number of decayed (DS) or filled surfaces (FS) of permanent teeth in children ages 6–11 by gender and age group: United States, 1988–1994, 1999–2004, 2011–2014



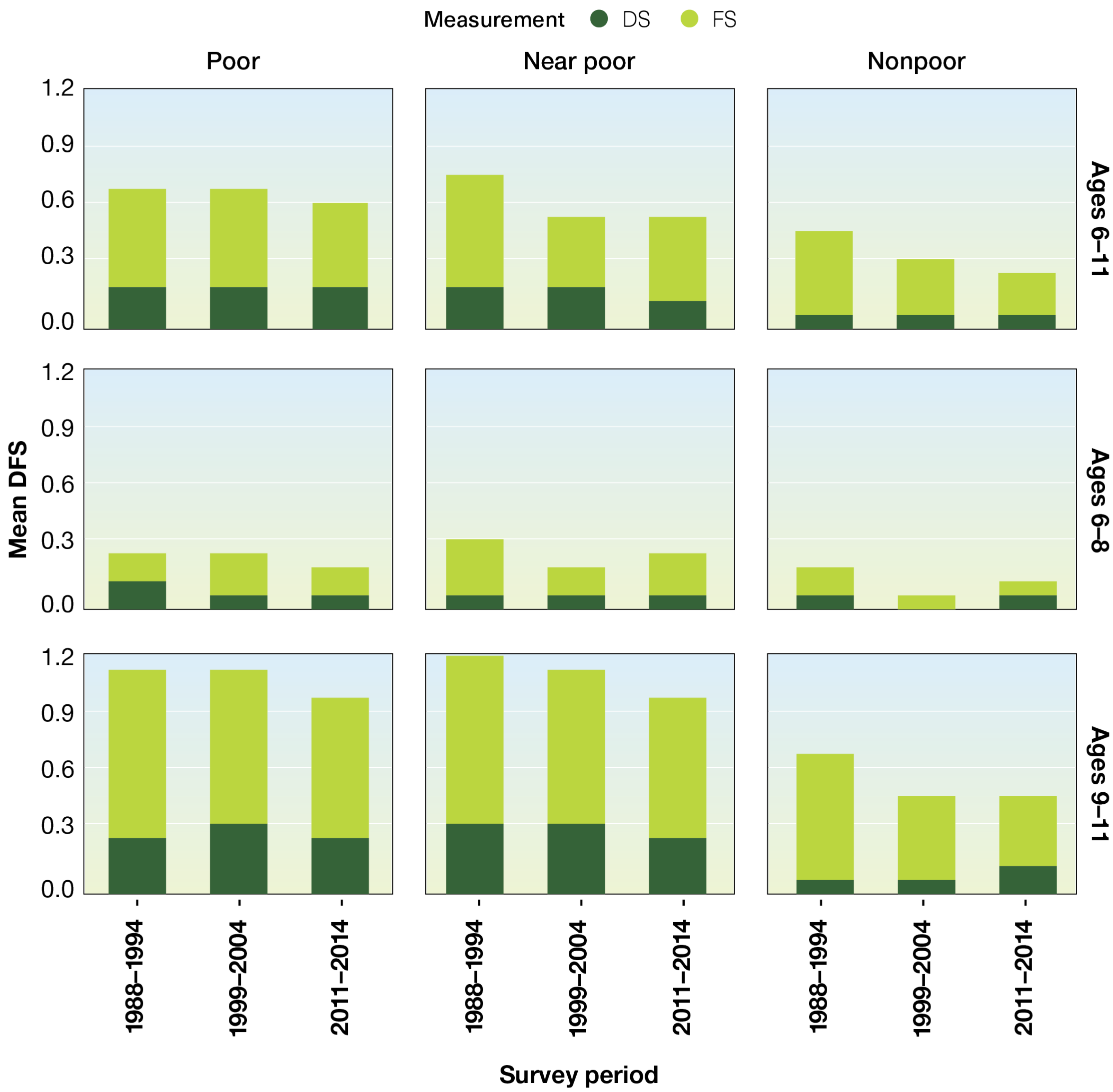
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

To address ongoing challenges in health inequities, questions need to be asked about why an increase in the utilization of dental care does not lead to better outcomes among some pediatric populations, whether those are defined by race/ethnicity or by income level.

Cultural-Level Influences

In the past 20 years, the U.S. population has become more diverse, with at least 25% of all children (17.5 million children out of 70 million) living in immigrant households (O'Hare 2011; Zong et al. 2016), in which language and cultural practices are recognized as important influences on oral health (Butani et al. 2008; Tiwari and Albino 2017). Language and cultural differences have an impact on these children's oral health behaviors and their use of services (Tiwari and Albino 2017). Interventions that recognize the complex interplay of these cultural and psychosocial factors are more likely to improve oral health knowledge, beliefs, and practices and have a long-term impact on the oral health of these children (Albino and Tiwari 2016).

Figure 29. Mean number of decayed (DS) or filled surfaces (FS) of permanent teeth in children ages 6–11 by poverty status and age group: United States, 1988–1994, 1999–2004, 2011–2014



Note: **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

One intervention that has demonstrated sensitivity to cultural factors and is increasingly being used by dental practitioners with the goal of impacting oral health behavior is motivational interviewing (MI). The MI approach involves person-centered, respectful communication designed to resolve ambivalence about behavior change and build intrinsic motivation for such change. MI has been used to successfully promote behavior change in brief medical encounters (Borrelli et al. 2007; Borrelli et al. 2016) and appears to be effective even for those who are not ready to change (Borrelli et al. 2017). Results of systematic studies related to the impact of MI on oral health outcomes, however, have been highly variable. A few studies have shown reductions in dental caries in children in some settings (Weinstein et al. 2004; Saengtipbovorn 2017; Wu et al. 2017; Colvara et al. 2018), yet only one large-scale controlled trial has produced these results—that one in an Australian Maori population (Jamieson et al. 2020).

Two major clinical trials of multi-year duration have demonstrated no such effects (Batliner et al. 2018; Henshaw et al. 2018). However, these and other studies have shown an effect of MI on oral health behaviors (Ismail et al. 2011) and oral health knowledge (Batliner et al. 2018; Henshaw et al. 2018), as well as improvements in oral health and diet and SSB consumption (Borrelli et al. 2015). Moreover, MI that targets caregivers has been readily accepted in some American Indian and Latino communities. Notwithstanding a number of limitations affecting the quality of evidence resulting from studies of MI interventions (Faghihian et al. 2020), the approach demonstrates considerable promise and is at least as effective as conventional dental health education in controlling tooth decay in preschool children.

There are still relatively large gaps in our understanding of cultural beliefs and practices related to oral health, owing to the lack of both qualitative and quantitative research in these areas. For example, although Hispanic/Latino children have increased their utilization of preventive dental care more than non-Hispanic White and Black children (Tiwari and Palatta 2019), their oral health outcomes have not been reflected by important reductions in oral health disparities (Dye et al. 2012). There also is a paucity of validated instruments for assessing the impact of culture on oral health. It is vital to develop standardized measures to assess cultural beliefs and practices related to oral health, particularly in populations experiencing the greatest burden of oral disease. Some recent efforts to develop and validate tools are gaining momentum (Wilson et al. 2014; Albino et al. 2018). The next step would be to design acceptable and effective prevention and treatment programs.

Community- and State-Level Influences

Influences at community and state levels affect children's oral health, and some important advances have occurred in the past two decades. Increasing access to fluoridated water (Kumar et al. 2010; Aguiar et al. 2018), facilitating neighborhood dental health programs, expanding public insurance (Fisher-Owens et al. 2007), and implementing such policies as taxation of SSBs all function to improve children's oral health outcomes. SDoH-mediated risk factors for poor oral health include interruption of SNAP benefits (Ostberg et al. 2017; Ettinger de Cuba et al. 2019), lack of preventive care in the community, lack of dental insurance, and a paucity of providers willing to accept public insurance (Lin et al. 2012). Public health strategies addressing oral health in children have to consider these underlying SDoH and will need community support to improve oral health in childhood and reduce inequalities in high-risk communities (Watt 2005; Phantumvanit et al. 2018).

Prevention and Management of Oral Diseases and Conditions

Management of Dental Caries

Pediatric oral health has shifted its focus during the past 2 decades to recognize dental caries as a chronic disease process, with cycles of demineralization and remineralization of the tooth structure (Edelstein and Ng 2015; Fontana et al. 2018). This recognition transforms our ability to identify and manage dental caries using a person-centered, risk-based philosophy (Fontana et al. 2018). In addition, researchers have made strides in synthesizing the best evidence for disease prevention and management and making it accessible to providers. For example, the American Dental Association's (ADA) Center for Evidence-Based Dentistry has published a series of guidelines on caries detection, prevention, and management to be used in clinical practice and to help identify knowledge gaps that will focus future research (Fontana et al. 2018; Slayton et al. 2018).

Policy efforts aimed at improving young children's oral health have included introduction of the concept of the dental home (an ongoing relationship with a dentist) and the first dental visit at 1 year of age; expansion of the state Children's Health Insurance Program (CHIP), which increased access to dental care for an additional 4 million low-income children; and the use of such interventions as fluoride varnish applications in medical offices, along with physician reimbursements for this service for Medicaid-insured children (Dye et al. 2017). These initiatives during the past 20 years most likely have contributed substantially to the significant reduction observed in untreated dental caries in children, particularly preschool children. Various U.S. Department of Health and Human Services agencies and state health departments have undertaken a number of other activities that have helped guide, initiate, and support policies and programs that have benefited children's oral health (Crall and Vujicic 2020). These activities, as well as expansion of Federally Qualified Health Centers (FQHCs) that include dental clinics (see Section 4), have improved access to care for low-income children, which has resulted in the receipt of more dental services, including treatment for dental caries. Overall, these initiatives contributed to the prevalent view that both dental restoration in children and untreated decay have dramatically increased.

Important advances have been made to promote interprofessional collaboration to prevent ECC. A child who follows AAP's schedule of recommended preventive health care would see a pediatric health care provider 15 times by their fourth birthday (American Academy of Pediatrics 2020). However fewer than 10% of toddlers typically have had a dental visit by age 2 (Bouchery 2013), which has accelerated efforts focusing on encouraging primary care providers to provide preventive dental care. Some studies show that early visits with medical providers result in lower rates of dental decay (Braun et al. 2017) and caries-related treatments (Pahel et al. 2011). Early preventive oral health visits in the medical home also have been shown to reduce health care costs (Stearns et al. 2012). Providing oral health care very early in childhood, with a strong focus on prevention, assessment of a child's risk, surveillance to evaluate disease progression, and appropriate preventive and nonrestorative treatment for carious lesions, along with restorative treatment when indicated, is important in altering the caries disease process (Slayton 2015).

Policymakers and payers are promoting innovative quality-improvement approaches to reduce the incidence of caries. Local efforts that rely on the active engagement of families, risk assessment, reliable delivery of evidence-based care, and care coordination between medical and dental practices are emerging as community models for reducing incidence of dental disease (Ng et al. 2014; Crall et al. 2016). Risk-based protocols are being studied (Rechmann et al. 2018), and payers are beginning to experiment with risk-based benefit plans and value-based health plans (Martin et al. 2018). Because most individuals are unaware of these nontraditional alternatives to typical dental insurance plans, ADA has developed educational materials to encourage patient acceptance (Mark 2018). A typical health insurance plan is a contractual relationship among health providers, patients, and payers using a fee-for-service (FFS) payment model that focuses more on volume-driven health care services than value-based payment models, which focus more on quality, outcomes, and cost containment using health provider incentives to help inform the direction of care. Value-based care has been proposed to replace FFS, but implementation of successful models that reimburse providers for health outcomes rather than the amount of service units per patient or even the quality of those units remains challenging. Obstacles to a value-based care system may include provider indebtedness and financial commitments, lack of data, inadequate vertical data management systems, lack of educational emphasis, provider resistance, and payers' reluctance to pilot extensive change. See Sections 1 and 4 for more information on value-based care.

Another important change in the past 20 years has been greater acceptance of minimally invasive techniques to manage tooth decay in young children. Procedures employing these techniques typically avoid the use of rotary dental instruments (drilling) and anesthesia (injections) to provide an interim restoration that is durable and controls the caries process. They range from atraumatic restorative treatment using glass ionomer filling materials to more traditional dental filling materials (such as composite resins and amalgam) to seal in the tooth decay under preformed stainless-steel crowns (the Hall technique). These dental caries management approaches provide several advantages over traditional restorative treatment options and are used globally in a variety of settings. Although evidence varies with regard to the success of these noninvasive alternate management techniques of tooth decay in young children, their effectiveness clearly depends upon the progression and severity of the tooth decay (Tedesco et al. 2018). Nevertheless, these noninvasive techniques challenge conventional approaches in the management of dental caries and provide alternatives to treat tooth decay in children safely and more efficiently.

Increasing the number of children who have no tooth decay also requires reducing risk for the disease, and this requires an accurate risk assessment. Unfortunately, challenges remain in implementing well-validated caries risk assessments. The strong performance of risk assessment models for preschool children appears to weaken as they grow older and progress into adolescence (Mejàre et al. 2014). An ongoing challenge in using risk assessment models in older children is a lack of data on how the risk-based approach impacts caries and patient-related outcomes (Fontana et al. 2020). Dental caries is a multifactorial disease, which means there are many elements to consider in creating a comprehensive caries risk assessment, including health history, biology, and behavior. Therefore, experts have concluded that the science of caries risk assessment would benefit from a better understanding of microbiological end points, salivary chemistry, and genomics (Dental Quality Alliance 2018a; Halasa-Rappel et al. 2019). In addition, evidence supports a strong association between dental caries burden in children and sociodemographic and community characteristics, such as income and race/ethnicity. However, algorithmic models are better at determining oral health outcomes at the population level, compared to the individual level (Gao et al. 2013; Divaris 2016; Halasa-Rappel et al. 2019). This disparity in model performance presents a challenge in translating population risk into individual risk; one that affects clinical decision making of oral health care providers and their patients.

Perinatal oral health and infant oral health care are important in preventing onset or progression of tooth decay in young children. Some infant oral care models, which focus on an approach tailored according to individual patient risk, have been promoted to prevent and manage ECC (Ramos-Gomez et al. 2012). Uncertainty remains concerning the use of some of these approaches, however—particularly with regard to the notion of risk modification. A panel of experts has identified 15 factors important in the assessment of caries risk, several of which are common to many assessment tools currently in use (Table 1). This panel has noted that the interactions among individual factors in modifying a patient's risk remain largely understudied, and thus patients are being assigned much too subjectively into their risk-level group (Dental Quality Alliance 2018b). This subjectivity may challenge efforts focused on patient-centered care approaches for preventing and managing dental caries in children and should be addressed in future efforts. Although evidence linking caries risk to improved oral health is limited, it is important to educate patients and manage modifiable risk factors using the best available evidence (Fontana 2015; Dental Quality Alliance 2018b).

Fluoride Agents for Dental Caries Prevention and Management

During the past 2 decades, the range of dentifrices available to consumers has dramatically changed. Today, several manufacturers offering toothpaste and other oral care products promote them as natural options to conventional oral care products. However, most of these natural products contain no fluoride, the critical anticavity ingredient of any product that is effective against caries (Walsh et al. 2019). Unfortunately, many parents assume that "natural" toothpaste also promotes good oral health. Improving the labeling of oral hygiene products for home use would give parents helpful information to make better-informed decisions. For example, toothpaste without fluoride could be labeled as "not proven to prevent cavities." In addition, the labels for fluoride toothpaste could be updated with evidence-based information on proper dosage and safety for young children (Casamassimo et al. 2014). Nearly 2 in 5 children aged 3 to 6 years used more toothpaste than is recommended by the Centers for Disease Control and Prevention, and nearly 4 in 5 children aged 3 to 15 years started brushing later than recommended (Thornton-Evans et al. 2019). Among children aged 3 to 6 years, only about half used the age-appropriate, pea-sized amount of fluoride toothpaste (Thornton-Evans et al. 2019). Children ingesting more than the recommended amounts of fluoride are vulnerable to mild fluorosis later in childhood (Wright et al. 2014).

Since the early 2000s, more evidence has emerged to support the benefits from the application of fluoride varnish to prevent early-childhood caries (Weintraub et al. 2006). Subsequent to these studies, the U.S. Preventive Services (USPS) Task Force has found sufficient evidence for the benefits of early application of fluoride varnish to primary teeth by non-dental providers. In 2014, the USPS Task Force made a recommendation grade of "B" to support medical providers' application of fluoride varnish to primary teeth (Moyer 2014). This recommendation is important because young children typically have multiple medical visits compared to dental visits. Consequently, pediatric and family health providers who care for young children often have the opportunity to provide preventive oral health services, including fluoride varnish applications. For example, children attending a community health center who had received at least four

Table 1. Factors to consider when assessing risk for new dental caries in children
Protective Factors
Brushes 2 times daily with fluoride toothpaste
Drinks predominantly fluoridated water
Receives professionally applied fluoride
Uses over-the-counter fluoride mouth rinse (over age 6)
Uses at-home prescription fluoride products (over age 6)
Disease Indicators
Current active initial lesion(s) (enamel lesions)
Current active moderate or advanced lesion(s)
Risk Factors
Consumes more than 3 sugar-sweetened beverages or snacks between meals each day
Has physical or behavioral health issues that impede home care
Clinically, has dry mouth or little saliva due to medical condition or medication
Recent caries experience (since last assessment, or in last 3 years)
Parents or siblings had cavitated lesions in the last year
Has visible plaque
Has uncoalesced and unsealed pits and fissures
Has orthodontic or prosthodontic appliances that impede oral hygiene

Source: American Dental Association. Guidance on Caries Risk Assessment in Children. Dental Quality Alliance.

fluoride varnish applications by 3 years of age had a 20% lower prevalence of tooth decay than those who had not received fluoride varnish applications (Braun et al. 2017). In North Carolina, children who received at least four fluoride varnish applications in the medical setting had fewer caries-related treatments than children who received fewer treatments (Pahel et al. 2011).

Not only have fluoride varnish products evolved during the past 20 years, but their use has changed with a shift in the field of restorative dentistry to a more conservative, noninvasive approach to caries. As a preventive agent, 5% sodium fluoride varnish has been shown to be effective in reducing caries in children of all ages (Weyant et al. 2013). In 2018, ADA convened a panel of experts to develop evidence-based guidelines for nonrestorative treatment options for carious lesions. The panel's report included recommendations on the use of fluoride varnish and other nonrestorative treatments to arrest and reverse noncavitated and cavitated lesions (Slayton et al. 2018).

Fluoride varnish is recommended for the treatment of noncavitated carious lesions either as a single agent or as part of the course of treatment combined with resin infiltration or sealant placement, depending on the lesion's location. The recommended treatment option for cavitated carious lesions is 38% silver diamine fluoride, which is discussed further in Chapter 5.

However, some current findings are challenging the notion that fluoride varnish is effective in preventing tooth decay in preschool children's primary teeth (de Sousa et al. 2019). Although debate continues on which fluoride varnish application protocols are most effective, it is clear that more than one application is necessary to prevent caries in children at mild to moderate caries risk (Lenzi et al. 2016). Variations in products and mode of use is a concern and may explain some of the variation in studies, as well as the underlying experience of the populations in which these products are used. Nevertheless, the challenge is getting fluoride varnish applied to the teeth of high-risk children whose parents' insurance benefits do not provide coverage or who have persistent problems accessing dental care despite qualifying for Medicaid.

Dental Sealants for Caries Prevention and Management

In the past 20 years, the prevalence of children aged 6 to 8 years with at least one permanent molar sealed has more than doubled, from 14% to 31% (Figure 30). The largest gains, among Mexican American children and children living in poverty (an estimated fivefold increase), have nearly eliminated this health disparity among these groups (Figures 31 and 32). Similarly, the prevalence of dental sealants among children aged 9 to 11 years has increased from 29% to 53%, with large gains observed among low-income children and Mexican American children. This also represents a significant reduction in disparities for this health measure during the past 20 years.

Although dental sealants have been used for decades to seal healthy occlusal surfaces to prevent dental caries, guidelines published during the past 20 years now support their additional use for application to posterior chewing surfaces, including those with noncavitated dental caries, in children and adolescents to stop tooth decay in its earliest stages (Wright et al. 2016). These ADA and American Academy of Pediatric Dentistry (AAPD) recommendations also advocate sealing primary molars in high-risk populations. During the past decade, other techniques have been introduced to seal off tooth decay. Resin infiltration permeates a small noncavitated carious lesion with dental material to prevent the tooth decay from further damaging the tooth (Faghihian et al. 2019). For larger carious lesions in which portions of the tooth enamel have been destroyed, permitting caries to progress into dentin, the Hall crown technique is sometimes used on posterior primary teeth. This minimally invasive intervention seals decay under a stainless steel crown using a self-curing glass ionomer cement, arresting the decay and achieving better long-term outcomes, compared with standard fillings (Innes et al. 2011; Ludwig et al. 2014).

Prevention and Management of Orofacial Pain

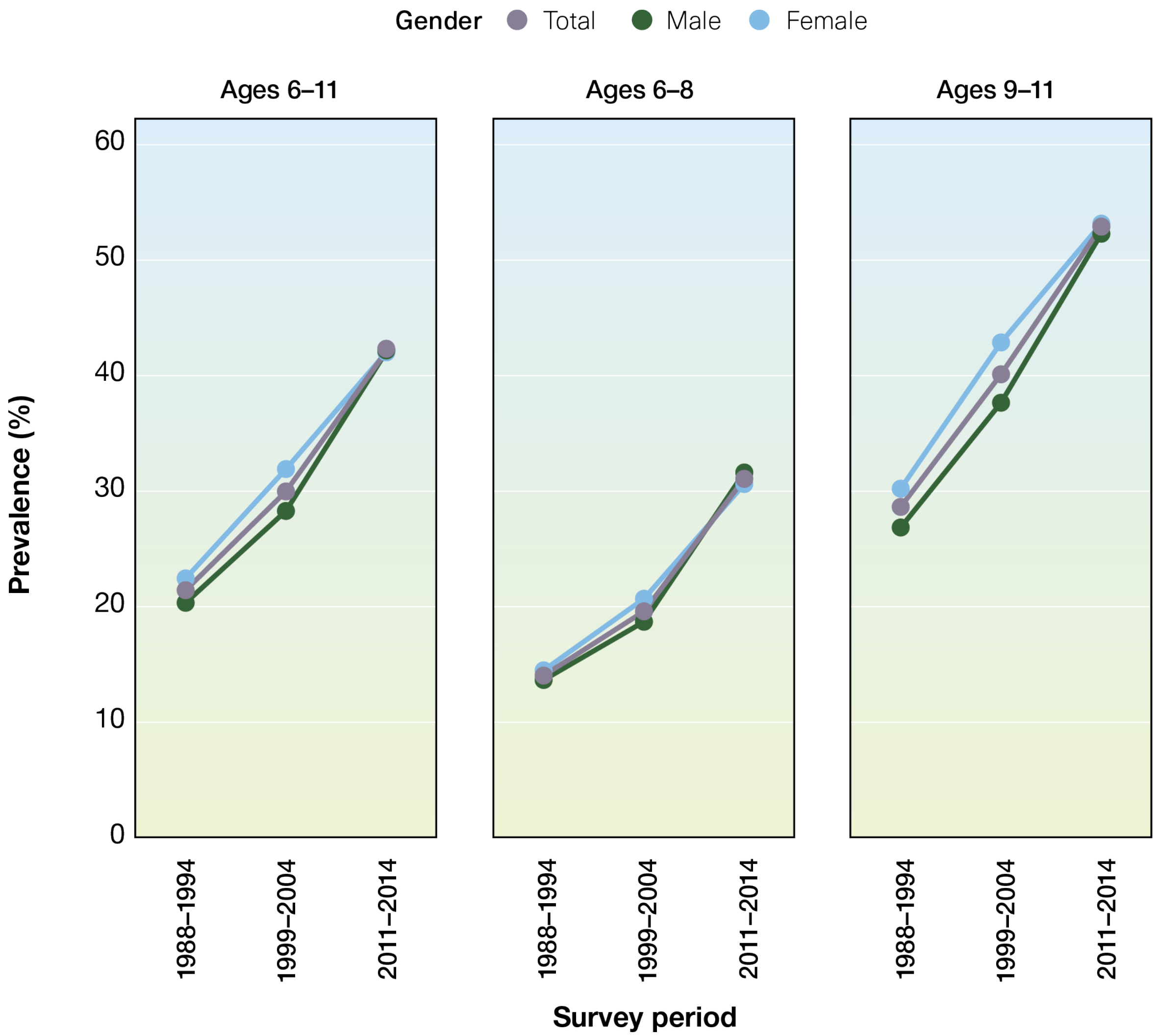
During the past 20 years, considerable knowledge has been gained regarding some areas of pediatric pain, leading to its recognition as a fifth vital sign. Much of this progress is related to the validation of pain assessment tools. Seminal papers, such as those by Finley and McGrath (1998) and O'Rourke (2004), outlined the use of scales such as the Face, Legs, Activity, Cry, Consolability pain scale. Garra and colleagues (2010) validated the Wong-Baker FACES® pain rating scale (Wong-Baker FACES Foundation 2016) in emergency departments. In 2008, a government-industry collaborative established the Pediatric Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (Ped-IMMPACT) to identify core domains, assessments, and rigor for publications addressing pain in the pediatric population (McGrath et al. 2008). Cohen and colleagues (2008) noted that, despite its comprehensive scope, Ped-IMMPACT lacked substantial information on pain intensity, distress behaviors, and caregiver behaviors for all ages of childhood.

Provider organizations, such as AAP, AAPD, and ADA, have developed evidence-based guidelines on the use of pain medications in children (American Academy of Pediatric Dentistry 2020h). These guidelines focus on patient safety and make the critical connection lacking in Ped-IMMPACT, namely, linking behavior, pain, and procedural outcomes. This has resulted in the increased use of sedation in pediatric dentistry, including the use of general anesthesia, to provide definitive care for those children who cannot tolerate dental procedures in a typical dental office setting.

Prevention and Management of Dental Erosion

Our understanding of the prevention and management of dental erosion and tooth wear in children remains incomplete, with little change in the past 20 years. In general, there is a need to identify techniques that prevent dental erosion. There also has been a lack of knowledge about dental erosion among parents and caregivers in the United States, especially with regard to the potential irreversible loss of tooth structure from consuming acidic beverages, foods, and candies. This has been compounded by a lack of reimbursement for nutritional counseling to help children and their parents understand the potential for dental erosion from foods and beverages as well as erosion that results from acid reflux. There is a need for a more precise understanding of the role of exposure to dietary acid, gastric acid, and chlorine in children's dental erosion, as well as the potential synergistic interaction with bruxism (teeth grinding). Another impediment is the

Figure 30. Percentage of children ages 6–11 with dental sealants on permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of dental sealants is having at least one permanent molar tooth sealed.

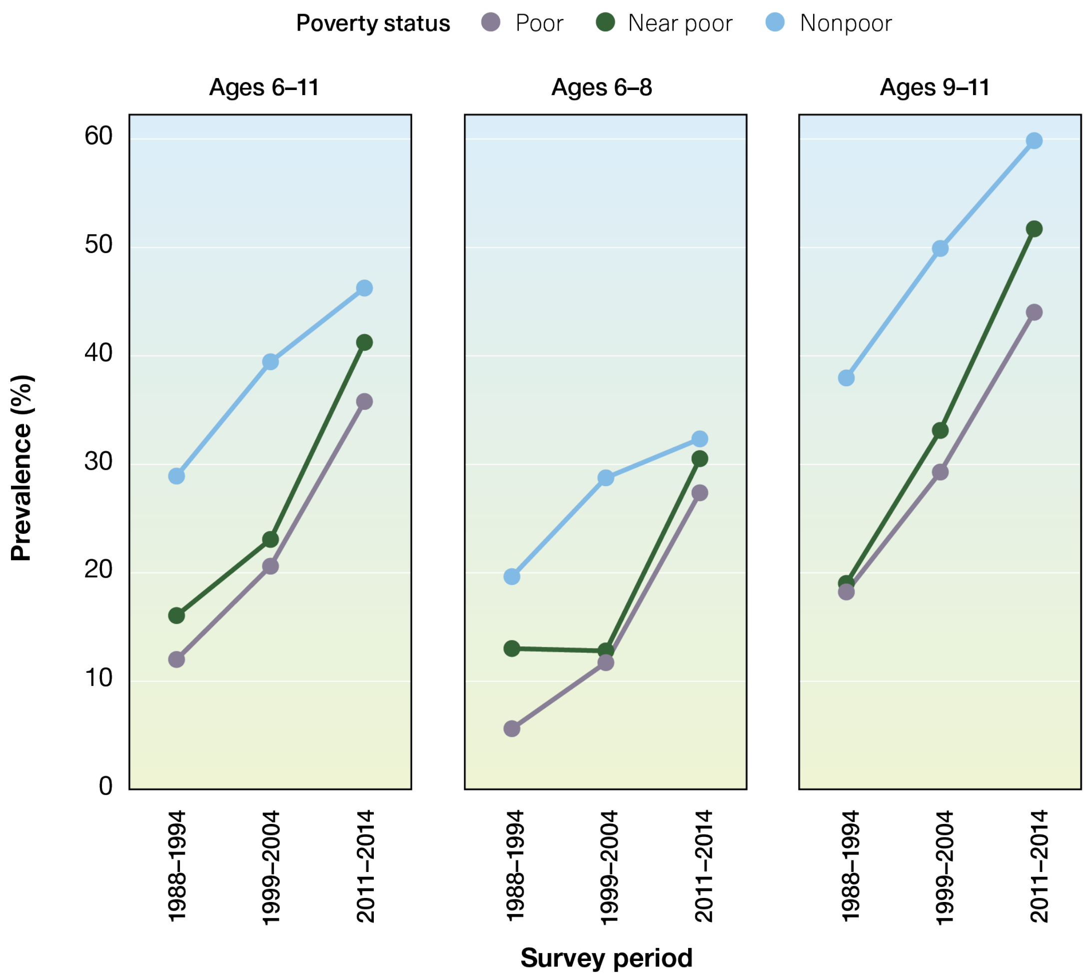
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

cumbersome nature of communication between dentists and physicians when gastroesophageal reflux disease is suspected in youth with severe dental erosion. Other challenges include a lack of contemporaneous epidemiologic information in the United States on dental erosion and tooth wear to help identify population groups at risk and lack of a validated scale to track progression of dental erosion and tooth wear over time in clinical practice.

Pharmacologic Management of Children by Oral Health Professionals

Important changes affecting the pharmacologic treatment of children have occurred in recent years. Drug utilization is an integral part of the risk-benefit evaluation of therapies for children (Chai et al. 2012). In the past decade, recognition has been growing among oral health providers of the potential drawbacks to antibiotic overuse and opioid use. National trends show total prescriptions

Figure 31. Percentage of children ages 6–11 with dental sealants on permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental sealants is having at least one permanent molar tooth sealed. **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

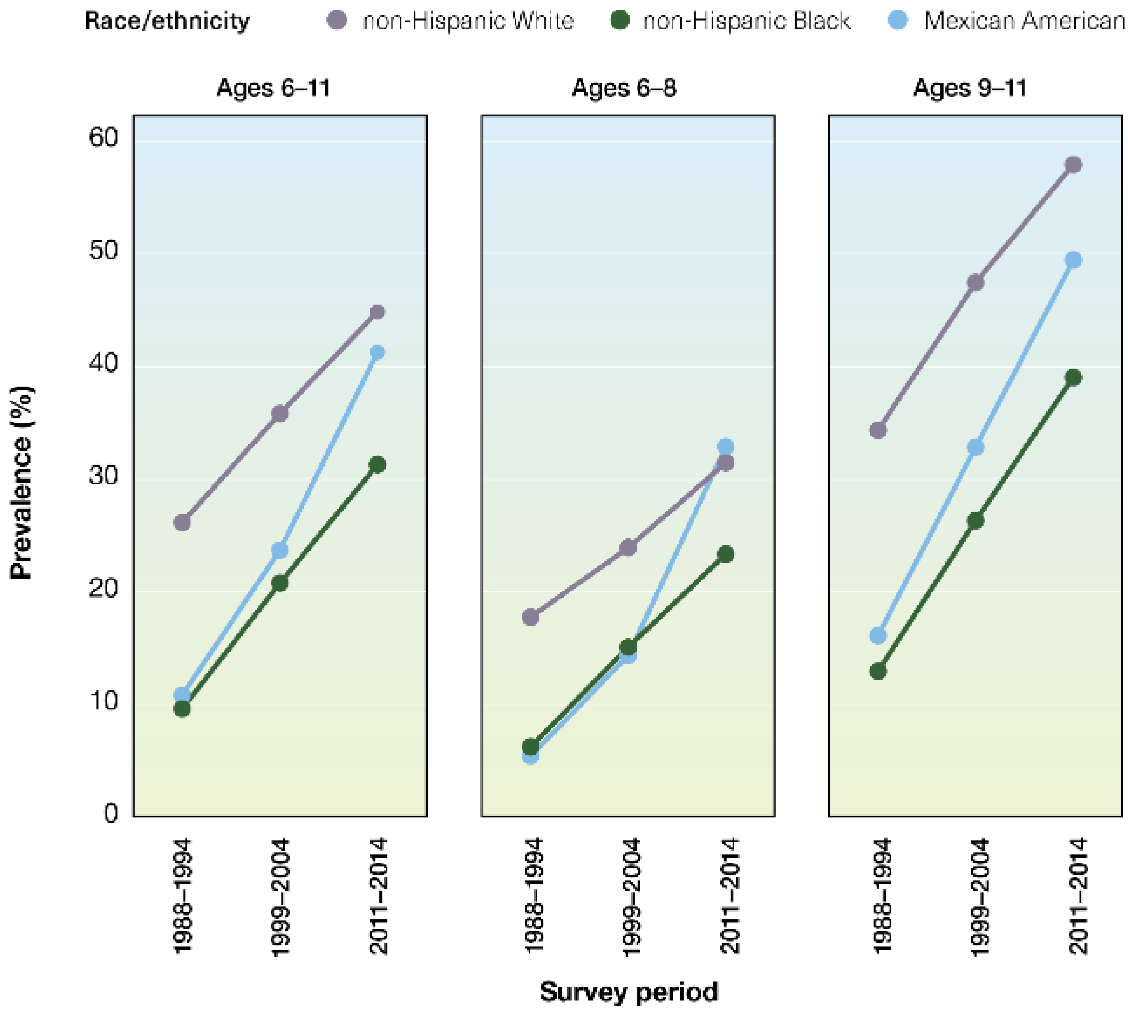
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

by dental providers decreased by 22% from 2009 through 2018, with 1.8 to 2.3 million prescriptions dispensed each year by U.S. retail pharmacies for children aged 1 to 10 years. (Analyses of these trends do not include medications administered or dispensed in other settings, such as oral surgery clinics and dental offices.)

Among patients 1 to 10 years, antibiotics were the drug class dental providers most commonly prescribed, followed by fluoride supplements and opioid analgesics (Figure 33). An estimated 64,000 prescriptions for opioid analgesics were dispensed to this age group in 2018, a 75% decrease from 261,000 prescriptions in 2009.

Before 2018, codeine/acetaminophen accounted for a large proportion of use in pediatric patients aged 1 to 10 years. However, in 2013, the FDA mandated the addition of a box warning and contraindication regarding the risk of respiratory depression and death with codeine use after tonsillectomy and/or adenoidectomy. In 2017, a contraindication was added to the labeling for codeine use alerting that codeine should not be used for the treatment of pain or cough in children younger than 12 years.

Figure 32. Percentage of children ages 6–11 with dental sealants on permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014

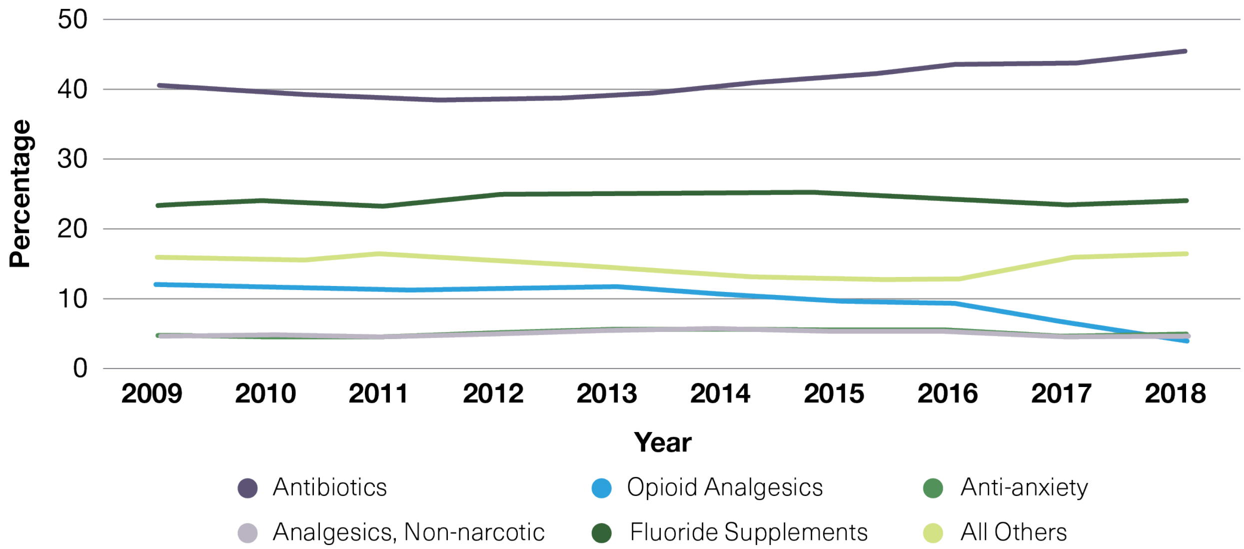


Note: Prevalence of dental sealants is having at least one permanent molar tooth sealed.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994, 1999–2004, and 2011–2014.

In 2018, FDA also required safety labeling changes for prescription cough and cold medicines containing codeine to limit the use of these products to adults aged 18 years and older. Dispensed prescriptions for codeine/acetaminophen written by dental providers for pediatric patients subsequently decreased substantially (U.S. Food and Drug Administration 2013; 2017; 2018).

Between 1999-2002 and 2011-2014, antibiotic use in children and adolescents decreased by almost half, predominantly in amoxicillin-containing antibiotics and cephalosporins (Hales et al. 2018). In the past 10 years, as prescriptions for antibiotics decreased for children and adolescents, the proportional distribution between children and adolescents has remained the same (Symphony Health PHAST™ Prescription Monthly Database Data extracted May 2019) (Figure 34). The distribution of retail prescriptions for fluoride supplements has shifted between 2009 and 2018; it decreased for children aged 1 to 10 and increased for adolescents aged 11 to 20 years. In 2009, about 60% of prescriptions for fluoride supplements were for children 10 years of age and younger.

Figure 33. Ten-year proportion trend of retail prescriptions dispensed by drug class to pediatric patients ages 1–10 years prescribed by dental providers: United States, 2009–2018



Source: Symphony Health PHAST Prescription Monthly. 2009–2018; extracted May 2019. Reprinted with permission.

By 2018, fluoride prescriptions were more evenly divided between those 1 to 10 years of age (45%) and those 11 to 20 years of age (55%) (Figure 35). This shift may reflect changes in clinical practice and caries management that focus on early prevention efforts.

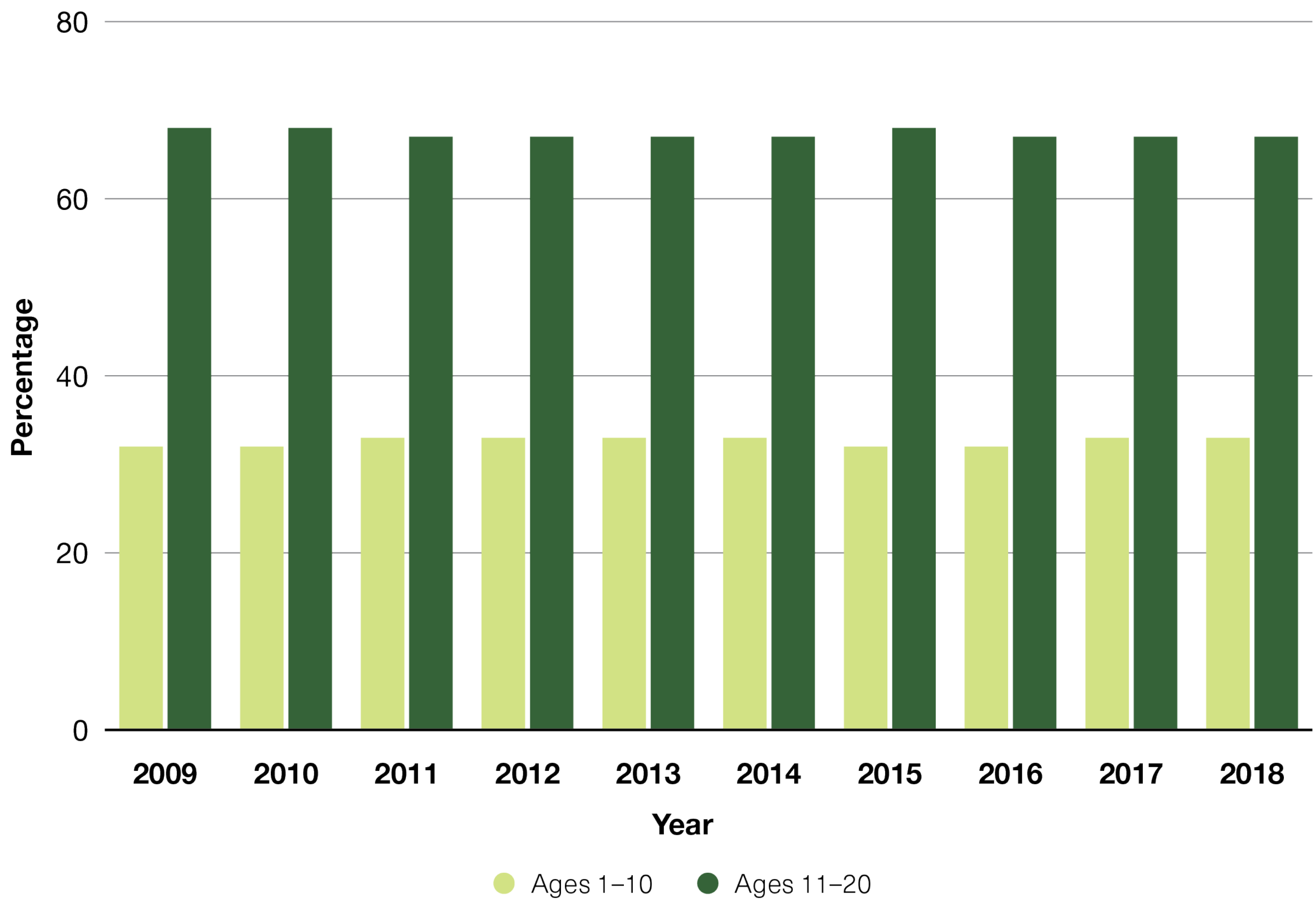
Children with Disabilities and Special Health Care Needs

Progress in dental care during the past 20 years for children with disabilities and SHCNs has hinged on a better understanding of the causes of their disabilities and the social and health care challenges these children experience. Advances in medical care have allowed children with serious disabilities and medical conditions to survive far longer than in decades past. Children with previously fatal conditions, such as sickle cell anemia, cancer, and epidermolysis bullosa, are living far longer, and their need for oral health care will increasingly challenge the dental community in the coming years (da Fonseca 2004; da Fonseca et al. 2007; Kramer et al. 2012). Recent scientific advances have pinpointed or better described the causes of disabilities, leading to cures or improved outcomes. Outreach and social service programs have identified and addressed previously unappreciated needs of children with SHCNs, such as quality of life and family stresses related to caregiving. As a result, the social, educational, care, and rehabilitative systems that serve children with special needs have responded in more effective ways, especially by integrating oral care into already existing health care delivery programs.

As of April 2019, there were more than 6,000 conditions with a known molecular basis involving more than 4,000 different genes (Johns Hopkins University 2020). Advances in understanding the unique molecular mechanisms that cause specific conditions affecting the craniofacial complex have led to novel therapies that ameliorate or even correct them (Whyte et al. 2003). Although many birth defects still have unknown causes, especially in the case of conditions involving both genetic and environmental factors, advances in knowledge of the human genome and translation of this knowledge into new therapies are expected to progress even further during the next 10 to 20 years (Baum 2014).

Changes in societal behaviors, such as diet and physical activity, have added leisure-related illness to the disorders of childhood, including obesity, early-onset diabetes, and childhood hypertension, rarely present in children and adolescents a generation ago (Hoge et al. 2008; Ferraz et al. 2012).

Figure 34. Ten-year proportion trend of retail prescriptions for antibiotics by age group dispensed to patients ages 1–20 years prescribed by dental providers: United States, 2009–2018

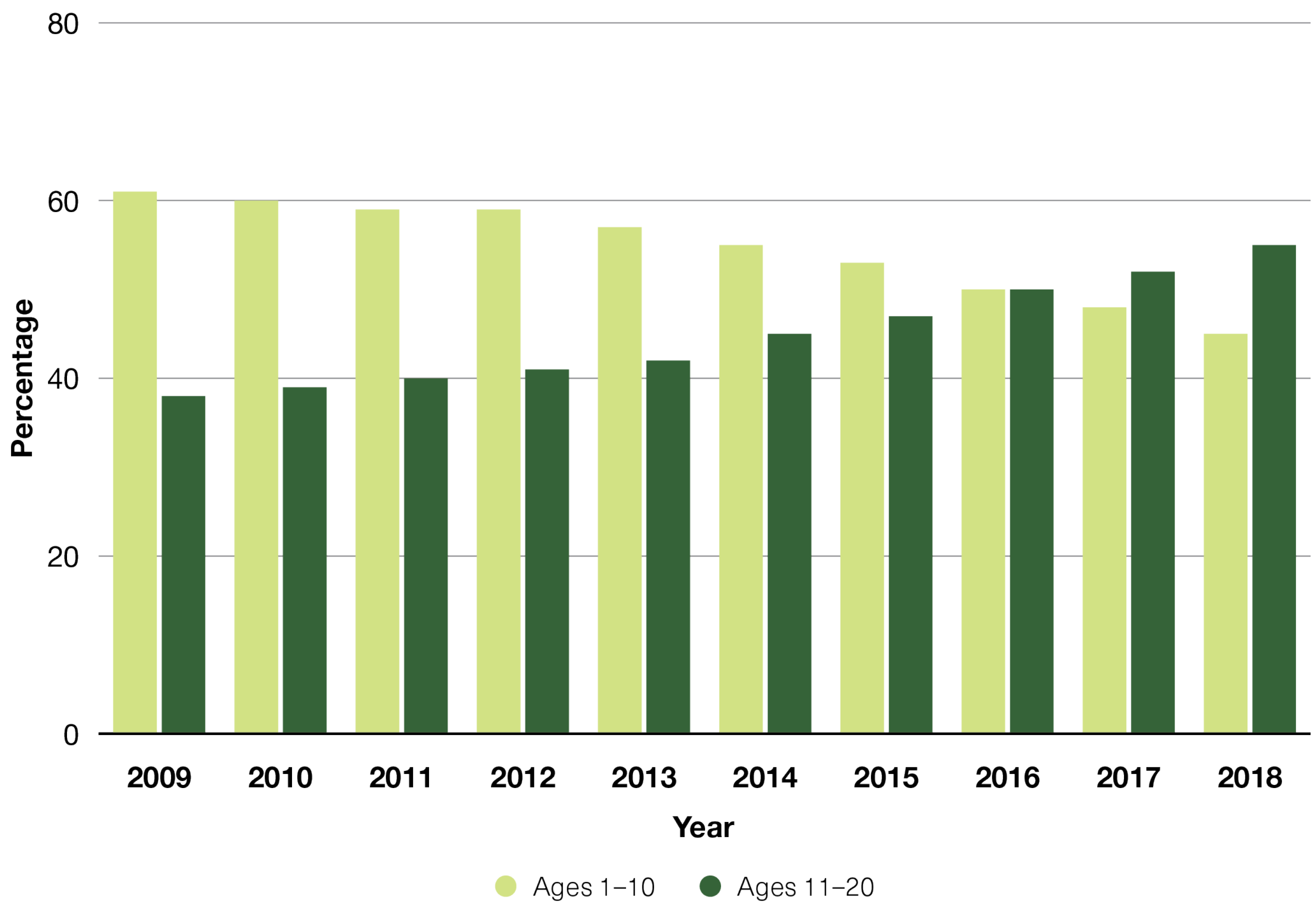


Source: Symphony Health PHAST Prescription Monthly. 2009–2018; extracted May 2019. Reprinted with permission.

The implications of these conditions and their health consequences are only now becoming known (Novotna et al. 2015). Other challenges remain because many dental professionals do not receive training on how to provide optimal care for children with conditions such as autism spectrum disorder in the dental office or how to meld community programming with oral health care delivery (Delli et al. 2013). Children with SHCN often have difficulty accessing the oral health care system because they need medical management during dental care. For example, children with bleeding disorders and severe forms of rare diseases, such as epidermolysis bullosa or osteogenesis imperfecta, may require treatment in a hospital setting by clinicians with the requisite experience and expertise. Long-term oral health care for individuals with complex craniofacial involvement can easily cost tens to hundreds of thousands of dollars, and many patients are forced to travel long distances to receive such specialized and complex care. The U.S. health care system does not provide resources to manage all affected children and resources for disabled adults are even scarcer (Okumura et al. 2013). Despite treatment cost challenges, access for many individuals with SHCNs has improved during the past 20 years. For example, states have included certain disabilities in special payment programs that recognize the additional burden that SCHNs place on families.

Another persistent challenge is that not enough dentists feel confident in their ability to treat children with disabilities and SHCNs, especially those with chronic medical conditions and behavioral difficulties.

Figure 35. Ten-year proportion trend of retail prescriptions for fluoride supplements by age group dispensed to patients ages 1–20 years prescribed by dental providers: United States, 2009–2018



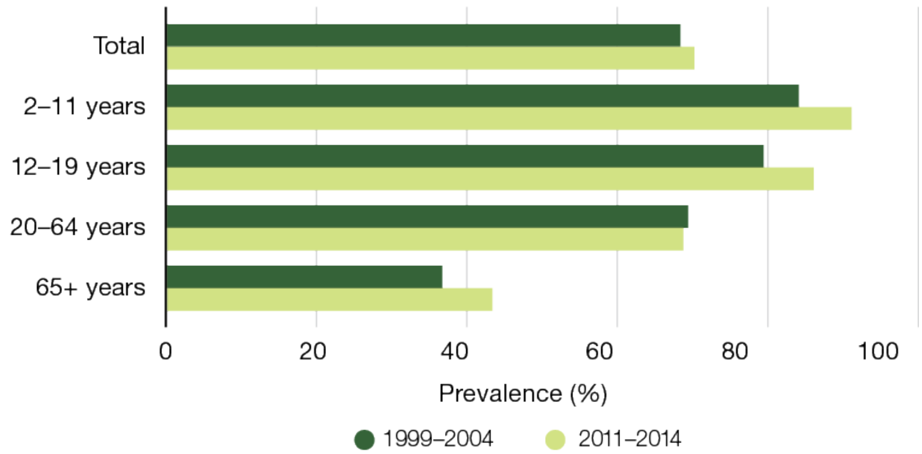
Source: Symphony Health PHAST Prescription Monthly. 2009–2018; extracted May 2019. Reprinted with permission.

Dental education has been slow to embrace children with disabilities within a system that remains oriented toward a nondisabled population. Traditional treatment-focused care in which dental caries is managed surgically and requires intensive resources can now be seen as an impediment to getting children the oral health care they need and can tolerate (Edelstein and Ng 2015). The introduction of newer technologies like silver diamine fluoride (discussed in Chapter 3) to control disease and postpone treatment, as well as strategies for using other oral health professionals to free up time for dentists to care for more complex patients, could help meet the dental needs of children with SHCNs (Friedman and Mathu-Muju 2014; Crystal et al. 2017). Finally, there is great need to advance research on oral health issues specific to children with SHCNs and, as a result, bring much-needed improvements to their oral health and care.

Dental Insurance Coverage and Utilization of Dental Services

Several positive changes impacting the delivery of pediatric oral health services since 2000 have revolved around expanded payment for dental care, increasing the number of pediatric dental residencies, acting upon early intervention, and delivering preventive dental services using a variety of health providers. But the most important advancement since the publication of the last report on oral health is 9 out of 10 children now have dental insurance coverage in the United States, representing the age group with the highest coverage (Figure 36).

Figure 36. Percentage of the population with any dental insurance coverage by age group: United States, 1999–2004 and 2011–2014



Source: Agency for Healthcare Research and Quality, Medical Expenditure Panel Survey (MEPS), Agency for Healthcare Research and Quality, public use data, 1999–2004 and 2011–2014.

The United States realized dramatic improvements in dental coverage and payment for children and adolescents between 2000 and 2015 (Manski and Rohde 2017). During this 15-year period, the percentage of persons younger than 21 years of age with no private or public dental coverage decreased dramatically, from 28% to 12%. As a result, this age group's use of dental services increased from 42% to 48%. Publicly-insured children showed far greater increases in utilization than privately-insured or uninsured children. Among children with Medicaid and CHIP coverage, use of dental services nearly doubled, from 28% to 50% (Centers for Medicare & Medicaid Services 2020; Medicaid and CHIP Payment and Access Commission 2020), whereas use by privately-insured children remained relatively stable. The gap in utilization between publicly- and privately-insured children closed most rapidly before 2011, then stabilized at about 16% through 2016 (American Dental Association 2018).

Expanding dental benefits coverage during the past 2 decades has led to more children utilizing dental care. Using the metric of at least one annual dental visit, the percentage of children with private dental insurance, from 2006 to 2016, increased from 58% to 67%. The percentage of children with Medicaid or CHIP, in comparison with the previous statistic, increased from 35% to 50%, narrowing the gap in dental utilization between privately and publicly-insured children from a difference of 23% to only 17% in that period (American Dental Association 2018). Several states have made important improvements in dental care use during the past decade, and in a couple of states (Hawaii and Texas), children with Medicaid or CHIP have a higher dental care use rate than privately-insured children (American Dental Association 2018).

As dental care among children and adolescents increased between 2000 and 2015, total spending increased by 4% after adjusting for inflation (from $25.7 billion to $26.7 billion in 2015 dollars), and dental care for children and adolescents became increasingly affordable. Annual inflation-adjusted dental expenditures per child and adolescent decreased by 12% (by $86, from $722 to $636), and average out-of-pocket costs declined by 36% (by $83, from $312 to $229). For private insurance, inflation-adjusted dental expenditures per child and adolescent decreased by 15% (by $50, from $339 to $289), whereas costs to public insurance doubled, from $52 to $105. Because Medicaid prohibits, and CHIP limits, cost sharing, parents of Medicaid- and CHIP-insured children incurred little or no out-of-pocket expenses for covered dental services (Manski and Rohde 2017).

Regardless of coverage, children's dental care requires oral health professionals who are comfortable with and competent in treating children. Between 2001 and 2019, the number of active dentists in the United States increased by 22% (American Dental Association 2020), although their distribution continued to skew toward urban and suburban areas. Most dental care provided to children is delivered by general dentists and pediatric dentists, whose numbers increased by 21% and 61%, respectively (American Dental Association 2020). Among pediatric dentists, the proportion of care provided to publicly-insured children increased between 1998 and 2009, from 11.5% to 18.1% (American Dental Association 2010). This percentage continues to increase, reflecting the larger proportion of children, as compared to adults, covered by public insurance.

Demographic shifts among dentists also have had an impact on the availability of dental care for children. Between 2001 and 2019, the proportion of women and dentists younger than 35 years of age increased (American Dental Association 2020). Both groups see more children than male and older dentists. African American, Hispanic/Latino, Native American, and other racial and ethnic minority dentists, although still significantly underrepresented in dentistry, provide disproportionate amounts of care to minority and underserved communities (Mertz et al. 2016).

Dentists also are increasingly practicing in groups, which see about 50% more children than solo practitioners (American Dental Association 2020). The advent of Medicaid-only dental management companies also has contributed to increasing numbers of children accessing dental care. An estimated 1 in 5 children with public insurance obtains care in privately-owned practices of this type (Children's Dental Health Project 2012). Taken together, these practitioner workforce trends have steadily and significantly expanded dental care for children, especially publicly-insured children. Between 2001 and 2017, the percentage of children covered by Medicaid or CHIP who had a dental visit in a given year nearly doubled (from 26.6% to 50.4%), whereas 67.1% of privately-insured children had a visit in 2016 (American Dental Association 2018). Dental hygienists also have an important role in providing care to publicly-insured patients, using preventive oral health services and referring children to a dental home. Dental practice acts governing dental hygienists' scope of practice differ by state, but in 42 states patients can directly access care from a hygienist.

Since 2000, the number of pediatric dental residency training programs has been increasing as existing and newly established programs have become eligible to receive dedicated funding from the Health Resources and Services Administration under Title VII, under the Health Professions Education Partnerships Act of 1998 (American Academy of Pediatric Dentistry 2020i). This Act has provided start-up funds either to increase pediatric dentistry positions in existing training programs or to initiate new programs of this type. More than 60 programs, including 10 new programs, have received an estimated $90 million in the past 2 decades. Support for these training programs has been important because two-thirds of the pediatric patients treated are Medicaid recipients and the majority of the programs' trainees graduate to later provide care for underserved populations. For example, more than 2 out of 3 pediatric dentists treat children enrolled in Medicaid, CHIP, or both, which represent on average 25% of their patients (American Academy of Pediatric Dentistry 2017).

About half of all U.S. children still do not utilize dental care on a regular basis, and an increasing number find care in safety net clinics, rather than private dental practices. These safety net clinics now provide emergency and regular oral health care for millions of socially vulnerable children and generally serve all who seek care, regardless of insurance status or ability to pay.

Nearly 1,400 FQHCs deliver care at more than 13,000 locations in urban, suburban, and rural communities across the country. More than one-fourth (27.5%) of all patients seen at FQHCs in 2020 were younger than 18 years of age, representing about 1 in 9 U.S. children. Of these, 73.6% were Medicaid or CHIP beneficiaries (Health Resources and Services Administration 2021). Although all FQHCs are required to provide preventive dental services, broadly defined to include basic restorative care, not all offer dental services at their sites (Crall et al. 2016). Reflecting this gap, about 2 million of the 7.9 million children seen at FQHC facilities received a fluoride treatment in 2020 (Health Resources and Services Administration 2021).

As part of the ongoing consolidation in dental care, dental management organizations (DMOs) or dental service organizations with sufficient scale and cost efficiency are increasingly serving safety net populations (Langelier et al. 2017). A 2017 survey of 47 DMOs found that about 61% of affiliated dentists reported that their patient loads comprised about half Medicaid or CHIP beneficiaries, whereas nearly 44% of affiliated dentists provided dental services exclusively or almost exclusively for Medicaid and CHIP beneficiaries (Langelier et al. 2017). In other words, corporate owned and operated practices have become a substantial contributor to the dental safety net. A 2012 investigation found that dental management companies served about one-fifth of all publicly-insured children, approximately the same proportion of children served by pediatric dentists (Children's Dental Health Project 2012).

Because many of the children receiving care at FQHCs or other safety net clinics are at high risk for tooth decay, underutilization of preventive services may challenge efforts at reducing dental caries experience among lower-income children and may perpetuate oral health inequities. Equally important, access to dental care also challenges many publicly insured children, especially in rural settings where there are fewer pediatric dentists and dental service organizations and fewer general dentists participating in Medicaid or other publicly supported, reduced fee models. A few areas are exploring or implementing interprofessional health care and emerging workforce models that include primary care medical providers, dental hygienists, and dental therapists, as well as teledentistry. However, when children living in rural areas need extensive restorative dental care, challenges will persist.

Oral Health Quality of Life

During the past 20 years, oral health-related quality of life (OHRQoL) measures for children have emerged, with particular focus on dental caries and the impact on children of severe tooth decay and oral pain. Validated assessment tools have demonstrated that among all oral health problems, ECC exerts one of the greatest negative effects on OHRQoL (Kramer et al. 2013), surpassing traumatic dental injuries and malocclusion. The association between ECC and OHRQoL is consistent across multiple measures of socioeconomic status, underscoring ECC's potential to undermine the well-being of children in all social groups (Chaffee et al. 2017). Moreover, studies have consistently shown that ECC has diverse negative effects on children, from physical symptoms and function to psychological aspects, self-image, and family and social interactions (Kramer et al. 2013). Recent knowledge about the impact of ECC and oral pain on young children has helped to inform professional policy guidelines and health services planning for the improvement of children's oral health.

Other advances related to our understanding of OHRQoL have shown that severe tooth decay and its rehabilitation have a significant impact on children of all ages. Kumar and colleagues (2014) found in a systematic review that maternal age, family structure, household crowding, and presence of siblings were significant predictors of children's OHRQoL. Children from families with higher incomes, higher levels of parental education, and smaller family size had better OHRQoL.

Several assessment tools to assess children's OHRQoL have been developed during the past 20 years. Table 2 provides an overview of the instruments developed to assess children's OHRQoL directly. All of these instruments ask children to provide answers on either 5-point (Jokovic et al. 2002; Jokovic et al. 2004; Jokovic et al. 2006; Broder and Wilson-Genderson 2007; Broder et al. 2012) or 4-point (Gherunpong et al. 2004; Huntington et al. 2011) rating scales, a task often considered too challenging for children younger than 8 years of age. Consequently, researchers have developed the Scale of Oral Health Outcomes for 5-year-old children, using a 3-point answer scale about the impact of oral health issues on seven different activities (Tsakos et al. 2012).

Quality of life measures primarily remain tools for research and have limited application as health outcomes or treatment quality indicators in pediatric dental care. Measurement of improved quality of life after surgery, for example, offers a patient-reported outcome of care (American Academy of Pediatric Dentistry 2020j) that can be used to assess quality of care. Although many scales focus on children assessing their own OHRQoL, it is important to note that assessment scales for parents and caregivers can also play a role in improving quality. Research shows that these proxy scales offer a second reliable and valid way to measure children's OHRQoL (Inglehart et al. 2007; Barbosa and Gaviao 2008).

OHRQoL assessments provide greater understanding of the consequences of dental caries, and their use should be encouraged for use in prioritizing need for care.

Table 2. Overview of child oral health-related quality of life measures

Measure	Year First Published	No. of Items	Short Form Available?	Age Range	Any Positive Items?	Use to Date
Child as informant						
CPQ	2002[a]	37	Yes (8 items and 16 items)	8–14[b]	No	Considerable
Child Oral Impacts on Daily Performances	2004[c]	8	No	11–12	No	Moderate
COHIP	2007[d]	34	Yes (19)	7–16	Yes	Moderate
Pediatric Oral Health-Related Quality of Life	2011[e]	10	No	< 16	No	Low
Scale of Oral Health Outcomes	2012[f]	5	Not needed	5	No	Moderate
Proxy as Informant						
Parent-CPQ Items	2003[g]	33	Yes (8 and 16 items)	< 8	No	Considerable
ECOHIS	2007[h]	9	Not needed	< 8	No	Considerable
COHIP-Preschool	2017[i]	9	No	< 2–6	Yes	Low

Notes:
a) Jokovic et al. (2002).
b) Foster Page et al. (2013).
c) Gherunpong et al. (2004).
d) Broder et al. (2007).
e) Huntington et al. (2011).
f) Tsakos et al. (2012).
g) Jokovic et al. (2003).
h) Pahel et al. (2007).
i) Ruff et al. (2017).

CPQ = Child Perceptions Questionnaire; **COHIP** = Child Oral Health Impact Profile; **ECOHIS** = Early Childhood Oral Health Impact Scale.
Source: American Dental Association, 2018.

Such assessments can provide a useful adjunct measure of oral health gain in the management of dental caries beyond clinical parameters (Tinanoff et al. 2019). Their refinement in the coming years will make these assessments even more useful in improving the well-being of children with SHCNs. The current challenge is to identify the benefits of assessing children's OHRQoL in research and clinical practice.

Provision of Pediatric Oral Health Care in Alternative Settings

Early Childhood Oral Health Programs

Following the release of the 2000 Surgeon General's report on oral health, communities were encouraged to focus efforts on oral disease prevention and health promotion practices for families with young children (U.S. Department of Health and Human Services 2003). Many communities rose to the challenge, resulting in numerous programs across the United States to address oral health problems in children. Many of the programs are affiliated with public health, social service, or nutrition programs already in place, such as Head Start; the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC); and other Maternal and Child Health programs.

Studies show that these programs have focused on oral health education, preventive services, and expanding the workforce to address oral health in early childhood (Rubin et al. 2018). Educational programs work with caregivers and address family-level health behaviors to prevent ECC. They target predominantly urban, low-income populations with approaches grounded in behavioral theory, caries risk assessment, and public health principles (Wysen et al. 2004), and some have incorporated pharmacologic treatments, such as fluoride varnish or silver diamine fluoride. A key component of these community-based and public programs is care coordination for families using multiple professionals, predominantly dental hygienists and dentists, as well as community health workers, including Head Start and WIC staff (Whittle et al. 2008; Brickhouse et al. 2013; Quinonez et al. 2014; Glatt et al. 2016; Ng and Fida 2016).

Head Start programs help parents obtain oral examinations and follow-up care for their children and support their understanding of the benefits of prevention and proper oral health care, along with the importance of establishing a dental home early in life (Head Start Bureau 2016). In the past 2 decades, Head Start programs have been encouraged to promote good dental hygiene in the classroom. During this period, the Administration for Children and Families enacted a national policy that requires once-daily, supervised toothbrushing for all children older than 2 years of age enrolled in Head Start programs (Office of Head Start 2006). Because children served by Head Start also are at increased risk for ECC, the policy ensures that this high-risk population is exposed to fluoride toothpaste at least 5 days per week.

School-Based Oral Health Programs and School-Based Health Centers

For some families, issues of cost, geography, and time create barriers that limit access to oral health care. One way progress has been made to address this is through school-based oral health programs, which are expanding to fill the gap by providing onsite oral examinations, cleanings, and treatment. The emerging field of teledentistry and the virtual dental home model also are exciting options for delivering much-needed preventive and early intervention services in schools (Glassman et al. 2012), and the increased reliance on teledentistry during the coronavirus (COVID-19) pandemic should yield important information on the benefits and limitations of this service.

There are several different mechanisms for providing dental services in schools. After Bassett Healthcare Network (an integrated health care system serving an eight-county region in rural upstate New York) identified oral health care as an unmet need for students, it prioritized adding this service to its 20 school-based health centers. Beginning in 2000, an elementary school nurse conducted oral health screenings and referred students at high risk for oral disease to an oral health professional in the community. By 2007, a dental hygienist and oral health coordinator were conducting oral health screenings in three additional schools. A full-time dentist now provides treatment to students in three centers with dental operatories. In addition, a team of dental hygienists travels to 20 school-based health centers to provide oral health education, screenings, and preventive services and to identify students requiring treatment. In addition, a nurse care coordinator helps families obtain care from the dentist affiliated with the school-based centers or another oral health professional in the community (Bassett Healthcare Network 2020).

Another example is Future Smiles, a nonprofit organization established by a registered dental hygienist in 2009, which offers oral health education, oral screenings, preventive care, care coordination, and treatment at little or no cost to more than 60,000 students at high risk for oral disease in Clark County, Nevada, schools (Chandler 2017). The organization's mobile dental sealant program and Education and Prevention of Oral Disease high school site offer a range of preventive services as well as care coordination, connecting students with community-based dentists who provide free or reduced-cost restorative dental procedures.

Failure to anticipate challenges in establishing and operating school-based oral health programs can result in underutilization or closure of programs that provide valuable care to underserved children. Among the challenges frequently faced by proponents of school oral health programs are the following:

- Some states' scope-of-practice laws require either an onsite dentist or a dentist's prior examination and diagnosis before allowing a dental hygienist or other qualified oral health professional to provide services. In addition, some state Medicaid programs provide no reimbursement for preventive services delivered in school settings, and some state laws prohibit dental hygienists from billing Medicaid for services

provided in school settings. See Section 4 for more detailed information on scope of practice laws.
- Getting consent forms signed and returned to school can be difficult. Having the active support of a school's administration, health services team, teachers, and support staff is critical to facilitating the process.
- Ensuring treatment for students with urgent oral health needs is also critical. A case management protocol needs to be in place to serve students with urgent needs.

A more recent challenge affecting school-based oral health programs is the COVID-19 pandemic. Because these school-based programs are an essential access point for children to receive preventive oral health services, long-term disruption of these programs because of school closures may result in higher levels of dental caries for children dependent on these services for preventive care. This may disproportionately affect children from lower income and racial/minority groups (Tiwari et al. 2021). Conversely, the efforts made to connect stay-at-home students with schools, may contribute to teledentistry development and increased utilization in the future.

Interprofessional Care

Important progress has been made in interprofessional pediatric care among organizations, in practice, and in educational programs in recent years. FQHCs have grown in number. Increased funding for dental services and the opportunity for interaction between dental and medical providers within facilities because of proximity and shared electronic health records will lead to advances in collaborative care (Chang et al. 2019). Professional organizations such as AAPD and AAP have partnered on guidelines, such as those for sedation, and maintain ongoing liaisons (Coté and Wilson 2019). Pediatric medical and nursing curricula have added oral health (Hein et al. 2011), and correspondingly, dental and dental hygiene education have increased non-dental health content. As a result, there is a growing opportunity to evaluate the effects and benefits of interprofessional care on children's health.

However, concerns about limitations in dental knowledge and ability remain common among physicians and non-dental professionals who participate in interprofessional care. With appropriate training, however, these non-dental providers can identify dental caries risk and dental disease in children and make appropriate referrals for dental treatment (Bader et al. 2004; Bernstein et al. 2016). Children who receive referrals from primary care providers are more likely to have a dental visit (Bader et al. 2004; Bernstein et al. 2017). Interprofessional care has the potential to deliver coordinated care, especially to youth with complex health needs. Although ineffective communication and minimal collaboration continue to contribute to fragmented patient care that can lead to poor patient outcomes, efforts at improving collaboration and communication are increasing within interprofessional education across the health disciplines (Lapkin et al. 2013; Harnagea et al. 2017; Walker et al. 2018).

Chapter 3: Promising New Directions

Despite challenges, children's oral health is advancing in ways that promise better care, increased access to care, and enhanced oral health-related quality of life. Greater acceptance of noninvasive treatment for early carious lesions, increased collaboration between dentists and other health providers, new scientific discoveries related to causes of craniofacial defects, the potential for gene therapies, and the use of emerging technologies to improve parent oral health literacy offer opportunities for improving children's oral health. A growing field of research that seeks to expand our understanding of how social and behavioral factors affect children's oral health also holds promise for developing interventions to realize further improvements in this age group.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

In the past decade, progress has accelerated in the biological and molecular understanding of processes underlying dental caries. Moreover, whole-genome investigations of dental caries may further expand our understanding (Morelli et al. 2020). Specific risk loci for childhood and adult dental caries have been reported, although the evidence on this front is still developing (Shaffer et al. 2011; Haworth et al. 2018; Shungin et al. 2019). The genetic influence on caries is reportedly more prominent in children than in adults, perhaps because of mitigating biological and other factors later in life (Shaffer et al. 2011; Ballantine et al. 2018). Molecular studies of the caries-associated oral microbiome (Dewhirst et al. 2010; Tanner et al. 2011; Nyvad et al. 2013; Richards et al. 2017), its biogeography (Mark Welch et al. 2016), and its metabolome (Zandona et al. 2015) have generated additional scientific insights. Taken together, in the future, these scientific advances may lead to better preventive, diagnostic, risk assessment, and therapeutic applications, with better oral health for all children (Casamassimo et al. 2014).

Craniofacial Anomalies

Specific genetic factors cause some craniofacial anomalies, but the causes of others remain unknown. Early genetic screening of parents allows them to prepare for children who may require surgical and behavioral interventions early in life (Hart and Hart 2009; Yoon et al. 2016). Identifying and avoiding known teratogens (agents that cause birth defects) during pregnancy and avoiding trauma, preventable disease, and radiation all can reduce hereditary and acquired craniofacial problems.

The continued discovery of genetic, epigenetic, and environmental contributors to craniofacial development, as well as research on stem cells and tissue regeneration, will drive new procedures for prevention and therapy. Fetal surgery may offer some solutions for significant anomalies. Gene therapy may one day create minimally invasive or nonsurgical ways to correct craniofacial anomalies, greatly improving quality of life for patients who now face multiple, costly, and intensive procedures. Although protocols for care exist for several conditions, future care will require more detailed analysis and individualized planning by a multidisciplinary team focused on clear treatment goals, quality of life, and overall well-being.

High-Risk Behaviors

Efforts at the health policy level to support healthy oral health behaviors, such as the removal of soda and the limitation of sugar-sweetened beverages (SSBs) through the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) programs as well as the limitation of SSBs in early childhood education and schools are expected to help families improve oral health and reduce the possibility of acquiring such chronic diseases as diabetes, hypertension, or obesity. Oral health professionals are beginning to play a role in policy actions in this area. Additional guidance from the community in the form of community-based research participation will help ensure the development of culturally appropriate interventions that are more likely to be accepted and to prove both effective and sustainable (Butani et al. 2008).

The near-universal adoption of mobile phone use in the United States offers new ways of contacting populations that traditionally have been difficult to reach with oral health information. Text messaging programs are proving effective in changing behaviors in wide areas, such as smoking cessation (Whittaker et al. 2019), medication adherence, diabetes care (Saffari et al. 2014), and weight management (Stockwell et al. 2012; Finitsis et al. 2014). These programs also show promise for altering oral health behaviors (Borrelli et al. 2019). Four studies have investigated the use of text messaging in pediatric oral health, but they involved small samples and short-term outcomes (Sharma et al. 2011; Hashemian et al. 2015; Makvandi et al. 2015; Borrelli et al. 2019). In one, a well-controlled randomized trial used parent-targeted text messages with gamification to improve low-income children's oral health (Borrelli and Henshaw 2019). A larger study is underway to test the effects of oral health text messages on objective measures of caries (Borrelli et al. 2019).

Social Determinants of Health

There has been a recent shift toward a person-centered care model, in which health care providers not only treat patients but also consider their social and life circumstances and the impact of these circumstances on their oral health (Tiwari and Palatta 2019). Past studies of social determinants of health (SDoH) in pediatric oral health have predominantly focused on individual health and risk factors (Hooley et al. 2012); however, population-level assessments should also be part of these studies to enable them to better inform oral health policies and programs. Community-level interventions can be local, such as those within health systems, or broad, such as state policy. In the clinical realm, the number of health providers asking about SDoH and assisting with referrals has expanded impressively in the past decade. There also is the medical-legal partnership approach (Murphy et al.

2015), which connects patients with lawyers to address legal concerns that affect health, such as inappropriate housing conditions (Ryan et al. 2012; Murphy et al. 2015). Health Leads, a Boston program, uses trained volunteers to help families address challenges with SDoH; preliminary data show modest improvements in some, but not all, systemic health outcomes, and the effects on oral health conditions have yet to be evaluated (Berkowitz et al. 2017).

Several programs have shown health systems can successfully develop and implement programs that address health inequity aspects of SDoH. For example, Hennepin Health in Minnesota, an accountable care organization, restructured its care delivery to incorporate the physical, behavioral, social, and economic dimensions of care, achieving the dual goals of increased patient outcomes and saving money (Sandberg et al. 2014). Creative approaches, such as supplementing family income, have demonstrated a mostly positive impact on health outcomes (Akee et al. 2010; Costello et al. 2010). Culturally and linguistically appropriate care also are important.

The exploration of resilience suggests another promising area that deserves research. This involves both intrinsic factors, for example, an individual's self-efficacy, and external support, such as parents, other supportive adults, and schools. Although the relationship between resilience and oral health has not yet been studied, it is possible that it may lead to better understanding of the relationship between adverse childhood experiences and oral health outcomes. So far, there is little study of these kinds of programs' impact on pediatric oral health, which could be remedied and accelerated with research funding.

Prevention and Management of Oral Diseases and Conditions

Dental Sealants

Removing practitioner-based barriers as to who can apply dental sealants to children's teeth can enhance utilization and improve access to this valuable preventive treatment. Some states already have amended their practice acts to allow dental hygienists to provide sealants under the general supervision of a dentist, and other states are considering similar actions to allow hygienists to apply sealants through public health programs. Additional actions that could accelerate the adoption of these policies include funding the expansion of school-based programs that target at-risk children, eliminating legal barriers that use age and tooth restrictions to bar reimbursement, increasing Medicaid reimbursement rates, and providing reimbursement incentives for dentists to participate in public insurance programs.

Silver Diamine Fluoride

In recent years a product containing 38% silver diamine fluoride (SDF) has become commercially available to providers in the United States. SDF was used in other countries (including Australia and China) to arrest dental caries for many years (Li 1984; Gotjamanos 1996) before its introduction into the United States in 2014. SDF has gained increasing acceptance as evidence emerges for its efficacy in arresting progression of cavitated lesions in children and adolescents (Slayton et al. 2018). Although staining of treated cavities is an issue, SDF's noninvasive nature and cost-effectiveness make it an important option for children, including those with special health care needs and those who face barriers to accessing dental care (Crystal et al. 2017; Johhnson et al. 2019; American Academy of Pediatric Dentistry 2020k).

The silver in the SDF compound is a short-term antimicrobial agent that inhibits proteolytic enzymes in dentin. Because of that antimicrobial action combined with fluoride's remineralization properties, SDF shows great promise for managing cavitated lesions (Duangthip et al. 2018). However, use for this purpose is off label according to the U.S. Food and Drug Administration regulations, and general dentists have been slower than pediatric dentists to begin using it. The uses of SDF continue to expand. At publication, limited studies suggest that beyond its caries-arresting benefit, SDF also may act to prevent new caries (Sorkhdini et al. 2020), offering an additional benefit to patients at high risk or already afflicted with caries. Through teledentistry, SDF is being used as a therapy provided by expanded-duty dental personnel to reach previously underserved populations and those for whom traditional care is not an option because of health concerns, distance, and isolation requirements (Cripe 2020).

As SDF use increases, opportunities for prevention and modified treatment using combinations of SDF and traditional restorative care will continue to emerge.

More insurance plans can also be expected to cover SDF as its use expands, which may encourage broader training of oral health professionals in its use.

Organizational Change to Improve Oral Health

The most effective way to reduce the burden of early childhood caries (ECC) is through primary prevention, that is, actions taken before the first clinical signs of disease appear. Across the health professions, engagement with parents (Pitts et al. 2019; Tinanoff et al. 2019) is needed in promoting healthy eating, including avoiding sugar before 2 years of age and restricting sugar intake during childhood and adolescence. Parents also are positive targets for public health messages about adopting healthy behaviors and the need for social and policy changes, such as reducing sugar availability at school, ensuring the accurate labeling of products, and increasing the cost of SSBs.

There are a number of promising new directions in the prevention of caries. For example, the integration of pediatric oral health promotion into general health promotion is showing promise in reducing tooth decay. The delivery of preventive oral health services, such as fluoride varnish, during well-child visits in medical offices is proving cost-effective in reducing dental caries among preschool-age children in North Carolina (Mathu-Muju et al. 2008; Stearns et al. 2012; Achembong et al. 2014; Kranz et al. 2014; Kranz et al. 2015). Well-child visits allow families to access preventive oral health services in general and to receive referrals to dentists for their young children (dela Cruz et al. 2004). Pediatric primary health care providers also are offering oral health promotion and disease prevention services, thereby eliminating or delaying dental disease and the need for treatment at a very young age.

Organized efforts to improve communication and collaboration between medical and oral health professionals are already underway. For example, all 50 states now allow physicians to apply fluoride varnish to children's teeth, and in some states properly trained physician assistants, nurse practitioners, nurses, and medical assistants also can apply it (Moyer 2014). The American Academy of Pediatrics has developed its own Oral Health Risk Assessment Tool (American Academy of Pediatrics 2011) for non-dental personnel to use during patient encounters.

Engaging caregivers and emphasizing the importance of early childhood dental visits are strategies that reflect new thinking about promoting oral health in children. Implementing activities that aim to improve oral health literacy in families is a key element in raising awareness and improving children's oral health. For example, Maryland's Office of Oral Health, part of that state's Department of Health, developed an effective campaign in 2012 to take these messages to low-income mothers of at-risk children from birth to 6 years old (Box 1). This campaign was based on an extensive series of statewide surveys of health practitioners and caregivers and involved partnerships with several foundations and other government entities, activities that were catalyzed by the death in 2007 of 12 year-old Deamonte Driver from an infection that began as a simple dental abscess (Horowitz and Kleinman 2012; Horowitz et al. 2013).

Dental Insurance Coverage and Utilization of Dental Services

New payment approaches that reward quality and outcomes hold promise for increasing the efficiency of dental coverage, improving children's oral health, and reducing disparities. Established provider payment approaches in dentistry, such as fee for service, capitation, and salary, are insufficiently linked to performance, as measured by health processes or outcomes (Rubin and Edelstein 2016). New alternative payment methods either expand on these payment approaches to increase accountability and reward performance or establish entirely new approaches that include rewards and penalties for financial risk sharing between payers and providers (Health Care Payment Learning and Action Network 2016). For example, the Oregon Medicaid authority held 16 county-level delivery systems financially accountable for performance measures on dental sealants and dental care for foster children, achieving 12% and 11% increases in sealants after 1 and 2 years, respectively (Oregon Health Authority 2017).

The COVID-19 pandemic may have paved the way for more permanent use of telehealth applications in pediatric oral health care. Because of the now ubiquitous availability of telephone visual technology

Box 1. How does a community use social marketing to improve oral health behaviors?

Almost 15 years ago, the Maryland Department of Health, Office of Oral Health, developed a comprehensive set of reforms in response to statewide oral health surveillance data, the 2000 Surgeon General's Report on Oral Health, and the tragic death of a young child from an untreated dental problem. One of these reforms was a statewide communications campaign designed to improve access to dental care for children in Maryland. The *Healthy Teeth, Healthy Kids* campaign was launched in 2012 and targeted to parents of children from babies to age six who were at risk for dental disease.

Healthy Teeth, Healthy Kids used principles of oral health literacy to improve understanding, and the tenets of social marketing to inspire changes in behavior. The campaign featured radio and television advertisements; direct mailing of 100,000 brochures to families of young children; a kick-off event at the Dr. Samuel D. Harris National Museum of Dentistry; outreach events at health, child care, and education centers; and the distribution of 100,000 oral health kits. Surveys conducted before and after the campaign showed increased awareness of the importance of oral health as part of overall health and the importance of taking children for their first dental visit by age one. The campaign won seven national awards, including Best of Show from the Public Relations Society of America in 2013.

Funding for *Healthy Teeth, Healthy Kids* came from the Centers for Disease Control and Prevention. Major partners included the Maryland Dental Action Coalition and the University of Maryland School of Public Health. Additional support was provided by the CareQuest Institute for Oral Health (formerly the DentaQuest Foundation), Dental Trade Alliance Foundation, Henry Schein, and United Health Care.

across socioeconomic strata, teledentistry has grown in importance as an alternative to some types of in-person visits and holds promise for connecting children with oral health needs to providers (Glassman 2020). Similarly, the lack of opportunities for general anesthesia care during the pandemic may have enabled the further adoption of nonsurgical management of dental caries techniques for children, resulting also in a lower cost alternative to traditional treatment (American Academy of Pediatric Dentistry 2020k).

Provision of Pediatric Oral Health Care in Alternative Settings

Early Childhood Oral Health Programs

Efforts to translate research findings into reduced rates of ECC and improved oral health are moving more interventions from dental offices to community-based settings, such as schools, where it is possible to reach many more people at high risk for oral diseases. These promising moves require partnerships among health care providers, health care settings, and nontraditional organizations, such as Head Start and WIC Centers, public housing authorities, public school systems, and food pantries. Community-based interventions of this type have potential as more cost-effective strategies to reduce ECC and eliminate oral health disparities, and thus warrant further exploration (Garcia et al. 2015).

The emerging development of pediatric oral health registries has the potential to provide valuable quality improvement information to promote patient-provider engagement and shared decision making. Such registries also generate actionable data to use in improving quality of care and outcomes at the individual and population levels (Rozier et al. 2003; Ng et al. 2014; Kakudate et al. 2015; Ramos-Gomez et al. 2017; Fisher-Owens and Mertz 2018; Ruff et al. 2018). Collectively, there has been a lack of reporting on the various pediatric oral health programs. Such reporting could identify best practices and create collaborations to benefit children and families most affected by oral health disparities. Pediatric oral health programs are now found in early childhood programs, medical and dental care integration programs, and foundations and nonprofit organizations, as well as in advocacy and policy organizations, ECC collaboratives, and resource centers.

An example of the integration of digital health into dentistry is the MySmileBuddy Program led by Columbia University, which brings preventive oral health intervention to urban families through technology. This program used an electronic tablet (Apple iPad) to assist community health workers to interact with poor, minority, low-literacy parents of young children to evaluate a child's risk for ECCs and to provide information promoting oral health (Levine et al. 2012; Lumsden et al. 2019).

Other promising strategies for optimizing oral health care delivery for young children include early establishment of a dental home, risk-based approaches, and integration of dental and medical care (Hale 2003; Crall 2005; Ramos-Gomez et al. 2010; Mouradian et al. 2014). There is evidence that Federally Qualified Health Centers and primary medical care practices improve access to, and quality of, oral health care for children (Bernstein et al. 2016; Crall et al. 2016; Atchison et al. 2018). But some barriers to achieving successful medical-dental practice integration remain, including a need to enhance dental facilities, including adding appropriately trained personnel and advanced information technology to support care coordination and integrated health records. In addition, practice management and technical assistance are needed to support staff (Close et al. 2010), and ongoing training is needed for providers and their staff in key clinical areas such as caries risk assessment, risk-based approaches to prevention and disease management, and family-centered care for diverse populations. This area of pediatric care is constantly evolving, and the future looks promising as new practices emerge that will improve children's oral health.

Interprofessional quality improvement learning collaboratives have been shown to improve the practices of medical and dental personnel and clinic administrators (Rozier et al. 2003; Ng et al. 2014; Quinonez et al. 2014; Braun and Cusick 2016; Braun et al. 2017). Other innovations that can further oral health integration are smartphone applications that help community health workers provide caries risk assessment, engagement, and referral in ways acceptable to the communities they serve (Chinn et al. 2013).

Interprofessional Care

Most low-income children regularly receive medical care. Ninety percent of children younger than 6 years received well-child visits in 2017 (Child Trends Databank 2018), which provide opportunities to deliver oral health services. Several implementation studies and related work have provided a roadmap for strengthening interprofessional care for children. For example, an initiative supported by the Health Resources and Services Administration, the Integration of Oral Health and Primary Care Practice, provides a framework for the successful integration of oral health with primary care through five domains of clinical activities and competencies (Maxey 2014): risk assessment, oral health evaluation, prevention intervention, communication and education, and interprofessional collaborative practice.

Interprofessional care in primary care offices, pediatric medical offices, hospitals, and community-based settings, such as Head Start, now address children's medical, dental, and other needs in the settings where they are most likely to access care. Two keys to further success will be further development of an integrated electronic health record and expansion of telehealth beyond the few states that currently allow it to include the provision of dental services. The expansion also would include the participation of third-party payers.

Safety net clinics have become models for interprofessional care and increased access to oral health care (Bernstein et al. 2017). Combining medical and dental care in the same setting makes resources more readily available to address language barriers, including translators to discuss oral health care. Practically speaking, combining medical and dental care in safety net settings also limits the hardship that multiple appointments place on parents. Even though co-location of medical and dental services is a promising new direction, it does not guarantee coordinated care or promotion of preventive services (Horowitz et al. 2014), and these models will require careful implementation to achieve full benefits.

Chapter 4: Summary

There are both challenges and opportunities with regard to improving children's oral health. During the past 20 years, the most significant advancement affecting oral health in children has been the dramatic decline in untreated dental caries. Although earlier disparities observed by either family income or race/ethnicity also have decreased during this period, socioeconomic health inequities have persisted. Expansion of dental insurance coverage during the past 2 decades has been an important factor in helping to reduce untreated dental caries in children to historical lows. Congenital craniofacial conditions, including cleft lip and cleft palate, developmental tooth defects, and other craniofacial abnormalities affect fewer children than does caries, but their impact on the lives of children and families is severe. Advances in care management during the last 2 decades have led to some improvements, yet much remains to be done.

Many factors—diet, hygiene, tobacco product use, stress, and trauma—that affect oral health are common risk factors for other chronic conditions affecting individuals through the lifespan. In addition to public health strategies, a collaborative, interdisciplinary, comprehensive management and prevention approach to medical and oral health care and wellness, rather than disease-specific strategies, may ultimately improve the country's oral health. Enlisting non-dental providers, such as social workers and lay health workers, as well as pediatricians, nurses, and the full range of dental providers, in prevention programs for oral health is one way to reach more at-risk families in their communities. Ideally, preventive measures in children start at the time their first tooth erupts. The integration of oral health care within existing programs, such as Early Head Start, Head Start, and the Special Supplemental Nutrition Program for Women, Infants, and Children includes early dental screening and referral mechanisms.

Given the role of personal behaviors in oral health, activities and programs to prevent oral disease must address both children and their caregivers. The public has greater access than ever to health information, but there also is much misinformation. Education and guidance are needed to empower parents to engage in healthy choices and self-care practices that provide children with the greatest health benefits. Finally, policy changes to support risk-based, patient- and family-centered caries management approaches should include incentives for helping children to stay healthy.

Decades of evidence suggests that traditional approaches to caries prevention and control have had limited success in reducing the overall burden of caries experience in children in the United States. Although young children have received considerable attention in research and in care delivery during the past 2 decades, new prevention strategies need to be tested and implemented in order to affect a substantial decline in caries experience similar to the level observed for untreated dental caries in children. Early interventions, including the use of interim therapeutic restorations and other noninvasive caries management strategies, are effective in reducing recurring dental caries, arresting existing lesions, and reducing pain and hospitalizations.

As work continues to control caries incidence and improve its prevention and management, other problems relevant to patients, such as dental erosion and dental pain, must be better addressed. Dental pain is poorly understood and underappreciated. Research efforts should be directed toward better understanding of the effects of dental pain on care-seeking behaviors and development. The scope and awareness of dental erosion remains limited in the United States, requiring new efforts to better understand its impact on teeth in childhood and which effective preventive and therapeutic strategies could be used to effectively address erosive tooth wear.

Policy and practice must advance to address racial and ethnic and income disparities in pediatric oral health and look at systemic biases that may be present, as they are in other parts of the U.S. health care system. A combination of community-based, interprofessional, policy, and financing efforts needs to focus on the most vulnerable populations. Part of this effort must involve better understanding of the social determinants of health, including such factors as family behaviors that will affect oral health over the lifespan. The transition to school age brings more challenges and opportunities for oral health promotion in children, but only a handful of oral health behavior interventions have shown positive effects. More research is needed in this area, particularly with respect to multilevel interventions that target individual, family, and community. In addition, the use of mobile health technology as a "provider extender" could support oral health cost effectively in real time and on a large scale.

Childhood represents a pivotal time for the prevention of caries and other oral diseases and conditions. A few themes have emerged from national surveillance data regarding U.S. children's oral health (Box 2). Overall, progress in reduction of untreated dental caries in children is encouraging, particularly in preschool children who are now receiving more services for the treatment of early childhood caries.

Although dental caries continues to be a problem and remains concentrated in certain groups of children, access to both preventive and restorative oral health services continues to improve. Our understanding of the biological basis of dental caries in children continues to evolve, and over the past 20 years, recognition of the strong influence of social determinants of health, high-risk behaviors, poor oral health literacy, and lack of access has helped formulate new approaches to reduce the prevalence of dental caries. Finally, dentistry is witnessing a positive evolution of care models built on public-private partnerships among traditional private practices, community health centers, and school-based care. These activities have been shown to improve access to dental care, helping children to transition into adolescence with better oral health than the generation before.

Box 2. Key summary messages for Oral Health Across the Lifespan: Children

- In the past 20 years, we have made some progress in reducing dental caries, also called tooth decay, but not all children have benefited equally.
- About half of all American children do not receive regular dental care because of social, economic, and geographic obstacles.
- Integrating dental care within family and pediatric medical care settings is improving children's oral health.
- Nearly 1 in 5 children have special physical or health care needs; providers trained in active prevention and management of these children's oral health problems help to support their overall health and quality of life.
- More effective approaches to preventing and treating dental cavities are emerging from better understanding of the social determinants of health, high-risk behaviors, and caregiver and provider oral health literacy.
- As dental caries becomes better controlled, other conditions should be addressed, such as dental erosion, which is an increasing cause of tooth destruction in youths.

Call to Action:

- Public policies and improved training are needed to reduce oral health inequities by encouraging health providers to focus more on individual and public health approaches to preventing the occurrence of new disease and managing disease earlier.

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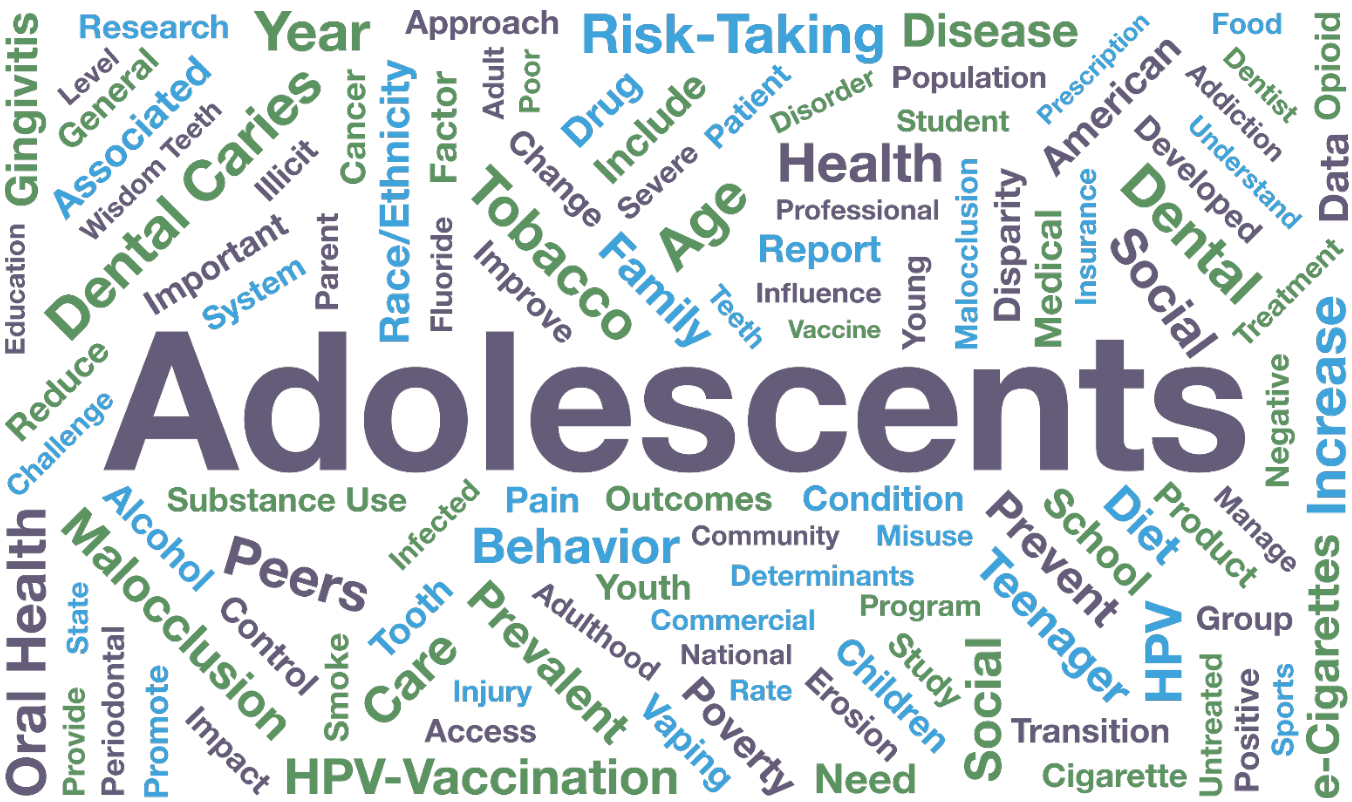
Adolescents
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Cancer
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Drug
Include
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Addiction
Student
Understand
Developed
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Health
Change
Severe
Tobacco
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Insurance
Dental
Social
Treatment
Education
Important
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Improve
Family
Report
Teeth
Influence
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Negative
Reduce
Challenge
Substance Use
Infected
Pain
Outcomes
Condition
Prevent
School
Diet
Product
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Oral Health
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Malocclusion
Peers
Behavior
Community
Misuse
Determinants
Youth
Teenager
HPV
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Tooth
Prevalent
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Social
Promote
Impact
Injury
Rate
Poverty
Erosion
Access
Vaping
Transition
Untreated
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Sports
HPV-Vaccination
Need
Cigarette

Oral Health in America: Advances and Challenges

Section 2B: Oral Health Across the Lifespan: Adolescents

Chapter 1: Current Knowledge, Practice, and Perspectives

Adolescence—the stage of life when youth aged 12 to 17 years mature into young adults—often is overlooked in activities designed to study, evaluate, and improve oral health, with more attention aimed at younger children or adults. Yet, adolescence is an important time of life for adopting new responsibilities and behaviors affecting overall health and well-being. The current status of our understanding of adolescent oral health is similar in some ways to what is known about oral health in childhood. Research has increased knowledge of disease processes and contributed to better preventive and restorative options.

Despite reductions in overall disease prevalence, dental caries among adolescents has remained a concern since the National Health and Nutrition Examination Survey reported national prevalence figures more than 20 years ago. Moreover, disparities in caries development and treatment persist in adolescents from lower income, racial, and ethnic minority populations, who experience more disease. Although federal programs such as Medicaid and the Children's Health Insurance Program were expected to influence these prevalence rates through increased access to care, outcomes have fallen short of the most optimistic projections. Social determinants of health (SDoH), parental behaviors, and peer influence have a powerful impact on adolescent oral health in ways that still are not well understood. Health habits and behaviors are beginning to be established as adolescents move into adulthood. It is a pivotal time in the lifespan, when age-appropriate dental interventions (such as orthodontics), reinforcement of positive oral health habits, and dietary choices can influence oral health far into adulthood.

Biology, Growth, and Development

Adolescents experience dramatic physical and neurologic changes, some of which may directly affect their oral health. Others may lead to behaviors that can affect their teeth and mouths. From playing sports to smoking, these new behaviors can have negative impacts that carry into adulthood.

Adolescence is a period when youth begin to shift from their childhood bodies to their adult bodies. In addition to the emergence of primary and secondary sexual characteristics, pubertal changes in adolescents include a physical growth spurt, altered distribution of fat and muscle, and increased circulatory and respiratory capacity. The average age for first menstruation is 12 years, followed by 2 years of skeletal growth in females. For males, the growth spurt occurs later. In both males and females, jaw and facial growth are tied to puberty. Physical issues affecting personal and social development include obesity, short stature, scoliosis, acne, and chronic conditions that may limit functional or developmental status. Also, adolescence is a time when the population shifts toward obesity—1 in 5 adolescents aged 12 to 19 years are obese (Hales et al. 2017)—and since the 1960s, obesity has tripled in adolescents (Fryar et al. 2018).

Increased physical growth and coordination during adolescence and the desire of some to participate in sports, along with an increased capacity and freedom for risk-taking behavior, raise the likelihood of traumatic orofacial injury. A study from 2015 using data from a large sample of high schools in the United States participating in the National High School Sports-Related Injury Surveillance Study reported that the rate of dental injuries in competition (1.8/100,000 events) was three times higher than the rate in practice (0.6/100,000 events)

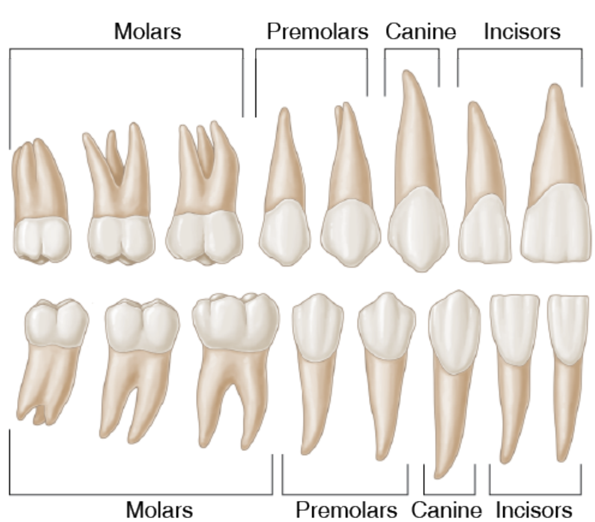
(Collins et al. 2016). The rate of dental injuries varied by sport, with the highest rates in girls' field hockey (3.9) and boys' basketball (2.6). Although orofacial injuries are uncommon, the majority occurred while the athlete was not wearing a mouthguard (73%).

The brain continues to mature through the adolescent years into young adulthood, which eventually results in higher levels of cognition, planning, attention, and impulse control. However, risk-taking behaviors peak during middle adolescence, prompting exposure to infections that can appear in the oral cavity, such as sexually transmitted diseases. Other risks include the initiation of substance use, including alcohol, illicit drugs such as marijuana, and tobacco, which are known to negatively affect oral health.

Craniofacial and Tooth Development

Adolescence begins with the late transitional dentition and ends with a complete permanent dentition (Figure 1). In some cases, third molar eruption (commonly referred to as wisdom teeth) late in adolescence or in early adulthood can present problems because of inadequate space in the jaws, resulting in malposition and subsequent pain, risk of caries, and periodontal complications (Zawawi and Melis 2014). Although third molars can be problematic, they should not routinely be extracted for preventive reasons. Jaw growth follows the trajectory of general body growth, and an adolescent's face begins to assume adult characteristics of vertical length and jaw position. This is when malocclusion fully manifests. Heritability and genetics play an important role in the wide spectrum of malocclusions, but environment and oral habits also are critical factors in the dental and facial variations observed in children or adolescents (Carlson 2015; Moreno Uribe and Miller 2015). In many cases, these malocclusions are simply cosmetic. Adolescents with congenital malformations may require additional surgical operations during this period.

Figure 1. Permanent teeth



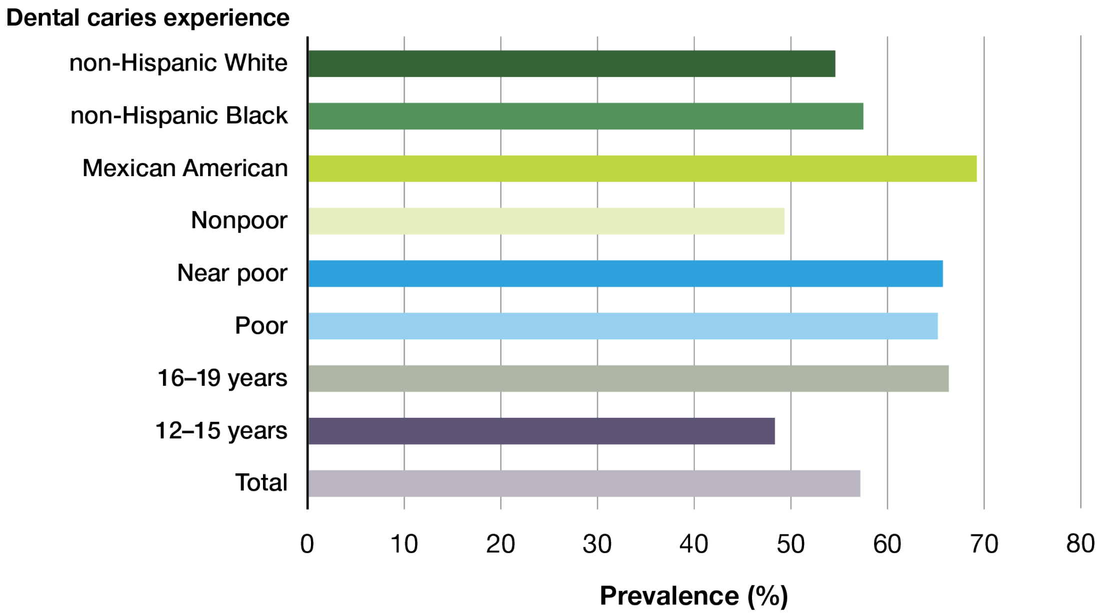
Source: Created by Jonathan Dimes for this NIH Report.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

High caries experience during early childhood is the single-strongest predictor of caries experience in adolescence and into adulthood (Twetman and Fontana 2009). In general, if the factors associated with dental caries risk in childhood persist, the incidence of dental caries affecting permanent teeth will continue to increase during adolescence. In the United States, this increase is observed regardless of poverty status, but its prevalence is higher among adolescents living in poverty than among those who do not (Slade and Sanders 2018). Overall, more than half of those aged 12 to 19 years have dental caries (57%); however, the prevalence increases substantially from the ages of 12 to 15 years to the ages of 16 to 19 (48% to 66%, respectively) (Figure 2) (Centers for Disease Control and Prevention 2019a). Among adolescents, the prevalence of caries is higher for those living in poverty compared to those living in more affluent households (65% vs. 49%). Nearly 7 in 10 Mexican American adolescents have dental caries, whereas 57% of non-Hispanic Black and 54% of non-Hispanic White adolescents experience dental caries. Poverty is a very important factor influencing caries experience in adolescents (Dye et al. 2017). Unlike what has been observed in preschool children (see Section 2A, Figure 9), disparities in dental caries are more likely attributable to poverty status, because the prevalence of dental caries is higher for poor adolescents than for more affluent adolescents, regardless of race/ethnicity (Figure 3) (Dye et al. 2017). The average number of permanent dental surfaces affected by dental caries begins to diverge between poor and nonpoor children during their elementary school years until its widest gap is seen at age 15 (Dye et al. 2017). However, by age 18, the gap narrows to a point where little difference exists in the average number of dental surfaces affected by dental caries according to poverty status.

Figure 2. Percentage of adolescents ages 12–19 with dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 2011–2016



Notes: Dental caries experience (DMFT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

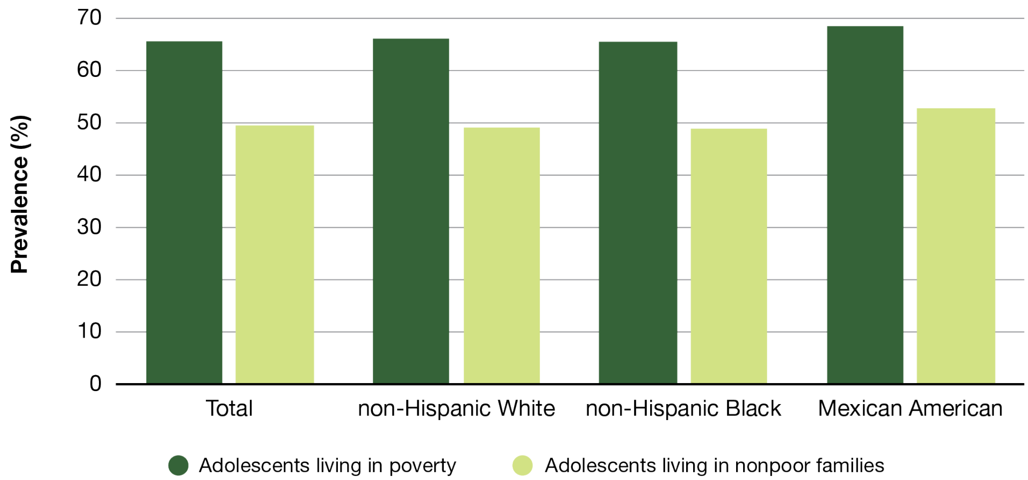
Source: Centers for Disease Control and Prevention (2019a).

Also, there is greater disparity related to poverty status in untreated dental caries among U.S. adolescents. One in six adolescents has untreated dental caries (17%). Considering income level, 23% of those aged 12 to 19 years living in poverty have untreated dental caries, whereas only 11% of those living in households at twice the federal poverty level have untreated caries (Figure 4) (Centers for Disease Control and Prevention 2019a). Overall, 16% of non-Hispanic White, 20% of non-Hispanic Black, and 21% of Mexican American adolescents have untreated dental caries. The highest prevalence of untreated caries by race/ethnicity is among poor, non-Hispanic white adolescents with nearly 1 in 3 having untreated tooth decay (32%) (Figure 5). Untreated caries affects 28% of poor non-Hispanic Black adolescents and 21% of poor Hispanics (Dye et al. 2017). Although adolescents living in lower income households are more likely to have higher levels of tooth decay compared to adolescents living in more affluent households (Dye et al. 2017; Rozier et al. 2017; Slade and Sanders 2018), the combined influence of race/ethnicity and poverty among adolescents is more pronounced, resulting in unexpected differences in the prevalence of untreated dental caries (Figure 5) compared to overall caries experience (Figure 3). For additional information on dental caries epidemiology and etiology, see Section 2A.

Developmental Tooth Defects

Developmental tooth defects are irregularities in tooth morphology that occur during tooth formation (Wright 2000). As previously discussed in Section 2A, there are several types of defects, but the main three are dental fluorosis, enamel hypoplasia, and amelogenesis imperfecta. All three are the result of factors affecting the mineralization of tooth enamel. Hypomineralized teeth often wear more poorly or fracture more easily than normally formed teeth, and they may be esthetically compromised and/or more susceptible to tooth decay. As a result, these teeth are likely to require more extensive restorative treatments beginning in later childhood and through adolescence. The need for restoration also depends on severity; for example, teeth with mild enamel fluorosis are not more prone to decay and their appearance may not be significantly compromised.

Figure 3. Percentage of adolescents ages 12–19 with dental caries in permanent teeth by race/ethnicity and poverty status: United States, 2011–2014



Notes: Dental caries experience (DMFT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; and ≥ 200% FPG = nonpoor.
Source: Dye et al. (2017).

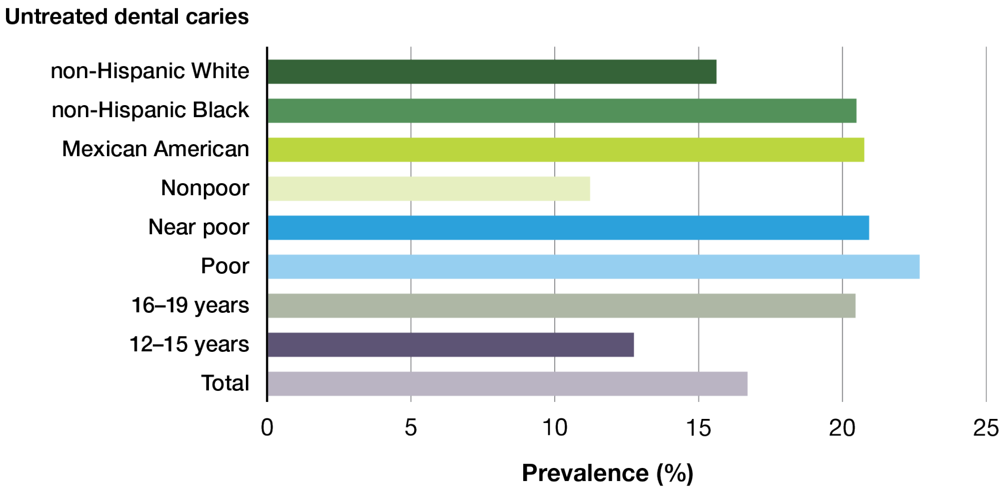
Dental fluorosis is a developmental tooth defect that was widely studied in the 1930s and 1940s by H. Trendly Dean and others (Centers for Disease Control and Prevention 1999). As a result of that landmark research, an epidemiologic relationship between fluoride concentration in water supplies, dental fluorosis, and dental caries began to materialize from information collected across 21 cities in four states (Centers for Disease Control and Prevention 2021a). This information ultimately formed the justification for supporting an original fluoride concentration of 1 part per million (ppm) in water supplies to reduce dental caries incidence, while maintaining a very low risk for the more severe forms of dental fluorosis. In 1962 this recommendation for a single concentration was amended, adjusting fluoride levels in a range from 0.7 ppm to 1.2 ppm to compensate for increased water consumption in warmer climates. Because Americans now have access to more sources of fluoride than they did when water fluoridation was first introduced, and in response to epidemiological indications of increasing prevalence of mild fluorosis, the U.S. Department of Health and Human Services again updated its recommendation for fluoride concentration in drinking water to 0.7 ppm (milligrams/liter) in 2015 (U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation 2015). As of 2018, 73% of the U.S. population served by community water systems (accounting for 63% of total U.S. population) has access to community water fluoridation (Centers for Disease Control and Prevention 2020), and fluoride is more readily available through various products.

Dental fluorosis is prevalent in the United States, affecting at least 2 in 5 adolescents aged 12 to 15 years (Beltrán-Aguilar et al. 2010). When dental fluorosis is present, the majority of adolescents have the milder forms, characterized by barely visible lacy-white markings to small, white, opaque areas affecting less than 50% of the visible tooth surface. Among adolescents aged 12 to 15 years, about 29% have very mild fluorosis, 9% have mild fluorosis, and 4% have moderate and severe fluorosis.

Dental Trauma

Oral injuries are common among adolescents. The prevalence of fractures in permanent incisors among U.S. adolescents is 18% among those aged 12 to 15 years, and 22% among those aged 16 to 19 (Dye et al. 2007). Young men experience trauma in the permanent dentition more frequently than young women, which may be attributable to greater participation in contact sports or physically engaged behaviors. This trend is likely changing, as participation of young women in contact sports is increasing (Traebert et al. 2006; Lam 2016).

Figure 4. Percentage of adolescents ages 12–19 with untreated dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 2011–2016



Notes: Untreated dental caries (DT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: Centers for Disease Control and Prevention (2019a).

In addition, dental trauma can be a result of physical injury experienced by victims of interpersonal violence such as bullying and human trafficking (Administration for Children and Families 2019; Mid-Atlantic P.A.N.D.A. 2021).

Dental Erosion

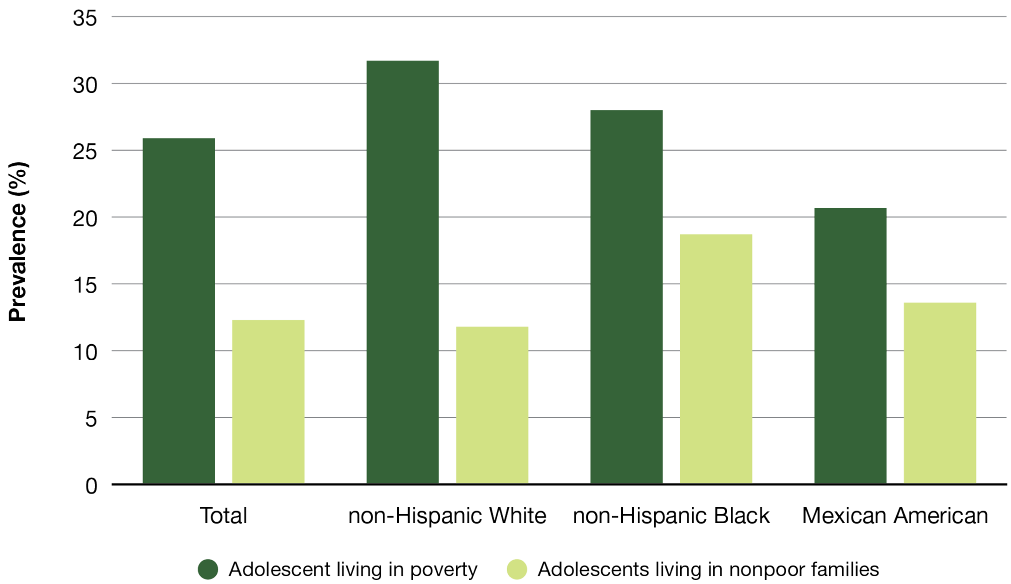
Dental erosion is the irreversible, acid-induced loss or wear of dental hard tissues not involving bacterial-secreted acids associated with dental caries (Imfeld 1996; Ganss 2014). Erosive tooth wear is estimated to affect as many as 40–55% of youth aged 13 to 19 years in the U.S. (Okunseri et al. 2011). Erosive tooth wear may be caused by extrinsic acids such as dietary acids—often from acidic beverages (juice, soda, and sports drinks), fresh fruit, and sour candies—and hypochlorous acid from chlorine used in swimming pools (Zero 1996; Lussi 2006; Lussi and Jaeggi 2006; Taji and Seow 2010), as well as intrinsic sources of gastric acid, such as gastroesophageal reflux disease, and recurrent vomiting associated with bulimia nervosa and other eating disorders (Lussi and Jaeggi 2006; Scheutzel 1996).

Carbonated beverage consumption, particularly in the evening, has been linked to erosion (Chan et al. 2020). The prevalence of dental erosion in adolescents with bulimia nervosa is more than 90% (Scheutzel 1996). The dental erosion pattern indicative of bulimia nervosa is loss of enamel on the lingual-palatal surface of the maxillary anterior teeth. The prevalence of bulimia nervosa among all adolescents in the United States is 0.3%, with an average age of onset at 18 years. It occurs five times more often in women than in men (Merikangas et al. 2010). Adolescents may be more prone to the chronic effects of erosive behaviors based on age and duration of habits. More information on erosion in children can be found in Section 2A.

Gingivitis and Periodontal Disease

Our understanding of gingival and periodontal diseases has evolved considerably during the past 20 years (Chapple et al. 2018; Papapanou et al. 2018). Gingivitis is inflammation of the gums in response to the accumulation of biofilm (plaque) on the gingival margin. Periodontal disease, a chronic inflammatory infection, causes gum inflammation, bleeding, and if it progresses, alveolar bone loss, loose teeth, and eventual tooth loss (Califano 2005; Caton et al. 2018; Rozier et al. 2017). Its causes include bacteria, host factors (e.g., genetics and immune response), systemic health (e.g., diabetes), poor oral hygiene, and tobacco use (Califano 2005; Tomar and Asma 2000). Limited research suggests a potential relationship between gingivitis and sugar consumption in teenagers (Lula et al. 2014).

Figure 5. Percentage of adolescents ages 12–19 with untreated dental caries in permanent teeth by race/ethnicity and poverty status: United States, 2011–2014



Notes: Untreated dental caries (DT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; and ≥ 200% FPG = nonpoor.
Source: Dye et al. (2017).

The risk of gingivitis caused by dental plaque is influenced by individual factors, such as poor oral hygiene, subgingival restoration margins, tooth anatomies, and xerostomia (dry mouth). This risk is exacerbated by systemic factors, such as those caused by elevated sex steroid hormones; metabolic factors that influence the immune inflammatory response, such as hyperglycemia; and hematologic conditions, such as leukemia, nutritional deficiencies; certain drugs; and smoking. In other cases, gingivitis typically is a manifestation of systemic conditions and disorders, including immune, metabolic, endocrine, and nutritional conditions; reactive and traumatic lesions; and viral, bacterial, and fungal infections (Chapple et al. 2018; Murakami et al. 2018). Periodontal conditions of oral tissues also can be associated with age-related behaviors ranging from lack of oral hygiene to sexually transmitted infections as well as medications for behavioral or other problems.

Although periodontal disease in children and adolescents is rare (Frencken et al. 2017), it can be more aggressive than it is in adults. Many instances of gingivitis and periodontitis in children and adolescents are associated with chronic systemic or congenital diseases, including connective tissue disorders (e.g., Ehlers-Danlos syndrome, systemic lupus erythematous) and genetic disorders that affect immunity (e.g., Down syndrome, neutropenia, leukocyte adhesion disorder, Papillon-Lefèvre syndrome, and hypophosphatasia, a condition that causes abnormal development of the bones and teeth) (Cabanilla and Molinari 2009) as well as other systemic conditions such as diabetes and obesity (Albandar et al. 2018; Jepsen et al. 2018). Some of these conditions can produce either a heightened inflammatory response in gums or gingival hyperplasia (an overgrowth of gum around the tooth), which increases susceptibility to periodontitis.

Because periodontal disease is not common in children and adolescents (American Academy of Pediatric Dentistry 2019), its prevalence in the adolescent and young adult population currently is not monitored nationwide in the United States. However, data collected from individuals between 1988 and 1991 indicate that only 2% of adolescents aged 13 to 17 years had any form of periodontitis reaching at least some level of a "mild" classification (periodontal attachment loss of 3 mm or higher) (Brown et al. 1996). A later collection of data revealed that adolescents aged 13 to 17 had the highest prevalence of gingival bleeding among any age group (73%) (Brown et al. 1996). Consistent with these earlier data, a 2018 study (Elias-Boneta et al. 2018) in Puerto Rico found that 83% of 12-year-old schoolchildren had gingivitis, described as bleeding on probing.

Malocclusion

The presence and impact of malocclusion is important for many adolescents. Malocclusion is a misalignment of the teeth and jaws that can affect oral function, alter facial appearance, increase the risk of dental trauma, and reduce quality of life. In many cases, these malocclusions are simply cosmetic. However, severe malocclusions can have a substantial impact on periodontal health, mastication, speech, and psychosocial development (Abreu 2018).

The last national surveillance of malocclusion in children, conducted from 1988 to 1991 (Brunelle et al. 1996), found that about half of those aged 12 to 17 years needed orthodontic treatment, with a higher need among Mexican American and non-Hispanic Black populations (Proffit et al. 1998). Those data also showed that overbite (vertical overlap of the incisors) was in the normal range for 66.2% of adolescents aged 12 to 17 years. In contrast, only 12% had no malalignment of the maxillary or mandibular anterior teeth, suggesting that the vast majority of children have some type of dental crowding. A small study (N=507) of Latinx youth in California found that 21.5% had Class II malocclusion (retruded lower jaw), and 9.1% had Class III malocclusion (protruding lower jaw) (Silva and Kang 2001). Later studies suggest that crossbite incidence in the United States is 5–8% in children aged 3 to 12 years (Bell and Kiebach 2014). In 2013, nearly 15% of all dental procedures affecting youth up to age 20 were orthodontically related (Laniado et al. 2017).

The psychosocial aspects of oral and occlusal health are especially significant in adolescence, including the capacity to speak, smile, and interact in social situations, because youth are developing adult identities through interactions with their peers (Glick et al. 2016; Silk and Kwok 2017). Appearance becomes highly important just at the time this age group is being treated for malocclusion with orthodontic appliances or braces. Healthy lifelong habits can be established by recognizing these priorities for adolescents and linking oral health messages positively to popularity and higher self-esteem (Silk and Kwok 2017).

Orofacial Pain and Temporomandibular Disorders

The most common causes of orofacial pain in adolescents are tooth decay and gingival-related problems caused by abscess (infection) of the tooth or the gums. In addition, a third molar (wisdom tooth) can be painful when its eruption path is blocked or when the tooth is only partially erupted and the gum tissue around it becomes inflamed, creating a condition called pericoronitis. Another type of orofacial pain that begins to appear around adolescence is the recurring aphthous ulcer, more commonly known as a canker sore. It is typically a roundish ulcer-like sore that appears inside the mouth, mostly on the inside of the lips and cheeks or on the tongue (Mayo Clinic 2021). Recurrent herpetic infection (cold sores) also are a problem. These oral infections may be related to changes in diet, emotional stress, and hormonal changes as well as sun exposure and can be transmitted through intimate behavior. They usually disappear on their own in 10–14 days.

Temporomandibular joint and muscle disorders (TMD) often begin in adolescence and continue to progress into adulthood. The seminal Orofacial Pain: Prospective Evaluation and Risk Assessment Study in Adults, funded by the National Institutes of Health, has described the complex, multifactorial nature of TMD as part of a constellation of pain disorders (Slade et al. 2013; Slade et al. 2016). Although the symptoms of TMD appear earlier in adolescents than in adults, the etiology of the disorder likely is similar across age groups (LeResche et al. 2007). As in adults, factors related to TMD in adolescents include female gender and negative somatic and psychological symptoms (LeResche et al. 2007). Another study showed TMD increasing with pubertal development, but no difference by gender after adjusting for pubertal stage (Hirsch et al. 2012). Little population data on TMD exist for U.S. adolescents. Clinically confirmed 3-year incidence of TMD in 11-year-olds (n = 1,310) was estimated at 2.3% per year (LeResche et al. 2007). In a German population of 10- to 17-year-olds, clinically confirmed point prevalence of TMD was estimated at 10.2% (Hirsch et al. 2012).

Oral Human Papillomavirus

Human papillomavirus (HPV) is the most common sexually transmitted infection in the United States, with 79 million Americans infected (Satterwhite et al. 2013) and direct medical costs of about $1.7 billion (Owusu-Edusei et al. 2013). Most HPV infections remain asymptomatic and resolve spontaneously in a few months. Persistent HPV infection has been associated with most cervical, anal, and oropharyngeal cancers (OPC) as well as with subsets of vaginal, vulvar, and penile cancers. More than 200 types of HPV have been identified and classified as high risk and low risk based on their association with cancer. The majority of HPV-related cancers are caused by HPV-16 and HPV-18.

Oral HPV infection is associated with the number of sexual partners, oral sex, anal sex, and age younger than 18 at the time of the first act of oral sex (Pickard et al. 2012). In addition, HPV infection is associated with cigarette smoking, heavy alcohol consumption, marijuana use, HIV infection, and a positive history of genital HPV infections (Beachler and D'Souza 2013; Gillison et al. 2012; Sonawane et al. 2017). Oral HPV-16 infection is present in about 1% of the U.S. population and increases the odds of HPV-associated OPCs nearly 15-fold (D’Souza et al. 2007; Gillison et al. 2012).

The prevalence of HPV-positive OPCs has increased steadily in the past three decades (Chaturvedi et al. 2011), especially among young men (78.1% vs. 21.9% for women) (de Martel et al. 2017; Osazuwa-Peters et al. 2017), and is expected to grow in older and White individuals as well (Lu et al. 2018; Tota et al. 2019).

Currently, the CDC Advisory Committee on Immunization Practices (ACIP) recommends a 2–3 dose vaccine series for both males and females at ages 11 to 12 years, or as late as age 26, if not begun earlier. The HPV vaccine has been approved by the U.S. Food and Drug Administration, after recommendation by ACIP, to be administered from ages 9 up to 45 years (U.S. Food and Drug Administration 2018) (see Table). HPV vaccination in adolescents is an important public health intervention at a strategic age, when older youth are expressing more independence and engaging in behaviors that put them at a higher risk for HPV infection. Additional information on HPV can be found in Section 3A-Adults.

High-Risk Behaviors Affecting Oral Health in Adolescents

The use of alcohol and illicit drugs are risk factors for poor oral health outcomes in adolescents that can extend into adulthood (Freddo et al. 2018; Oliveira Filho et al. 2013) and lead to substance misuse or abuse and behaviors in adulthood (Jackson et al. 2008) that may have negative oral health outcomes as well. For example, heavier alcohol use also is associated with high-risk oral HPV among older adolescents and young adults (Dalla Torre et al. 2016).

Alcohol and Illicit Drug Use

The use of alcohol and illicit drugs are major contributing factors to maxillofacial and oral trauma. Use of these substances puts individuals at higher risk for interpersonal violence, motor vehicle accidents, and other injuries (Shetty et al. 2011). Most oral trauma patients enter the emergency room having used alcohol and/or illicit drugs (Oliveira Filho et al. 2013). Alcohol and illicit drug use also are risk factors for recurrent injury and oral trauma (Shetty et al. 2011). Adolescent and young adult men are at the highest risk for these kinds of injuries.

Alcohol use is prevalent among U.S. teenagers and has implications for oral health. The most recent data from the Monitoring the Future report (Johnston et al. 2020) show that for 2019, 8% of 8th-graders used alcohol in the past month, and use increased with age, with 18% of 10th-graders and 29% of 12th-graders using alcohol.

Alcohol also increases the susceptibility to oral and dental disease. Heavy episodic drinking has been linked to a higher incidence of caries among adolescents, which may result from the additional consumption of sugar-sweetened beverages (SSBs) and poorer dental hygiene (Freddo et al. 2018).

Also, specific drugs have been linked to poorer oral health. Cannabis is the most commonly used illicit drug, with 6.6% of 8th-graders, 18.4% of 10th-graders, and 22.3% of 12th-graders reporting past-month use, and 1.3%, 4.8%, and 6.4% reporting daily use, respectively (Johnston et al. 2020). Use of illicit drugs other than marijuana is estimated at 3.4%, 4.2%, and 5.2% for 8th-, 10th-, and 12th-graders, respectively, reporting use in the past 30 days. Use of Adderall and other amphetamines in the past 30 days is 2.4% and 2.0% among 10th- and 12th-graders, respectively (Johnston et al. 2020).

Opioid misuse is reported by close to 2.8% of adolescents aged 12 to 17 years (Substance Abuse and Mental Health Services Administration 2019). Over time, opioid use may have a number of negative effects on oral health, including xerostomia and more frequent dental caries, related to poorer oral hygiene and increased sugar intake (D'Amore et al. 2011; Fraser et al. 2017).

The impact of different risk factors for alcohol and drug use (e.g., temperament, family, peers, environment) varies at different stages of development (Tarter 2002), as do the types of substances used. Younger adolescents, for example, have higher rates of inhalant use and misuse of prescription medication (Johnston et al. 2020). Older adolescents are increasingly exposed to and use alcohol and illicit drugs (Sussman and Arnett 2014). This period of exploration, identity development, and freedom from parental monitoring often corresponds to greater availability of alcohol and drugs (Sussman and Arnett 2014).

In addition, cognitive-developmental factors influence alcohol and substance use patterns and, in turn, oral health risk. Increases in responses to reward stimuli in middle and later adolescence, during a time when inhibitory functions are still developing (Brown et al. 2009), lead to difficulties in self-control related to alcohol and substance use. Indeed, the development of executive function, which incorporates basic cognitive processes that allow us to organize and control our behaviors, continues throughout the adolescent period and is critical to judgment and decision making related to behavior under the influence of alcohol and drugs (Brown et al. 2009; Chadi et al. 2018). For a more in-depth discussion of alcohol and illicit substance use and its relationship to oral health, refer to Section 5.

Tobacco Product Use

In 2020, according to data from the National Youth Tobacco Survey, nearly 7 of every 100 middle school students (6.7%) and about 23 of every 100 high school students (23.6%) reported current use of a tobacco product (Centers for Disease Control and Prevention 2021b). The prevalence of tobacco product use among high school students is 4.6% for cigarettes, 5.0% for cigars, 3.1% for smokeless tobacco, 2.7% for hookahs/waterpipes, 1.4% for heated tobacco products, and 0.7% for pipe tobacco. Among middle school students, the prevalence is 1.6% for cigarettes, 1.5% for cigars, 1.2% for smokeless tobacco, and 0.4% for pipe tobacco (Gentzke et al. 2020).

Among high school students, use of any tobacco product was reported by 25.9% of non-Hispanic Whites, 23.3% of Hispanics, 18.4% of non-Hispanic Black students, and 15.7% of non-Hispanic students of other races. E-cigarettes were the most commonly used tobacco product among White (23.2%) and Hispanic (18.9%) high school students. Cigars were the most commonly used tobacco product among Black high school students (9.2%). Among middle school students, use of any tobacco product was reported by 9.4% of Hispanic students, 6.7% of Black students, and 5.7% of non-Hispanic White students. Among middle school students, e-cigarettes were the most commonly used tobacco product among Hispanic (7.1%) and White (4.3%) students (Gentzke et al. 2020).

It has been suggested that teens perceive tobacco products to be acceptable among peers, relatively safe (in the case of e-cigarettes), and accessible. After 6 months to 2 years of experimentation, other motivations, such as addiction, come into play (Johnston et al. 2020; National Institute on Drug Abuse 2020; Gentzke et al. 2020). Parental smoking also has been linked to adolescent intention to smoke, smoking initiation (and often at an earlier age), and continued smoking, with longer parental tobacco exposure related to increased risk (Chassin et al. 2008; Fuemmeler et al. 2013; Kandel et al. 2015). Alternatively, smoking initiation rates are lower among children whose parents quit smoking (den Exter Blokland et al. 2004; Otten et al. 2007; Vuolo and Staff 2013). There is some evidence that nicotine intake can affect executive function and development in adolescents (U.S. Department of Health and Human Services 2014). Although the long-term effects are unknown, nicotine-related effects could increase the risks for behaviors that lead to poor oral health outcomes.

Although it can be difficult to assess the impact of tobacco use on adolescent oral health, a variety of problems can occur among regular teenage users and in some occasional users that include stained teeth, gum recession, periodontitis, bad breath, dental caries, tooth fractures, and leukoplakia (Akinkugbe 2019; Ayo-Yusuf et al. 2009; Cho 2017; Holmen et al. 2013; Silk and Kwok 2017; Sundar et al. 2016). These effects appear to result from the use of all tobacco products, including e-cigarettes (Akinkugbe 2019; Cho 2017; Huilgol et al. 2019; Mokeem et al. 2019; Sundar et al. 2016). A meta-analysis also suggests that prenatal and postnatal secondhand smoke exposure has a moderate influence on the likelihood of developing dental caries (Gonzalez-Valero et al. 2018).

Studies suggest that the recent trend in adolescents' use of e-cigarettes has a somewhat lower impact on oral health than combustible tobacco (Javed et al. 2017; Sultan et al. 2018; Tatullo et al. 2016). However, youth and young adults who use e-cigarettes may be more likely to use other tobacco products, particularly combustible tobacco products, which have known health risks. Nicotine, which is found in most e-cigarettes sold, can harm adolescent brain development, promote addiction, have negative pregnancy implications, and cause acute poisoning and possibly death if the contents of nicotine-containing refill cartridges or bottles are consumed (U.S. Department of Health and Human Services 2016). There is little research on the oral health consequences of marijuana, and its impact is complicated by the co-use of e-cigarettes and combustible and noncombustible tobacco (Ditmyer et al. 2013; Kowitt et al. 2018). Section 5 has information regarding vaping and effects of tobacco.

Dietary Behaviors

Adolescent diets are characterized by an increased need for calories for activity as well as growth, experimentation with fads and new foods, freedom from parental control, access to foods that may increase the risk of dental caries, financial ability to purchase foods because of part-time work or allowance, and the loss of school-based nutritional food sources (Roy and Stretch 2018). Intake of added sugars tends to increase with age among youth, resulting in males and females 12 to 19 years consuming an average of 17.5% and 16.6%, respectively, of their daily calories from added sugar (Ervin et al. 2012). Data from the 2011–2014 National Health and Nutrition Examination Survey revealed that 62.9% of youth consume at least one SSB on a given day, inclusive of soda, fruit drinks, sports and energy drinks, and sweetened coffees and teas (Rosinger et al. 2017). The average percentage of daily calories from SSBs for males and females aged 12 to 19 years is 9.3% and 9.7%, respectively (Rosinger et al. 2017). Easy access to and consumption of SSBs is a continued cause of dental caries in adolescents in general and a phenomenon of new dental caries in newly erupted permanent teeth in previously caries-free children. As discussed in Section 2A, carbonated SSBs combine the effect of sugar with acidic attack.

Social Determinants of Health

During the past 20 years, SDoH have been increasingly recognized as major contributors to oral disease in adolescents (Fisher-Owens et al. 2007; Kim Seow 2012; Patrick et al. 2006). Sociodemographic factors can shape biology and behaviors related to oral disease development and progression in children and adolescents (Fisher-Owens et al. 2007; Lee and Divaris 2014). For older children and adolescents, their knowledge, behaviors, and attitudes can affect their oral health, although parental influence is still a significant factor (Baker et al. 2010).

Consistent with definitions of SDoH already presented in this monograph, adolescent oral health is embedded in systems that regulate behavior, including family, culture, schools, neighborhoods, health care systems, and government institutions (Fiese et al. 2019). These systems have overlapping influences. For example, disordered or dangerous neighborhoods can disrupt parenting, which leads to poor health outcomes for youth (Kotchick et al. 2005). In one study, mothers who perceived very low levels of support in their neighborhood were more likely to report unmet dental needs and less likely to have preventive dental visits than mothers who reported supportive, trustworthy neighborhoods (Iida and Rozier 2013). However, protective factors, such as regular routines at mealtimes and bedtimes, can lead to more positive health outcomes for youth (Budescu and Taylor 2013; Jones and Fiese 2014).

Social determinants influence dental utilization and may explain why one-third of U.S. adolescents do not access preventive dental care services (Atkins et al. 2012). African American, Asian, Native American, and other/multiracial adolescents receive less dental care than Whites, and Hispanic youth are less likely to receive dental care than non-Hispanic youth (Atkins et al. 2012).

This reduced level of care may help to explain why more than half of all adolescents have a high prevalence of dental caries (57%), and at least 1 in 6 have untreated tooth decay (17%) (Centers for Disease Control and Prevention 2019a). Adolescent utilization of dental care is related to neighborhood poverty, even after controlling for household income, insurance, and parental education (Atkins et al. 2012). As shown in Figure 3, poverty can negatively affect dental caries prevalence among adolescents. Moreover, untreated tooth decay can vary substantially among adolescents by poverty and race/ethnicity (Figure 5). Because 18% of adolescents live in households with incomes below the federal poverty level (Office of Adolescent Health 2019) and at least 1 in 4 adolescents living in poverty has untreated tooth decay, improving access to dental care for this age group is important.

A cross-sectional study of a representative sample of 9th- and 11th-grade students found that lower socioeconomic status (SES) was associated with a higher prevalence of decayed, missing, and filled teeth and severe caries. This effect was not accounted for by SES-associated differences in brushing, flossing, sealant use, fluoride exposure, or recency of dental services (Polk et al. 2010). Clearly, social and community factors—including available dental care services and financing, and school-based prevention programs and other public health initiatives—also play a role in identified oral health disparities. Research is needed to identify the pathways within which SES-associated disparities occur.

Prevention and Management of Oral Diseases and Conditions

Efforts directed at preventing and controlling oral diseases or other adverse orofacial conditions in adolescents generally have been focused on dental caries and, with only a few exceptions, have used similar approaches to those developed for younger children. For dental caries, interventions using a primary prevention approach are aimed at preventing the occurrence of tooth decay. These activities often include health promotion activities that focus on changing poor dietary habits; using fluoridated toothpaste, receiving fluoride varnish, or drinking fluoridated water; and the use of dental sealants. Other primary prevention interventions that are appropriate for adolescents are (1) providing mouth guards and helmets to prevent sports injuries to the face and teeth; (2) tobacco, vaping, and substance misuse counseling to prevent periodontitis and other harms to the mouth; (3) providing HPV vaccination to prevent HPV-associated cancers, including oropharyngeal cancer; and (4) counseling related to the use of opioids and illicit drugs that have negative effects on oral health.

Secondary prevention efforts are intended to (1) reduce the impact of early disease onset and (2) to detect early signs of disease, generally through receiving regular care. Scientific consensus for a caries risk assessment to identify high-risk adolescents for dental caries development remains a work in progress, although such efforts have been more successful for children. One chemotherapeutic approach for reducing the impact of dental caries when the caries process has been limited to a small cavity is the use of silver diamine fluoride (Crystal et al. 2017). Controlling disease after diagnosis to prevent progression to tooth loss or to provide restoration of some function is the focus of tertiary prevention. For controlling caries progression in adolescents, this could range from interim restorative techniques or conservative restorative approaches to more complex restorative procedures. The goal of any of these preventive efforts for adolescents is to implement any intervention early enough to preserve as much of the natural tooth structure as possible.

Management of Dental Caries

Some risk factors for dental caries change during the adolescent years. For example, sports and social activities may result in changes in diet and consumption of sports drinks and caffeinated beverages, many of which are high in added sugars, increasing the risk of caries. Oral appliances that can make oral hygiene difficult are common in adolescents undergoing orthodontic treatment and increase the risk of caries. Thus, emphasis on identification of risk factors for dental caries and preventive efforts to reduce consumption of sugar-containing foods and beverages, improved oral hygiene, and adequate exposure to fluoride and sealants, among other strategies, are just as important in the adolescent years as in childhood.

The approach for treating tooth decay in youth is beginning to shift to minimally invasive procedures (e.g., silver diamine fluoride or interim restorative techniques). Although the evidence is still building to support their long-term effectiveness in this age group, these procedures are being used when decay occurs in adolescents. There is a building consensus that some proximal dental caries can be managed successfully with nonoperative, microinvasive, and restorative treatment according to the size of the cavity and history (Splieth et al. 2020). There has been a general shift away from the use of amalgam to more natural-looking, tooth-colored restorations, primarily because of concerns regarding mercury and aesthetics. These types of restorative materials are composites and glass ionomer cements. Because of the Minamata Convention on Mercury (U.S. Environmental Protection Agency 2020), there has been a push in the United States to capture dental amalgam before it enters the waste stream, for increased prevention efforts to reduce the need for any restorative material and for increased research to develop new biocompatible and environmentally friendly restorative materials (International Association for Dental Research 2019).

Fluorides for Dental Caries Prevention and Management

The use of fluoride-containing products is one of the most important strategies for the prevention of dental caries from childhood through adolescence. Fluoride-based strategies also have the potential to arrest and remineralize noncavitated dental caries lesions (Slayton 2015). There are many safe and effective ways to use fluoride, from community water fluoridation to the use of toothpaste, mouth rinses, and professionally applied products, such as gels and varnishes (Marinho et al. 2013; Wright et al. 2014). An expanded discussion of fluorides for caries prevention and management is provided in Section 2A.

Dental Sealants for Caries Prevention and Management

As discussed in Section 2A, a dental sealant is a thin coating that protects the chewing surfaces of posterior teeth from dental caries. Younger children are more likely to receive dental sealants from their dental provider or through participation in a school sealant program. However, adolescents could benefit from sealants as well (Wright et al. 2016). Because the second permanent molars erupt during adolescence when many youths are transitioning from elementary to middle school, these teeth are often missed. Typically, school sealant programs target the second grade (ages 7–8 years) for applying sealants on first permanent molars, and the sixth grade (ages 11–12 years) for sealing second molars (Association of State and Territorial Dental Directors 2015). Sealing newly erupted second molars is an important prevention strategy to reduce caries initiation in these teeth in youth at risk for tooth decay. Nearly 2 in 5 U.S. adolescents aged 12 to 19 have at least one permanent tooth with a dental sealant (43%). Non-Hispanic Whites had the highest prevalence of sealants (47%), followed by Asian (43%), Hispanic (40%), and non-Hispanic Black adolescents (30%) (Dye et al. 2015). Overall, adolescents average about five permanent teeth sealed (Beltrán-Aguilar et al. 2005).

Management of Periodontal Disease

Treatment procedures for adolescents range from patient education, counseling, and control of risk factors to removal of supragingival and subgingival plaque and calculus and chemotherapeutic and surgical approaches, followed by maintenance therapy (American Academy of Pediatric Dentistry 2017a). Recognition of adolescent periodontal issues as a gateway to adult periodontal concerns has focused attention on this age group (Califano 2005). Nonsurgical interventions, such as antibiotics, may be effective in addressing reversible or very early periodontal conditions in adolescents.

Management of HPV and Oropharyngeal Cancers

Most OPCs in the United States are associated with HPV infection (70%), making them the most common HPV-related cancers in the United States (National Cancer Institute 2020). With the incidence of HPV-associated cancers on the rise, the Centers for Disease Control and Prevention recommends that 11- to 12-year-old males and females get two doses of HPV vaccine, with the second dose given 6–12 months after the first (Centers for Disease Control and Prevention 2019b). At least 2 out of 3 adolescents (aged 13–17 years) received one or more doses of the HPV vaccine in 2018 (Walker et al. 2019). Among adults aged 18 to 26 years, 2 out of 5 had received at least one dose of the HPV vaccine (Boersma and Black 2020). The efficacy of HPV vaccination in preventing OPCs is at least 90% (Guo et al. 2016).

The American Dental Association (2018a), the American Academy of Pediatric Dentistry (2020a), and the American Academy of Pediatrics (2017) also support vaccination against HPV in adolescents. Oral health professionals who see adolescent patients should counsel their parents about the HPV vaccine and HPV's link to OPC. In addition to encouraging the vaccine, some oral professionals also can provide it when authorized under their state's scope of practice. For example, Oregon approved a law allowing dentists to provide vaccinations, including the HPV vaccination, in 2019. Additional information on OPC, HPV, and vaccinations can be found in Section 3A.

Managing Opioid Prescriptions to Prevent Misuse

In the late 1990s, dentists were the top professional specialty prescribers of opioids, accounting for 15.5% of all immediate-release opioid prescriptions (Rigoni 2003). By 2009, this proportion had decreased to 8% (Volkow et al. 2011) and, by 2012, to 6.4% (Levy et al. 2015). The median prescription during the period of 2010–2015 was for only a 3-day supply (Gupta et al. 2018a).

A relatively high proportion of young people have received opioid prescriptions following dental visits, primarily associated with wisdom tooth extractions (Gupta et al. 2018a; 2018b; McCauley et al. 2016). The trend also shows an increase in the quantity of opioids prescribed over time (Gupta et al. 2018b; Steinmetz et al. 2017), which is a source of concern given the risk of opioid-naïve patients for developing drug dependence (Larach et al. 2018), and the incidence of drug diversion among this population subgroup (McCabe et al. 2013).

Prescription opioids exhibit high rates of conversion to addiction, particularly in patients younger than 25 years of age. Major interventions to curtail the prescription of opioids are underway, and early indicators are showing major changes in prescription practices among oral health providers. Finding management approaches for acute pain that reduce or eliminate opioid prescription in dentistry could be a powerful deterrent to opioid misuse. Evidence favors the use of nonsteroidal anti-inflammatory drugs, with or without acetaminophen, to manage acute dental pain (American Dental Association 2020). Opioid misuse is covered in greater detail in Section 5.

Management of Other Issues

Dental damage resulting from sports injuries is a common problem in the adolescent population. Use of mouth guards (Fernandes et al. 2019) is the best available approach to prevention of sports injuries. This protection is now mandated in most school athletic programs, and effective, low-cost mouth guards are commercially available. Dentists are increasingly a part of the health team at sporting events for all ages and, in addition to preventive instruction and protective device construction, can respond to dental injury when needed. Teenage practices such as mouth piercings also create the potential for damage to the mouth. Although there has been very little systematic study of this problem, dentists can educate patients about the risks involved.

Adolescents with Disabilities and Special Health Care Needs

Pediatric dentists remain the primary source of dental care for children and adolescents with special health care needs (SHCNs), including chronic congenital or acquired conditions that affect physical, cognitive, behavioral, or emotional functioning, and needs beyond those experienced by most of their age cohort. The limitations of the dental care system for patients with SHCNs become obvious when adolescents transition to adult care. Because not all general dentists have been equally well prepared for treating patients with SHCNs (Fenton et al. 2003; Rutkauskas et al. 2015), referrals are not always successful (Nowak et al. 2010). Adolescence brings additional challenges for care of special-needs patients because of their increased size and strength, possible undesirable effects of medications, and the potential conflicts of self-help and decision-making programs with necessary care decisions. In some adolescent patients with special needs, the effects of long-standing physical changes in posture and organ function can alter treatment and treatment delivery.

Oral Health and Quality of Life

The concept of oral health, once narrowly focused on disease and deformity, has broadened to include physical, social, and psychological aspects (Locker 1988). This mirrors changes in the concept of general health as a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity, and is a key feature of one's overall quality of life (Inglehart and Bagramian 2002). Consequently, oral health–related quality of life (OHRQoL) highlights the relationship between oral health and general health and their overall relationship with quality of life.

Much of what is known about oral health and general health comes from younger children, with caregivers serving as proxy reporters. However, in one large cross-national study involving adolescents from 11 countries, researchers determined that structural determinants of health were associated with adolescents' OHRQoL and explained 5–21% of the variance in OHRQoL scores (Baker et al. 2018). Although some progress has been made in the assessment of OHRQoL among adolescents, the process is complex because of changes in psychosocial awareness, physical development, dental and facial anatomy, and linguistic and cognitive abilities. Despite concerns about longitudinal validity of OHRQoL measures in adolescents, most evidence supports OHRQoL stability in longitudinal studies, supporting their usefulness in adolescence and in life-course studies.

In adolescents, malocclusion appears to be a key factor that impacts OHRQoL (Sun et al. 2018). A systematic review by Liu and colleagues (2009) showed that untreated malocclusion with a defined treatment need (irrespective of the index used to categorize treatment need) was significantly associated with poor OHRQoL. Furthermore, the more severe the malocclusion, the worse the impact. In addition, adolescents with untreated dental caries, severe periodontal disease, and untreated dental trauma also reported poorer OHRQoL compared with those without these problems (Liu et al. 2009).

Chapter 2: Advances and Challenges

The recognition that adolescents' oral health needs are distinct from those of children and adults is an important advancement in the twenty-first century. Although some progress has been observed with a modest decline in dental caries, there has been no decline in untreated tooth decay in adolescents since national figures were reported in the last Surgeon General's report on oral health 20 years ago. Parental income remains the strongest predictive factor of poorer oral health (dental caries), and inequities still exist for specific adolescent populations. Yet, understanding adolescent oral health remains an ongoing challenge. During the last 2 decades, dental erosion has become more prevalent in adolescents, but not better understood. Also, developmental tooth defects, gingivitis, and periodontitis in adolescents are not as well studied, and there are no unique or age-appropriate strategies for adolescents to promote oral health. Adolescent populations that are at greatest risk for poor health outcomes include immigrants, LGBTQ adolescents, those in foster care or the juvenile justice system, homeless youth, and youth from underserved geographical areas (Tebb et al. 2018). These populations are often underrepresented or are nonparticipants in studies.

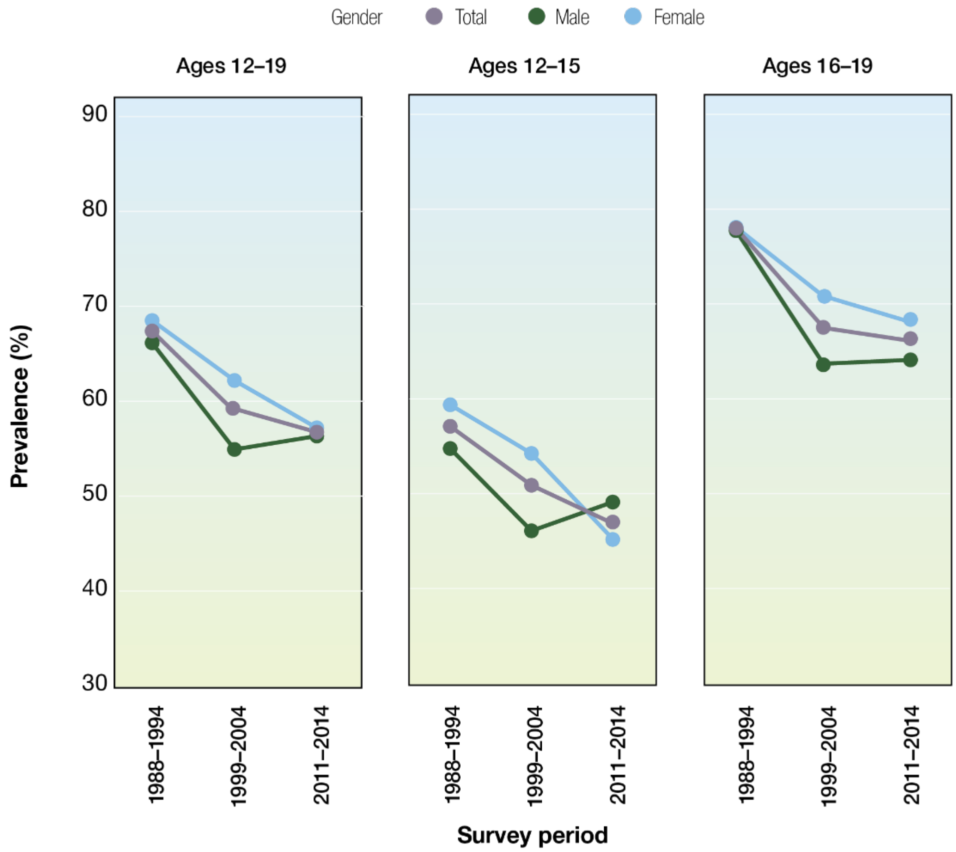
Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Since the publication of the 2000 report, improvement in adolescent oral health has been inconsistent and not as sizable as that seen for younger children in the United States, particularly regarding the prevalence of dental caries. Over the past 2 decades, the prevalence of dental caries decreased among adolescents aged 12 to 15 years from 57% to 48% and from 78% to 67% for those aged 16 to 19 years (Figure 6). However, not all adolescents have benefited from this decline.

Although the use of dental preventive services has increased among Latinx children, their oral health outcomes have not improved (Pourat and Finocchio 2010; Tiwari and Palatta 2019). For example, there has been a modest decrease in dental caries for adolescents overall, but this has not occurred for Mexican American adolescents, with 7 in 10 continuing to experience dental cavities (69%) (Figure 7). Because dental caries has decreased significantly for non-Hispanic Whites and for non-Hispanic Blacks, a disparity in caries experience for Mexican American adolescents, which did not exist at the time of the publication of the Surgeon General's Report on Oral Health, has developed. In addition, the magnitude of the disparity by poverty status has increased for all adolescents, particularly for those aged 12 to 15 years (Figure 8).

Figure 6. Percentage of adolescents ages 12–19 with dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014

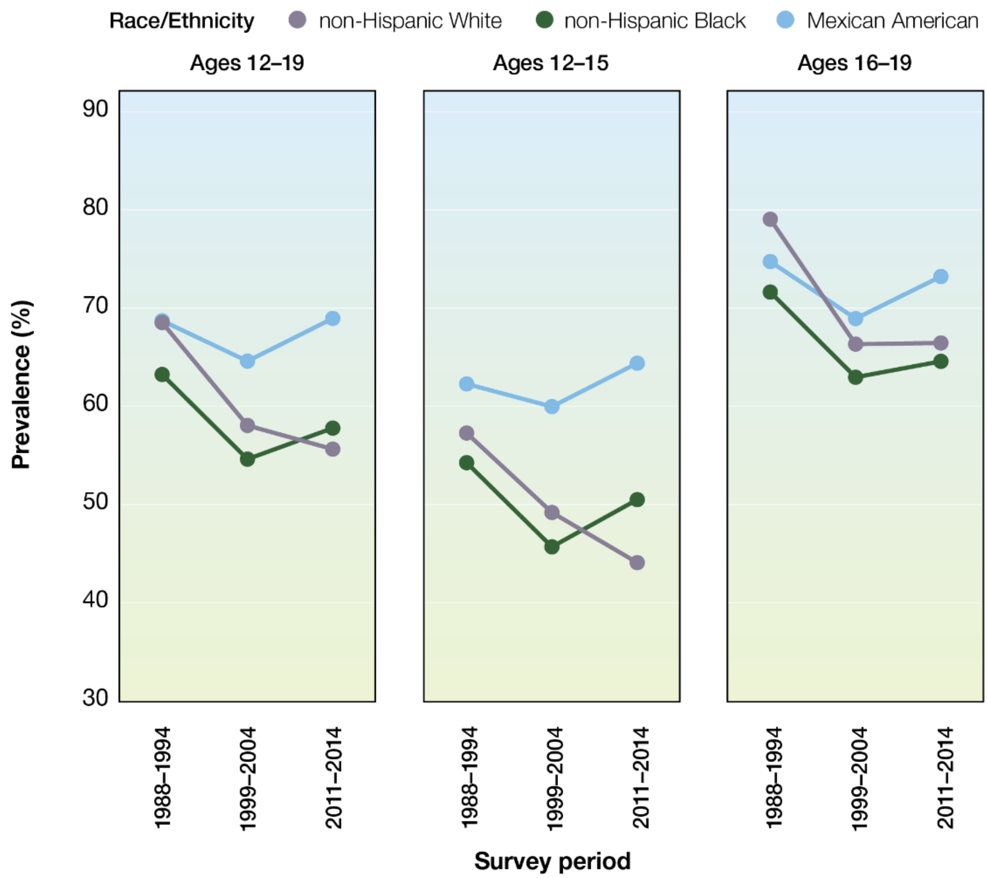


Note: Prevalence of dental caries in permanent teeth (DMFT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Since the publication of the Surgeon General's report on oral health in 2000, there's been little change in untreated dental caries prevalence among adolescents overall (21% vs. 19%) (Figure 9). However, this perception of stability in the overall prevalence of untreated dental caries masks important racial/ethnic differences. Mexican American and non-Hispanic Black adolescents had a significant decrease in untreated caries (33% to 24% and 33% to 23%, respectively) (Figure 10), whereas untreated caries among non-Hispanic White adolescents suggested a small (but nonsignificant) increase from 15% to 18%. In general, these changes in untreated tooth decay represent a decrease in disparities by race/ethnicity from that observed in untreated caries 20 years ago. Although there was a significant decrease in the prevalence of untreated dental caries for adolescents living in poverty (34% to 26%) during this period (Figure 11), disparities in untreated caries continue to be more highly impacted by poverty status than other sociodemographic indicators.

On average, adolescents have 4.4 permanent tooth surfaces affected by dental caries compared to 5.2 surfaces 20 years ago (Figure 12). However, this decrease was driven mostly by non-Hispanic White adolescents and those living in more affluent households (Figures 13–14). Overall, 4 out of 5 tooth surfaces affected by dental caries are restored (i.e., have dental fillings) in adolescents, but this proportion increases to about 90% for more affluent adolescents and decreases to about 75% for those living in poverty. The number of affected tooth surfaces has remained unchanged for those living in poverty (5.7 surfaces affected). The number of surfaces affected by dental decay continues to increase among adolescents as they age from 12 to 15 to 16 to 19 years.

Figure 7. Percentage of adolescents ages 12–19 with dental caries in permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of dental caries in permanent teeth (DMFT > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

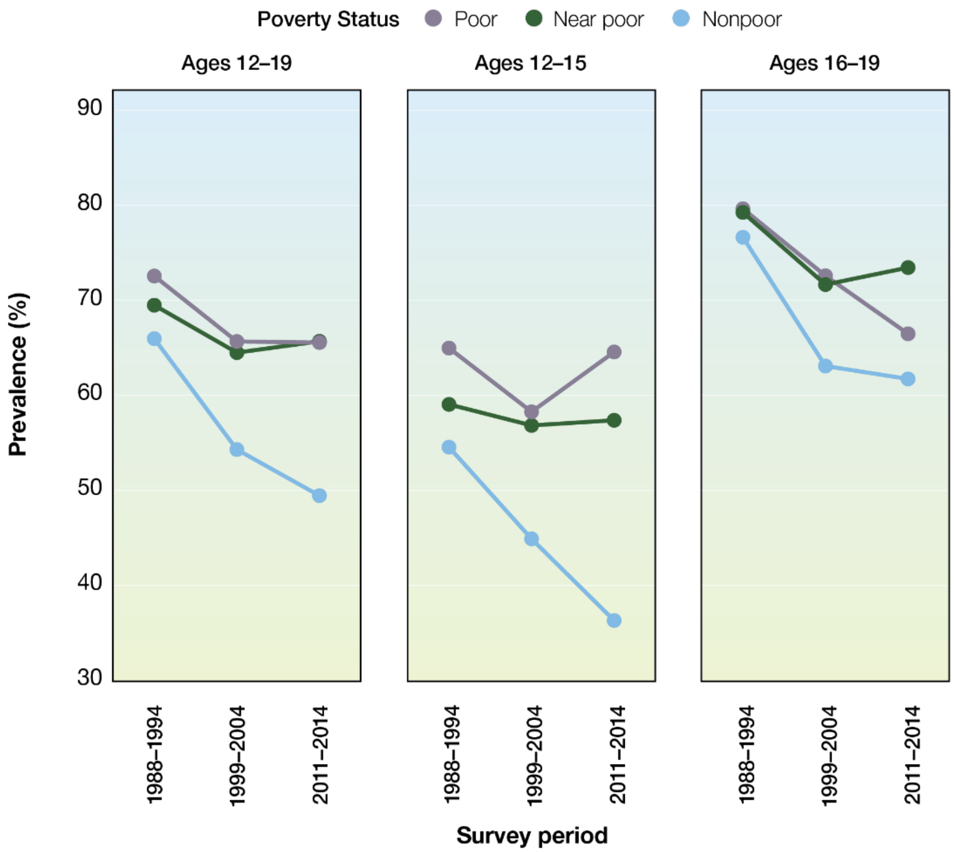
Dental caries continues to affect American Indian/Alaska Native (AI/AN) adolescents at higher rates than adolescents from other racial or ethnic groups. In one AI/AN study, 3 in 4 (75.4%) of adolescents aged 13 to 15 years in 2019–2020 who were dental clinic users experienced dental caries. The prevalence of untreated decay also is highest for this group; in the same period, 45% of dental clinic users aged 13 to 15 years had untreated dental caries, and 38% of students aged 13 to 15 years participating in a school health survey had untreated dental caries (Phipps et al. 2020).

Other adolescent health issues, such as asthma, smoking, and vaping, have garnered extensive public and policy attention. However, the 13.4% prevalence of untreated caries among adolescents aged 12 to 19 years is greater than the prevalence of both asthma (8.5–9.5%) (Akinbami et al. 2012; Miller et al. 2016) and any combustible tobacco use in this age group (Gentzke et al. 2020), which puts untreated caries at a similar level of public health priority.

Developmental Tooth Defects and Dental Fluorosis

The impact of developmental tooth defects among adolescents continues to be an understudied area in oral health. Several forms of hypomineralized teeth often wear more poorly or fracture more easily than normally formed teeth, and they can be more susceptible to tooth decay (Bullio Fragelli et al. 2015). As a result, these teeth are more likely to require more extensive restorative treatments beginning in later childhood and through adolescence.

Figure 8. Percentage of adolescents ages 12–19 with dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of untreated dental caries in permanent teeth (DMFT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

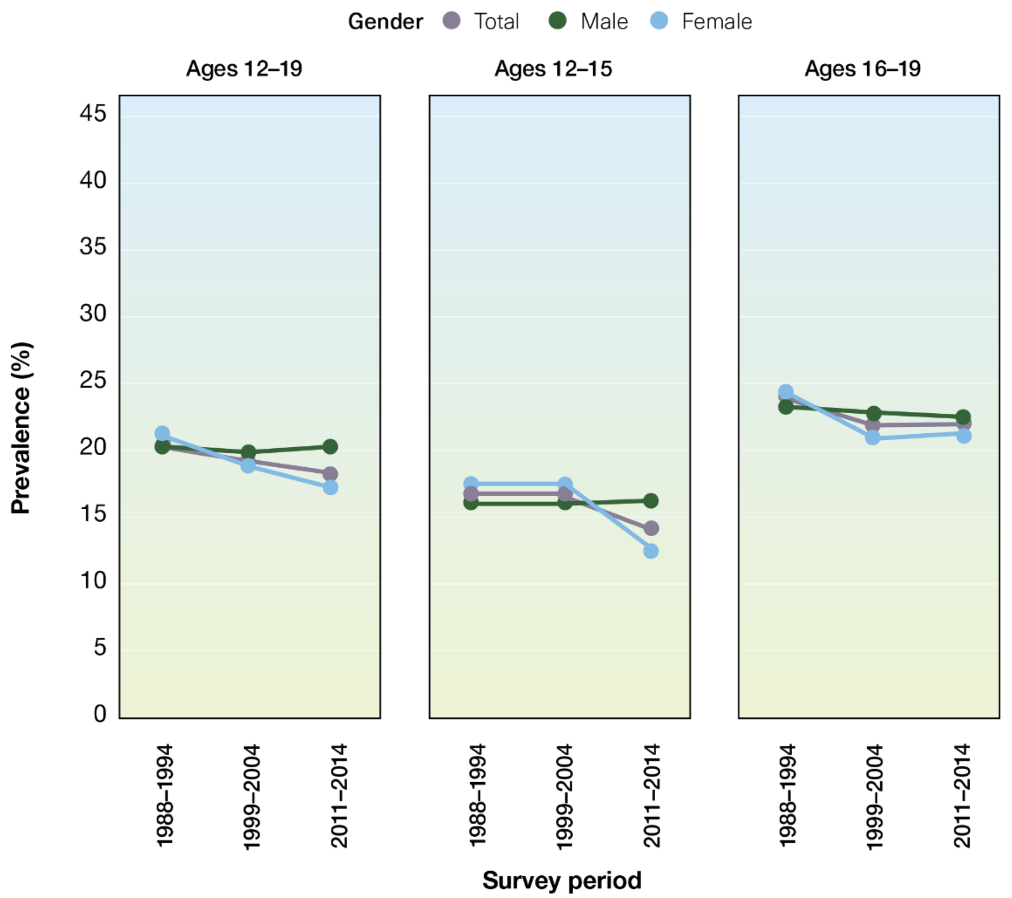
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Current understanding of the distribution, patterns and determinants of developmental tooth defects is severely constrained by the lack of data. Moreover, improving surveillance of these conditions, especially dental fluorosis, continues to be challenging.

Although the prevalence of moderate/severe forms of dental fluorosis is thought to be low in the U.S. adolescent population (estimated to be <4%), this assessment is nearly 2 decades old and limits our understanding of the epidemiology of dental fluorosis in America. In a global review of dental fluorosis trends among youth, which included studies from the U.S., the authors described a gradual, but small, increase in the global prevalence of dental fluorosis from 1980–2000 (Khan et al. 2005). Two recent reports have suggested that dental fluorosis is increasing among adolescents in the U.S. (Neurath et al. 2019; Wiener et al. 2018), but there is controversy regarding the increase reported for moderate forms of dental fluorosis, in particular (Kumar et al. 2020; Neurath et al. 2019; Neurath et al. 2020). Further adding to uncertainty, a technical report from the National Center for Health Statistics (2019) concluded that, although interrater examiner reliability assessments were within acceptable limits, observed increases in dental fluorosis in the National Health and Nutrition Examination Survey were uncertain, given concerns with biologic plausibility using historic assumptions.

It is important to recognize that later erupting teeth, such as premolars and second molars, are susceptible to developing fluorosis up to age 8 and possibly longer (Bhagavatula et al. 2016), resulting in some changes in dental fluorosis prevalence as youths age from childhood through adolescence.

Figure 9. Percentage of adolescents ages 12–19 with untreated dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

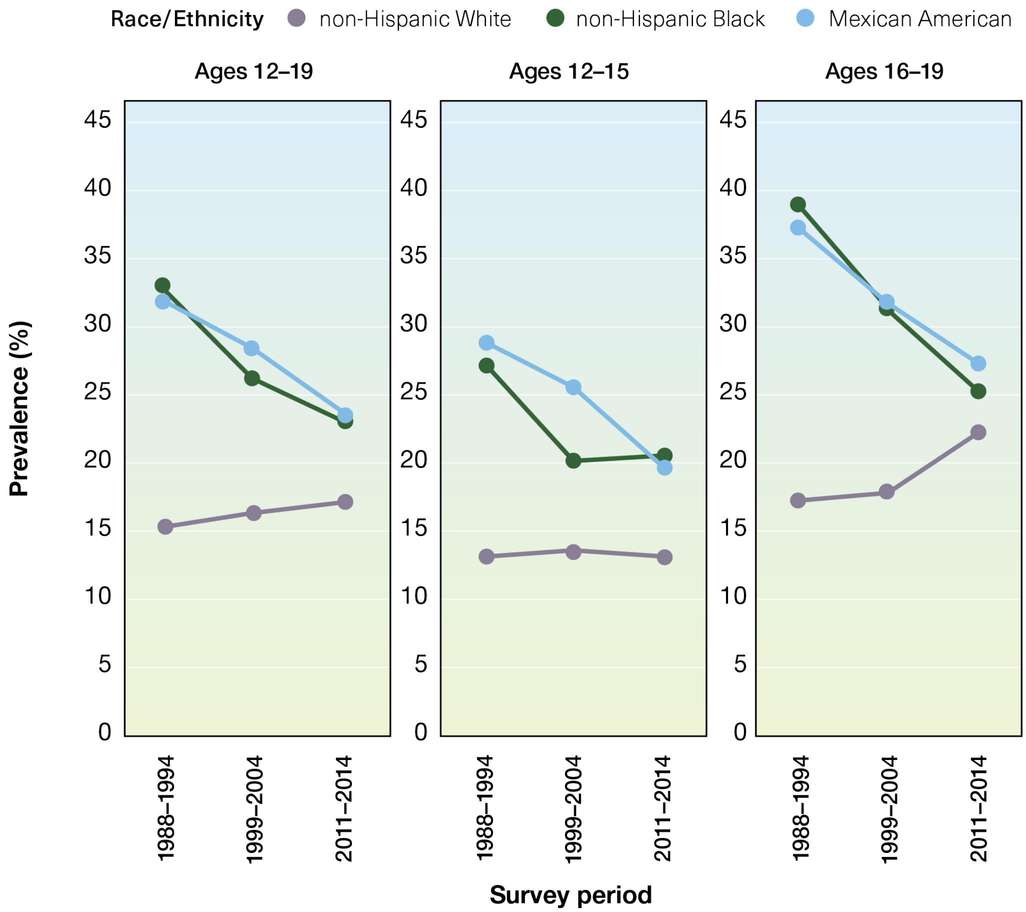
Although there have been substantial changes in lifestyle, behaviors, and preferences affecting fluoride exposure among youth during the past 20 years, better understanding is needed regarding the factors affecting dental fluorosis prevalence in the U.S.

Dental Erosion

Adolescents face many of the same oral health challenges as younger children, plus a few that are specific to them. Adolescents reporting gastric reflux problems also have increased problems related to dental erosion (Skalsky Jarkander et al. 2018). Some also experience dental erosion as a result of bulimia nervosa, which affects 0.3% of U.S. adolescents (National Institute of Mental Health 2017). The association of dental erosion with chronic self-induced vomiting may require psychiatric intervention as well as tooth repair. In cases of chronic gastroesophageal reflux disease from systemic illness, collaboration between medical and dental providers can facilitate an oral health care plan that addresses erosive factors. In general, a multidisciplinary approach may lead to better outcomes in overall health and long-term stability for adolescents.

Another ongoing challenge affecting our ability to better understand dental erosion is the lack of clarity about its prevalence, which remains unclear, and the absence of a common assessment methodology, such as a tooth wear index (Salas et al. 2015). Future research should focus on documenting the unique dental erosion patterns that can be attributed to specific dietary habits, such as swishing an acid beverage, bulimic behavior, or facial surface erosion.

Figure 10. Percentage of adolescents ages 12–19 with untreated dental caries in permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

The potential interaction of adolescent behaviors, such as smoking or vaping, with acid exposures and dental erosion requires further study. Effective techniques to change behaviors related to dietary acid consumption also need to be evaluated.

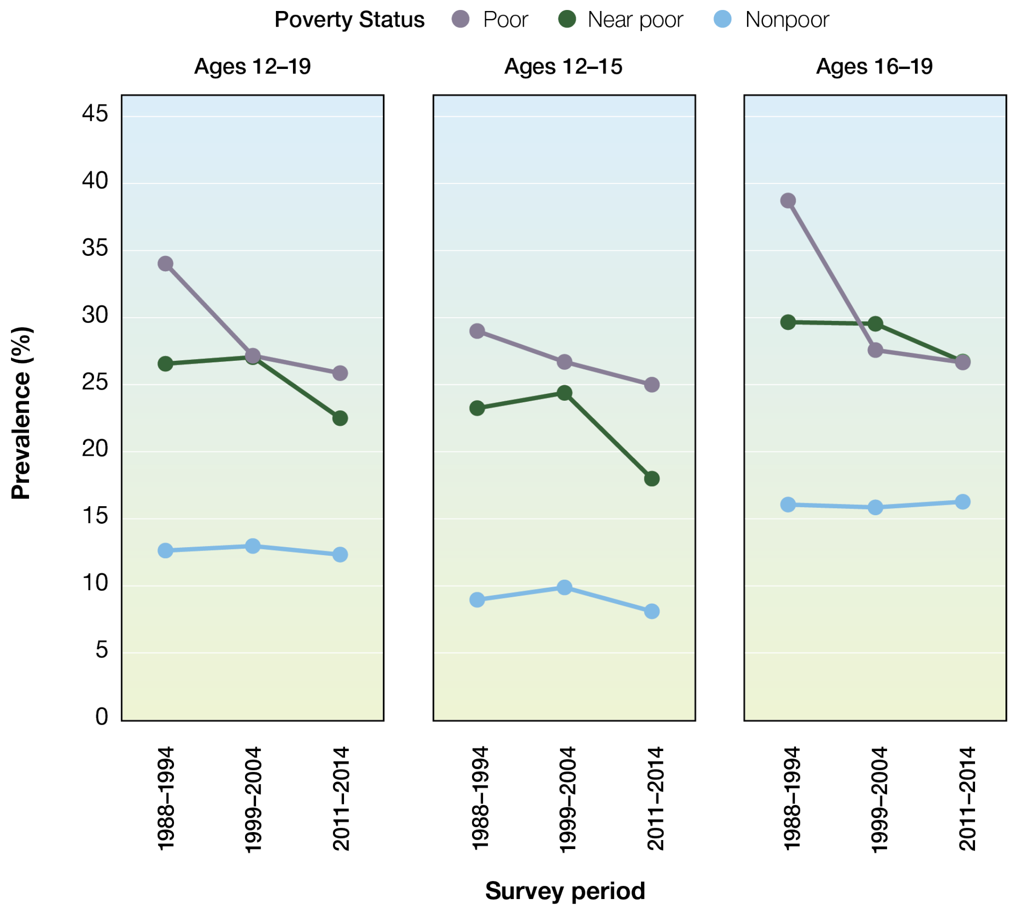
Periodontal Conditions, Malocclusion, and TMD

Unfortunately, there is little information about the prevalence of gingivitis and periodontal disease, or about malocclusion and temporomandibular disorders, among U.S. adolescents. Closing these surveillance research gaps would improve the body of knowledge on the prevalence of oral diseases and conditions for this age group. Treatment of malocclusion using alternative approaches, such as clear aligners, has not been vetted with clinical trials and remains unvalidated for managing orofacial conditions.

Oral Human Papillomavirus

Approved in 2014, Gardasil® 9 (HPV 9-valent vaccine, recombinant; Merck & Co., Inc.) is the only currently marketed vaccine in the United States that protects against high risk HPV types 16, 18, 31, 33, 45, 52, and 58 and low risk types 6 and 11. Data from clinical trials showed the HPV vaccine is effective in preventing oral HPV infections relevant for oropharyngeal cancers, as well as in preventing the incidence of cervical precancers and cancers.

Figure 11. Percentage of adolescents ages 12–19 with untreated dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of untreated dental caries in permanent teeth (DT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

In 2018, HPV vaccination coverage was 51.1% for adolescents aged 13 to 17 years, and 68.1% had received one or more doses of the HPV vaccine. Although this was substantial progress for the Gardasil® 9 vaccine, which was approved by the U.S. Food and Drug Administration (FDA) in 2014, no state met the more ambitious Healthy People 2020 target for HPV vaccination (receipt of 2 or 3 doses by 80% of persons aged 13 to 15 years) (U.S. Department of Health and Human Services 2021). More efforts at the state level are needed to meet this goal and to reduce geographic disparities in HPV-associated cancer incidence rates during the next few years, such as the state of Oregon's decision to allow dentists to administer the vaccine (Walker et al. 2019).

One of the best ways to increase HPV vaccination rates is for a medical professional to provide a recommendation (see Table) (Vadaparampil et al. 2014). Universal coverage has the potential to reduce the burden—not only of cervical cancer, but also of other HPV-related cancers, including those that affect oral health. Dental providers may be the first clinicians to diagnose HPV-related oropharyngeal cancers (OPCs), thereby playing a critical role in preventing oral HPV infections. Indeed, the American Dental Association (American Dental Association 2018a) urges dentists to support administration of the HPV vaccine (American Dental Association 2018a), and oral health professionals have been involved in several prevention programs

Table. HPV vaccine information

9-valent HPV vaccine (Gardasil® 9)	
Manufacturer	Merck
Year Licensed	December 2014 for males and females
HPV types protected against by vaccine	HPV types 6, 11, 16, 18, 31, 33, 45, 52, and 58
Adjuvant in vaccine	AAHS: 500 µg amorphous aluminum hydroxyphosphate sulfate
Recommended for…	• Females and males ages 11 or 12 (can start at age 9) • Persons ages 13 through 26 who have not been adequately vaccinated previously
Contraindicated for…	• People with immediate hypersensitivity to yeast
• HPV vaccines are administered as a two-dose series (0, 6–12 months) for most persons who initiate vaccination at ages 9 through 14 years, and a three-dose series (0, 1–2, 6 months) for persons who initiate at ages 15 through 45 years and for immunocompromised persons.	

Source: Centers for Disease Control and Prevention (2019b).

(e.g., tobacco cessation programs) in the past (Coan et al. 2015; Jannat-Khah et al. 2014; Omana-Cepeda et al. 2016), setting the stage for their involvement in the prevention of cancers caused by HPV infections (Daley et al. 2011; Vazquez-Otero et al. 2018). Because approximately 4 out of 5 adolescents aged 12 to 15 years visit a dentist in a given year and dental utilization has been improving the last 2 decades for those in lower income households (Figure 15), dentists and other oral health professionals are well positioned to be frontline advocates and implementers for this key health issue.

High-Risk Behaviors Affecting Adolescent Oral Health

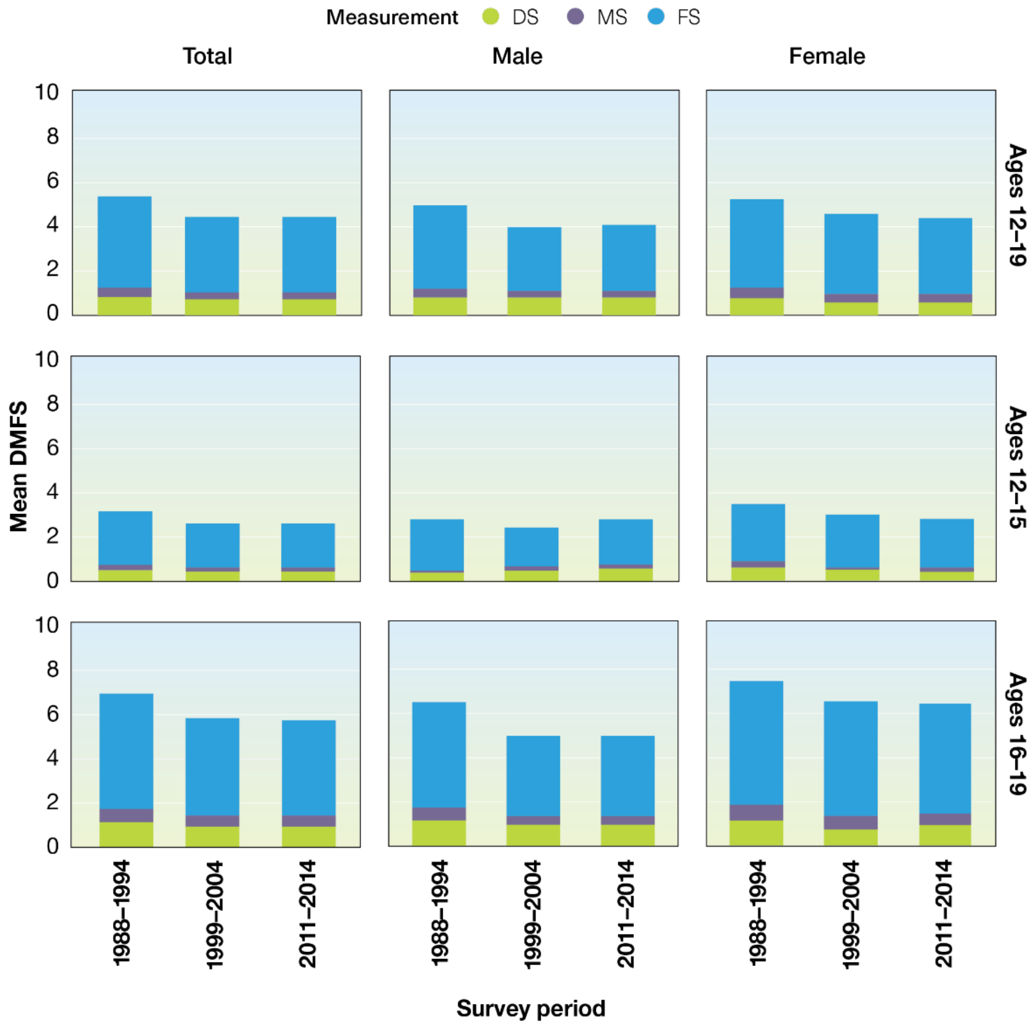
Alcohol and Illicit Drugs

Alcohol use by adolescents during the past 20 years has mostly trended downward (Johnston et al. 2020) across gender, race, and ethnicity. Heavy drinking (defined as consuming five or more drinks in a row within the past 2 weeks, with the possibility of a binge-drinking pattern) has declined in all age categories, from a prevalence of more than 25% for 12th-graders in 2000, to 14.4% in 2019. Heavy episodic drinking continues to be low for children younger than 13 years and is less than 1% for those between 10 and 12 years of age. Although African American adolescents continue to report a lower prevalence of binge drinking than their White and Hispanic peers, the differences diminish in 10th and 12th grades, as relative rates of decline have been more rapid among Whites and Hispanics (Johnston et al. 2018).

Although binge drinking has been declining among adolescents, marijuana vaping has seen a significant increase, with 7.0%, 19.4%, and 20.8% of 8th-, 10th-, and 12th graders, respectively, reporting that they had engaged in marijuana vaping during the past year, and 3.9%, 12.6%, and 14.0%, respectively, reporting that they had engaged in marijuana vaping during the past 30 days (Johnston et al. 2020). African American 12th-grade students have had the largest increase in marijuana use (Johnston et al. 2018). Marijuana use often occurs in combination with alcohol, e-cigarette, and other tobacco use, so it is difficult to determine whether the etiology of related poorer oral health (e.g., higher incidence of periodontitis and caries) is only associated with marijuana use (Ditmyer et al. 2013; Kowitt et al. 2018). The poorer oral health of marijuana smokers also may be the result of poor oral hygiene, dry mouth, frequent consumption of sugary food and beverages, and less frequent dental visits. Although use of most other illicit substances appears to be highest among Hispanic adolescents, prescription drug use continues to be higher among White than among Hispanic or African American adolescents.

The use of major illicit drugs (cocaine, opioids, and amphetamines) by adolescents also has declined since 2000 (Johnston et al. 2020), but opioid overdoses are increasing alarmingly among this group (Chatterjee et al. 2019), with opioid-related emergency-department visits increasing more than 1,000% for those younger than 19 (Hasegawa et al. 2014). This increase has corresponded to an increase in overdose deaths for adolescents since 2015, particularly related to nonmedical use of prescription opioids (Curtin et al. 2017).

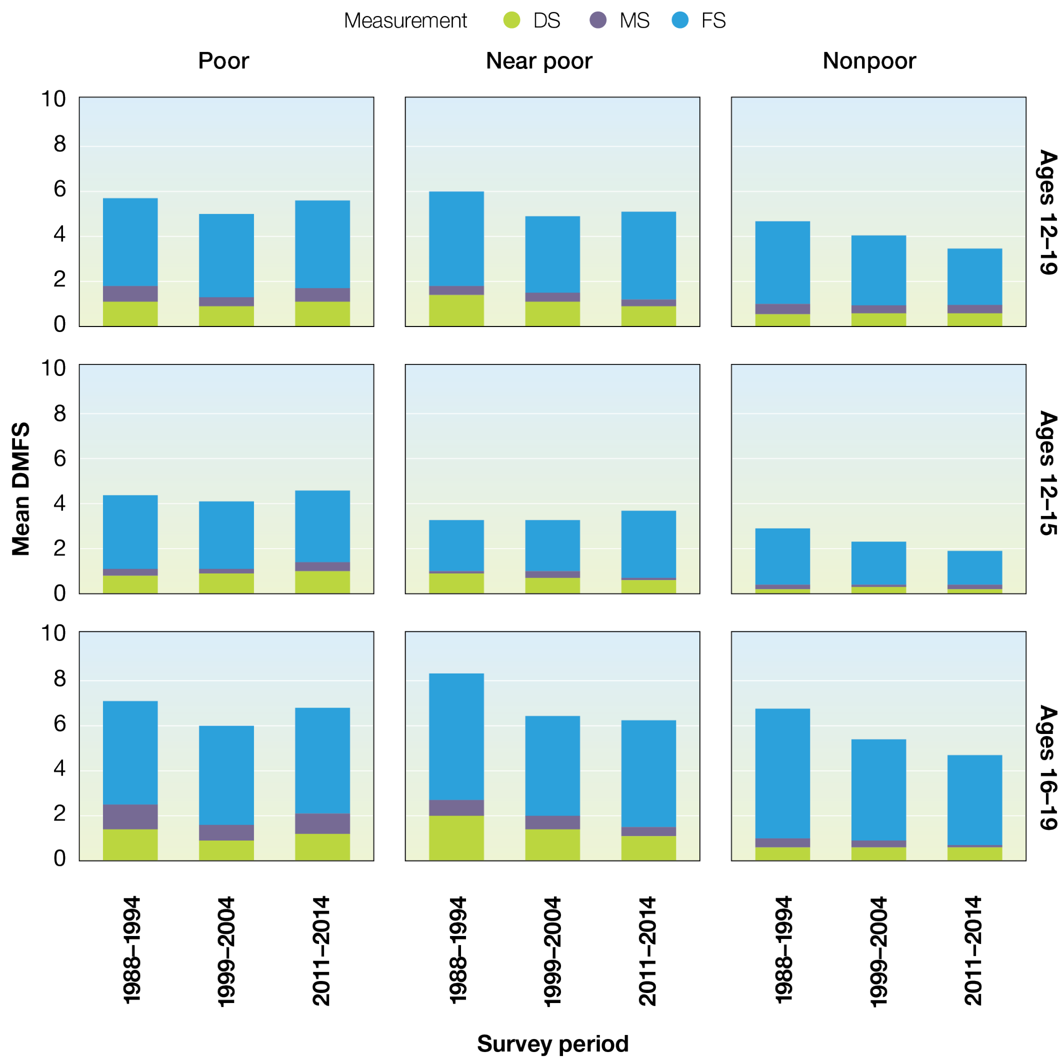
Figure 12. Mean number of decayed (DS), missing (MS), or filled surfaces (FS) of permanent teeth in adolescents ages 12–19 by gender and age group: United States, 1988–1994, 1999–2004, 2011–2014



Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Drug overdose deaths continue to be highest for non-Hispanic White men; however, women and African American adolescents have shown a higher rate of increase, with three- and fourfold increases in annual overdose deaths since 1999, respectively (Curtin et al. 2017). The availability of opioids and higher-potency opioids (e.g., fentanyl), as well as nonmedical use of prescription opioids, has been a key driver of this crisis. Given the negative consequences of alcohol and substance use on oral health (Baghaie et al. 2017; Bagnardi et al. 2015; D'Amore et al. 2011), the overall downward trend in alcohol and some illicit substance use among adolescents is good news for oral health. The relationships of heavy alcohol use to oral cancers (Bagnardi et al. 2015) and to oral trauma (Shetty et al. 2011) have become well established during the past 20 years. The negative impact of substance use on dental caries, tooth loss, and periodontal disease also has been well characterized (Baghaie et al. 2017). A greater understanding now exists of how substance-use patterns and risk factors in adolescence may establish lifetime patterns that lead to negative oral health outcomes. For example, researchers better understand how alcohol and substance use influence neurological substrates of reward and self-control among adolescents (Schweinsburg et al. 2010; Blest-Hopley et al. 2018).

Figure 13. Mean number of decayed (DS), missing (MS), or filled surfaces (FS) of permanent teeth in adolescents ages 12–19 by poverty status and age group: United States, 1988–1994, 1999–2004, 2011–2014

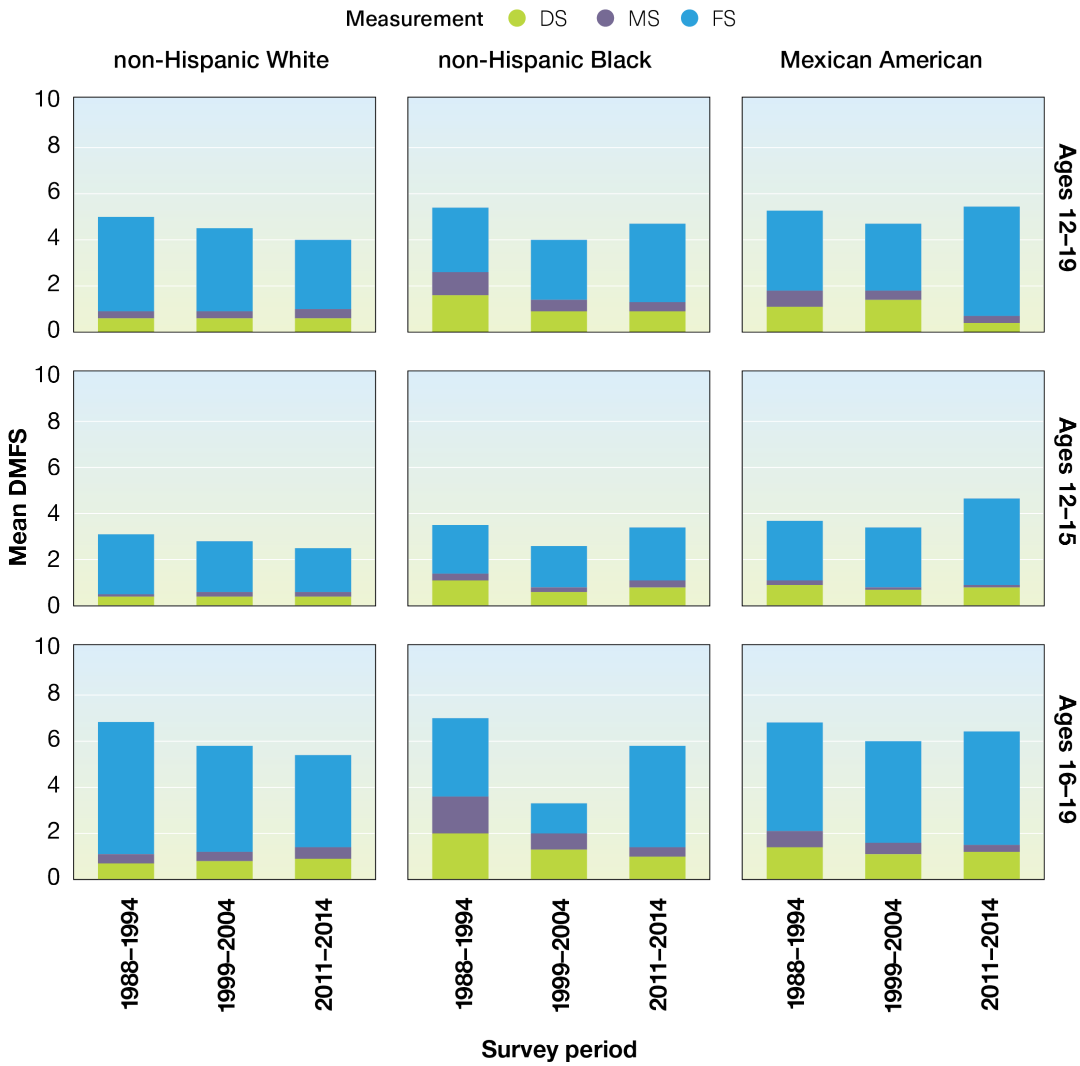


Note: **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

More generally, the growth of neuroscience research in the addiction field has advanced our knowledge about the consequences of alcohol and substance use on the developing brain and its impact on judgment and decision making (Conrod and Nikolaou 2016), providing new opportunities to identify substance-related risk factors, understand mechanisms of substance abuse, and clarify mechanisms of behavior change for adolescents (Feldstein Ewing et al. 2011).

Considerable research during the past 20 years has been devoted to the use of tools and strategies to identify and treat alcohol and illicit drug use in adolescents, which also can be assumed to benefit oral health. For younger adolescents, it is particularly important to consider broader social systems that affect them, including parents, families, and school systems (Chadi et al. 2018). A number of approaches that use motivational interviewing (MI) have been shown to reduce alcohol and substance use across a range of health care contexts (D'Amico et al. 2018), including situations involving facial trauma (Gao et al. 2014). MI also has been used to improve health behaviors among adolescents (Gayes and Steele 2014).

Figure 14. Mean number of decayed (DS), missing (MS), or filled surfaces (FS) of permanent teeth in adolescents ages 12–19 by race/ethnicity and age group: United States, 1988–1994, 1999–2004, 2011–2014



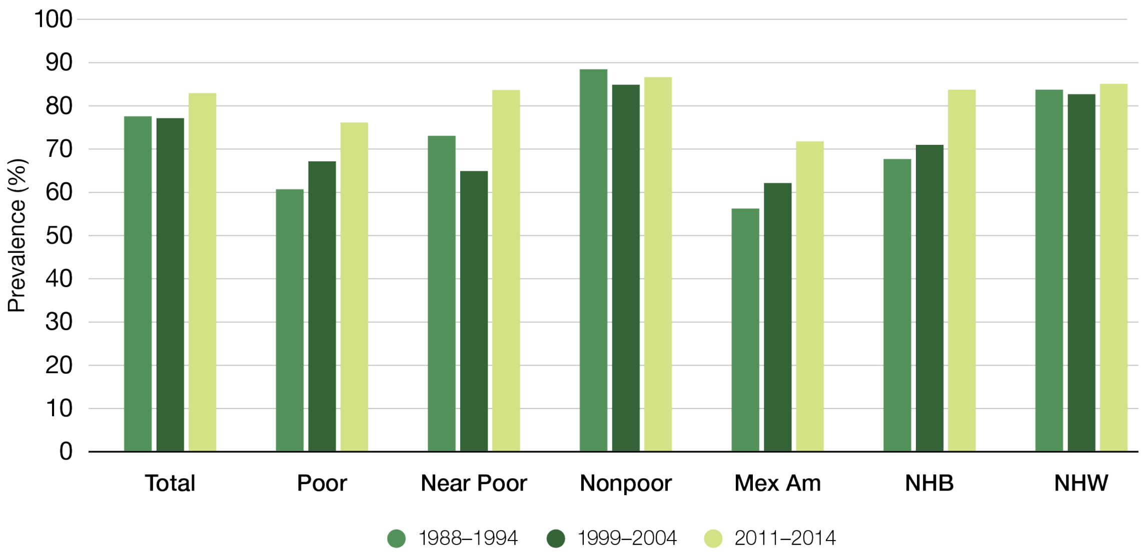
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Screening and brief intervention have been used in a variety of medical settings to address alcohol and marijuana use among adolescents (Bernstein et al. 2009; Monti et al. 2007; Newton et al. 2018). New conceptual models of how and when to conduct screening, brief intervention, and referral to treatment have greatly improved our capacity to address adolescent alcohol and substance use. This has been accompanied by considerable advances in behavioral health technologies (e.g., web intervention, smartphone apps, games, text messaging), which have the potential to further expand access to assessment and treatment.

Tobacco Product Use

The use of many tobacco products among adolescents has declined, with implications for positive outcomes in oral health. However, there are vulnerable populations that have a much higher prevalence of smoking than the adolescent population at large, including those in the juvenile justice system (American Academy of Pediatrics 2011), adolescents who live in trailer parks (Bhoopathi et al. 2016), and youth with physical disabilities (Borrelli et al. 2014).

Figure 15. Percentage of adolescents ages 12–15 with a dental visit in the past 12 months by poverty status and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: FPG = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Youth experiencing homelessness often have higher rates of smoking—including a much higher smoking intensity—than the adolescent population at large (Tucker et al. 2015), and smoking is associated with academic attendance and high school-dropout rates (Orpinas et al. 2016).

Past 30-day use of cigarettes among 12th-graders decreased from 39% in 1976 to 5.7% in 2019, according to the Monitoring the Future study (Johnston et al. 2020). Initiation of smoking among 8th-graders decreased from a peak of 49% in 1996 to 9% by 2018 (Johnston et al. 2020). Among 12th-graders, past 30-day smokeless tobacco use declined from a peak of 12.2% in 1995 to 3.5% in 2019. Past 12-month use of hookahs (i.e., tobacco called "shisha"—smoked using a pipe with a long tube that draws the smoke through water), decreased among adolescents from 17.1% in 2010 to 5.6% by 2019. Past 30-day use among 12th-graders in 2019 was 7.7% for flavored little cigars and 4.9% for regular little cigars or cigarillos (decreasing from 11.9% and 7.0%, respectively, in 2014 when first measured), and was 5.3% for large cigars (down from 6.4% in 2014) (Johnston et al. 2020). The declining use of these products has the potential to impact adolescent oral health.

The decreasing use of some tobacco products among youth during the past 20 years is tempered by the recent substantial use of e-cigarettes among adolescents. For example, between 2011 and 2019, e-cigarette use increased from 1.5% to 27.5% among U.S. high school students and from 0.6 % to 10.5% among middle school students, leading the U.S. Surgeon General to declare youth e-cigarette use an epidemic in 2018. (NYTS 2011–2019). The Monitoring the Future study found similar rates (Johnston et al. 2020)—35.5% of 12th-graders reported vaping nicotine in the past 12 months, and 25.5% reported using e-cigarettes at least once per month in 2019, up from 11% in 2017.

A disturbing aspect of the latter trend is that e-cigarette use may increase the risk for combustible cigarette smoking (Goldenson et al. 2017). A consensus report of the National Academies of Sciences, Engineering, and Medicine (2018) concluded that adolescents and young adults who use e-cigarettes are more likely than nonusers to start smoking combustible cigarettes. Another challenge related to e-cigarette use is how little is known about the effect of vaping on oral health, whether in adolescence or adulthood.

Regarding e-cigarettes, in 2016, the FDA finalized a rule to deem most tobacco products subject to the agency's regulatory authority, including electronic nicotine delivery systems, which include e-cigarettes. In January 2020, FDA issued an enforcement policy on unauthorized flavored cartridge-based e-cigarette products, including fruit and mint flavors, which may be appealing to youth (cartridge or pod that holds liquid that is to be aerosolized when the product is used). In 2018, U.S. Surgeon General Jerome Adams issued a Surgeon General's Advisory on E-cigarette Use Among Youth. The advisory warned about the growing epidemic and harms of e-cigarette use among youth, and provided action steps that could be taken by parents, teachers, and others to address this public health epidemic (U.S. Department of Health and Human Services, Office of the Surgeon General 2018). On December 20, 2019, the president signed legislation to raise the federal minimum age for the sale of tobacco products, including e-cigarettes, to the age of 21 (U.S. Food and Drug Administration 2020). Before this, 19 states and 500 cities and towns had already raised the minimum age of sale to 21 years. In addition, in 2020, the Office of the Surgeon General released a report on smoking cessation that reviewed and updated the evidence on the importance of quitting smoking. The report included information on patterns and trends in tobacco cessation among youth aged 12 to 17 years (U.S. Department of Health and Human Services 2020a).

Nearly two-thirds of youths (65.4%) who reported current tobacco use in 2019 intended to quit, a proportion that fell slightly to 62.5% in 2020 (Zhang et al. 2021). Sussman and colleagues (Sussman et al. 2001; Sussman and Sun 2009) found a quit rate of about 4% across at least 64 controlled trials comparing clinic-based programming to standard care control or minimal programming. Among youth who did not quit, there was a 57% reduction in smoking after at least 3 months of follow-up. Programming that combined cognitive-behavioral approaches led to the highest quit rates. A Cochrane review identified limited evidence that group-based behavioral interventions were effective treatments for smoking cessation, but cautioned that more rigorous research was needed (Fanshawe et al. 2017).

Oral health professionals can encourage teenagers to quit by discussing the negative oral health consequences of tobacco use, which may facilitate quit attempts (Semer et al. 2005). However, the percentage of dental practitioners who engage in screening and tobacco-cessation counseling remains low. According to the 2011 National Youth Tobacco Survey, only 32% of 18,385 nationally representative youth in grades 6 to 12 reported being informed about the dangers of tobacco use from their dentist, and only 37% of those with any current tobacco use reported having been advised to quit tobacco (Schauer et al. 2014). This lack of counseling is likely related to a lack of training, rather than to perceived importance on the part of dentists. For example, a survey of 1,700 American Academy of Pediatric Dentistry members revealed that although 75% of respondents agreed that it is the pediatric dentist's responsibility to help patients stop smoking, only 11% had prior prevention/cessation training, and only 22% reported always/often assisting with stopping tobacco use (Yee et al. 2008).

A lack of knowledge among oral health professionals about e-cigarettes is also a barrier to the implementation of cessation efforts. A study of 1,722 U.S. dental practices revealed that only 36% of dental professionals felt knowledgeable about noncigarette tobacco products, such as e-cigarettes, and 38% failed to screen for e-cigarette use among youth (Isett et al. 2018).

Social Determinants of Health

More is being learned about how social factors at the personal, family, community, and national levels can affect adolescent health. Many of the factors are related to education, income inequality, and institutional influences operating at these levels (Viner et al. 2012). In addition, safe and supportive families, schools, and peers are critical for helping adolescents make positive, healthy transitions to adulthood (Viner et al. 2012).

In addition, approaches to adolescent health have moved beyond risk-factor reduction to an emphasis on enhancing protective factors (Catalano et al. 2002). It is now clear that parent and adolescent consumption of SSBs are positively related (Lundeen et al. 2018). Factors such as self-esteem and health perceptions also play a significant role (Baker et al. 2010). Although not well studied in oral health, resiliency-based approaches have been successful in other areas of adolescent health. For example, interventions such as yoga and mindfulness have been helpful for mediating the impacts of adverse childhood experiences (Bethell et al. 2016; Davis et al. 2019; Ortiz and Sibinga 2017; Whitaker et al. 2014). Resiliency-based approaches focus on family and peer factors to protect young persons from harm, but also emphasize that a successful and healthy transition to adulthood involves positive social and emotional development as much as avoidance of drugs, violence, and sexual risk (Catalano et al. 2002).

Barriers to optimal adolescent oral health exist at every level, including the individual, family, community, and policy levels. *At the individual level*, studies show that the perception of personal susceptibility to oral disease is usually low in adolescents (Dodd et al. 2014), consistent with theories of adolescent development that emphasize the need for autonomy and a sense of invincibility (Arnett 2001). Studies show that adolescents are motivated to seek dental care more frequently for aesthetic reasons rather than for maintenance of oral health (Dodd et al. 2014). Also, they are influenced by social media and the portrayal of celebrity smiles (Du et al. 2008). Research has demonstrated the importance of interpersonal relationships and dating during adolescence and the influence of parents, peers, and the media on self-care and self-presentation (Maida et al. 2015).

At the family level, adolescents from disadvantaged families often do not engage parents in their oral health care decisions because they do not want to be a burden (Atkins et al. 2010). Transportation can be particularly difficult in rural areas, and accessing care can conflict with parent and adolescent work schedules (Maida et al. 2015). Unhealthy dietary practices in the home are associated with poor oral health for adolescents (Lundeen et al. 2018). In a study using self-reported data from 5th-grade students, the consumption of soda, fruit juice, diet soda, frozen desserts, sweet rolls, candy, white rice/pasta, french fries, and cereal were positively associated with dental pain (Nicksic et al. 2018). However, increasing knowledge of the association between consumption of sugary foods and beverages and caries has not translated to behavior change (Lundeen et al. 2018).

At the community and policy levels, there has been little systematic study of the effects of social determinants on adolescent health. One exception is a study that identified structural determinants (e.g., income, gender and ethnic inequalities, access to education, war and conflict) as having a stronger role in adolescent health than more proximal determinants (e.g., schools, families, neighborhoods, peers), although both were acknowledged as important (Viner et al. 2012). During the past 20 years, much evidence for the relationship between SDoH inequities and oral health has been generated, but progress in decreasing those health inequities has not been realized. A targeted collection of information on social determinants is not routine in medical and community settings. Most electronic health records do not allow providers to cohesively collect or view data on SDoH (Sabato et al. 2018), nor do they provide anticipatory guidance regarding intervention or referral.

The prevalence of obesity among adolescents remains a challenge, having risen from 10.5% in 1988–1994 to 20.6% in 2013–2014 (Ogden et al. 2016). Because obesity and poor health can continue into adulthood, greater attention to nutritional quality and oral health in adolescents is warranted. However, the evidence linking adolescent obesity to oral health is mixed. It is likely that the relationship between obesity and oral health is indirect and relies on more proximal variables, such as sedentary behavior and the consumption of high-sugar foods. For example, greater television use is associated with poorer oral health and being overweight/obese (Russ et al. 2009). Adolescents who reported that their teeth were in fair/poor condition also engaged in less physical activity and were less likely to be on a sports team than those who reported that their teeth were in good/excellent condition (Telford et al. 2011). In addition, minority youths' exposure to advertisements for SSBs also may raise susceptibility for poor oral health (Cervi et al. 2017).

Existing conceptual models of SDoH, including life course models, need to be extended to include adolescence as a discrete period during which health-promoting and health-compromising factors and pathways are identified. Both theoretical development and testing of mechanistic constructs are severely underdeveloped in adolescent oral health. Theoretical models that have been used to successfully predict adolescent behaviors in other areas of health also can be tested to determine whether they predict behaviors in oral health. For example, targeted theories of risk-taking (Zinn 2019), identity formation (Peake et al. 2013), and peer contagion (Dishion and Tipsord 2011) seem primed for application to adolescent oral health. Advances in family theory may be especially relevant to adolescent oral health. For example, coercion theory describes a parent-child coercive process in which a parent and child inadvertently reinforce each other's difficult and negative behaviors and escalate conflicts until one party "wins" and the other withdraws, thus reinforcing this pattern for future conflicts (Patterson 1982). Smith Slep and colleagues (2018) were the first to apply coercion theory to children's oral health, but the evidence is limited, and research is ongoing. Family process and social interactions play an important role in promoting adolescent autonomy and health behaviors, yet there is surprisingly little empirical evidence directly linking family functioning to adolescent oral health outcomes.

Prevention and Management of Oral Diseases and Conditions

Dental Caries Prevention and Management

During the past 20 years, important progress has been made in protecting adolescent teeth with dental sealants. The prevalence of at least one sealed permanent molar in adolescents aged 12 to 19 years increased from 18% to 48% between 1994 and 2014 (Figure 16). For adolescents living in poverty, the prevalence of at least one permanent tooth sealed has substantially increased from 12% to 43% (Figure 17). Very large gains have also occurred for non-Hispanic Black and Mexican American adolescents (8% to 37%, and 18% to 44%, respectively) (Figure 18). The progress made in increasing sealant use among adolescents during the past 20 years has helped to dramatically reduce the disparity for this important preventive service between poor and minority adolescents compared with those who are nonpoor or non-Hispanic White.

Although there has been a substantial increase in the application of dental sealants (Figure 16), there has been little change in the overall prevalence of untreated dental caries in adolescents since 2000 (Figure 9). Furthermore, the more recent trend for dental caries experience is concerning, as it suggests a widening of the disparity in dental caries by poverty status, especially for adolescents aged 12 to 15 years (Figure 8). This is a clear signal that challenges remain with implementing effective prevention strategies at the individual and community levels for adolescents. The caries prevalence curve continues to increase dramatically as young people move through adolescence; by the age of 18, at least 3 out of every 5 experience tooth decay.

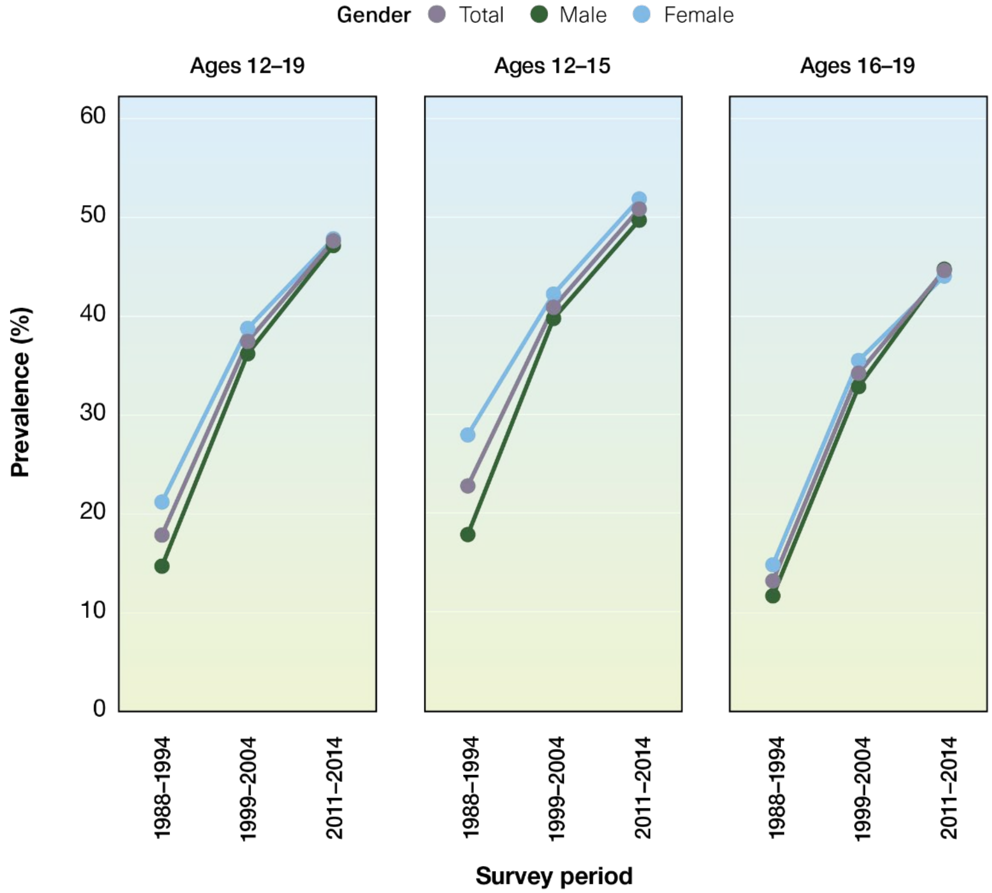
Currently, there are few policies specific to adolescents that promote oral health. Existing policies promote insurance coverage of fluoride varnish in young children by primary care providers, but not in teenagers. Also, current policies related to the inclusion of oral screenings and treatment covered under Medicaid's Early and Periodic Screening, Diagnostic, and Treatment provision (available for children under age 21 enrolled in Medicaid) or the coverage of preventive oral health services as an essential health benefit in the Affordable Care Act often appear to receive less focus for adolescents than for children.

Preventing and controlling dental caries in the adolescent population is critical for ensuring a lower caries burden as this group transitions from adolescence into young adulthood. Unfortunately, as teenagers age into adulthood, dental insurance coverage often changes owing to a variety of factors, including youth aging out of their parents' plans; the availability of insurance through public sources; and moving for college, employment, or other opportunities. More needs to be known about how to motivate adolescents and their parents toward healthy behaviors and away from the unhealthy ones that compromise oral health.

Management of Other Orofacial Conditions

Malocclusion and other craniofacial problems and their management remain challenges for a large segment of adolescents because of cost, duration of treatment, and emancipation from parental control. The number of dentists specializing in orthodontics is small, and adolescents seem to place a low priority on oral health compared to other aspects of life. Consequently, access to these services is challenging, and the management of malocclusion is rare for many segments of the adolescent population. In the future, this problem may be addressed to at least some extent by the use of telehealth, with alternatives to traditional orthodontic therapy. Unfortunately, surveillance of malocclusion has not been a priority for public health entities, and our knowledge about trends is sparse.

Figure 16. Percentage of adolescents ages 12–19 with dental sealants on permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



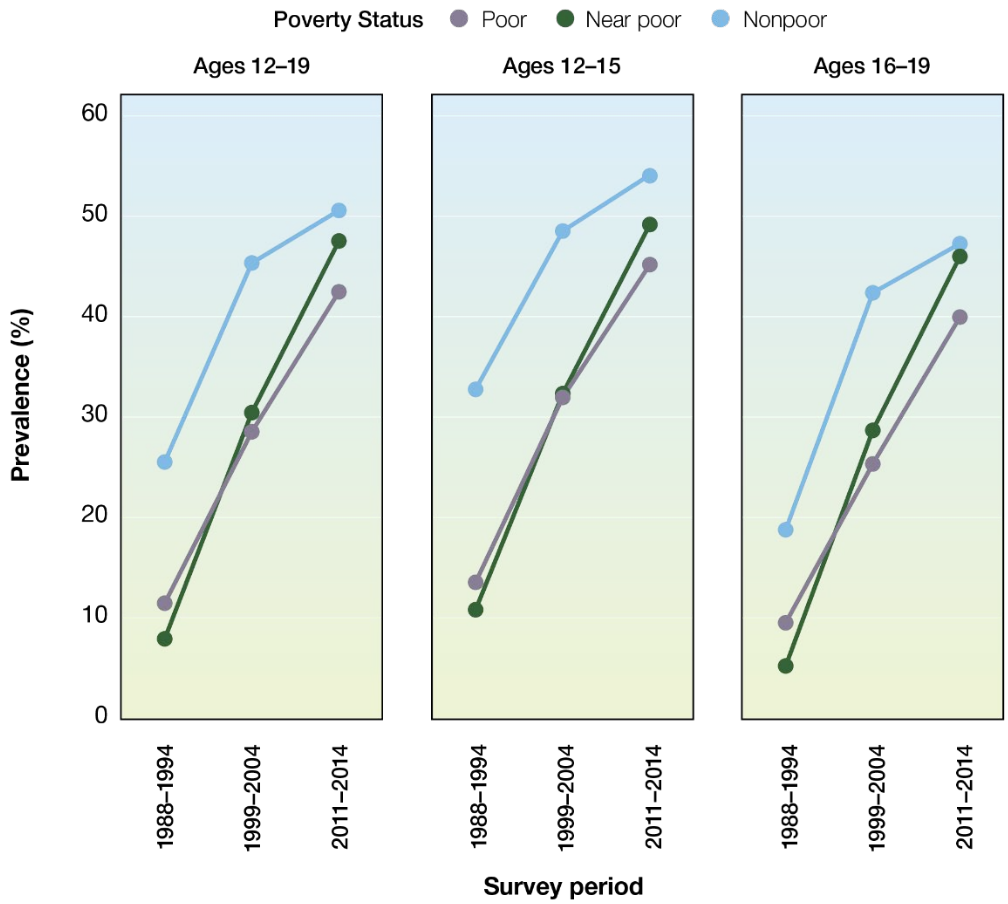
Note: Prevalence of dental sealants is having at least one permanent molar tooth sealed.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Pharmacological Management of Adolescents by Oral Health Professionals

Drug utilization is an integral part of the risk/benefit evaluation of oral health–related therapies for adolescents. Dental providers are known as significant contributors to outpatient antibiotic prescriptions in the United States (Durkin et al. 2017). From 2009 to 2018, antibiotics were the type of drug most commonly prescribed by dental providers for patients aged 11 to 20 years, followed by opioid analgesics and anti-arthritics (including nonsteroidal anti-inflammatory drugs). In 2018, dentists accounted for 15.8% of medical professionals who prescribed opioids, and 8.6% of opioid medications (Guy and Zhang 2018), with 9 in 10 reporting they were less likely to prescribe opioids to adolescents aged 11 to 18 years (Heron et al. 2021).

Numerous interventions to address the opioid crisis in recent years—by federal and state programs, professional associations, health care systems, insurance plans, and prescription drug monitoring programs—have resulted in a decline in opioid prescriptions by dentists (Rasubala et al. 2015). An estimated 1.2 million prescriptions were dispensed for opioid analgesics to patients aged 11 to 20 years in 2018, a 38% decrease from 1.8 million prescriptions in 2009, corresponding to a proportional reduction of 32% to 20% of all retail prescriptions dispensed to adolescents (Figure 19). By 2018, hydrocodone/acetaminophen was the most commonly dispensed opioid analgesic prescribed by dental providers for patients aged 11 years and older.

Figure 17. Percentage of adolescents ages 12–19 with dental sealants on permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental sealants is having at least one permanent molar tooth sealed. **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

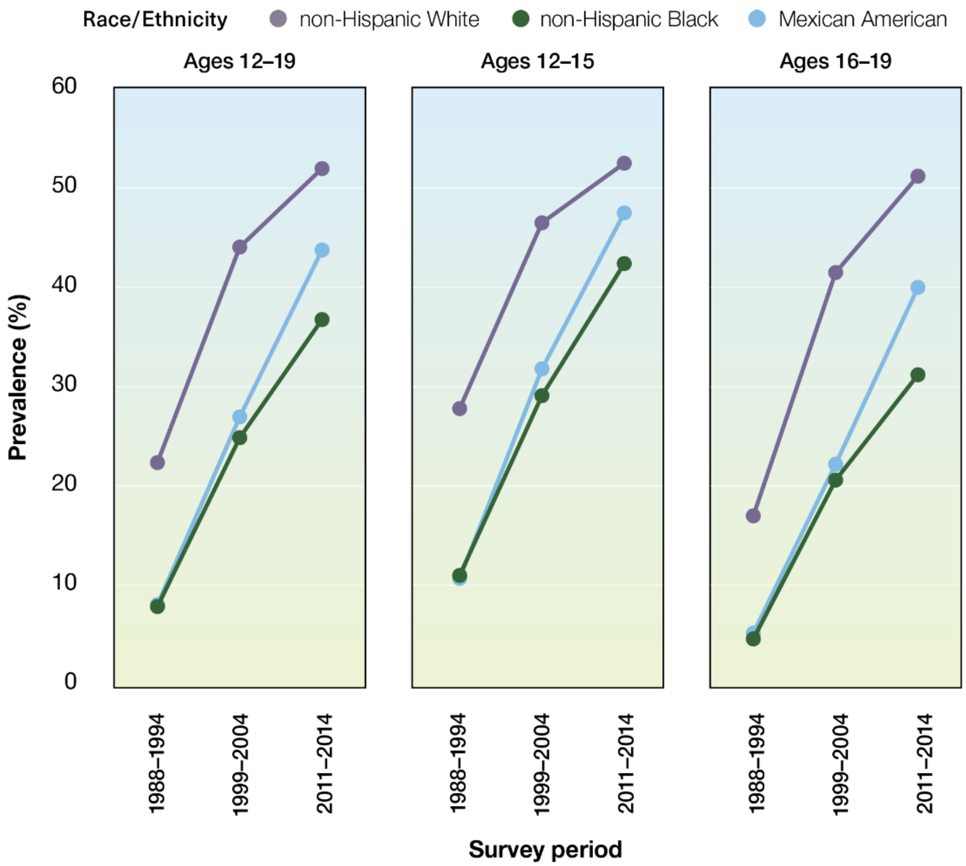
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Advances in pain control and the use of pain medication for delivery of dental care have evolved to make the procedures safer and more effective. These include enhanced guidelines (American Academy of Pediatric Dentistry 2020b), as well as certification of facilities and personnel for provision of sedation (American Association for Accreditation of Ambulatory Surgery Facilities 2019).

Health Promotion and Behavior Change for Disease and Injury Prevention

Use of mobile health and social media is prevalent among adolescents—crossing racial, ethnic, and income boundaries (Pew Research Center 2019). A recent systematic review assessing the effectiveness of nutritional behavior change using social media interventions reported that the most common improvement observed was with fruit or vegetable intake (Hsu et al. 2018). Two of four studies also reported decreased consumption of SSBs. However, the review also identified that most studies used outdated forms of social media, and that research using better quality interventions is needed. Although this review focused on improving adolescent nutrition, and not oral health, diet and oral health are closely connected. While there is much promise that mobile health and social media have the potential to positively impact adolescent oral health, substantial knowledge gaps remain on the benefits and limitations of social media for health communication purposes (Moorhead et al. 2013; Yonker et al. 2015).

Figure 18. Percentage of adolescents ages 12–19 with dental sealants on permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental sealants is having at least one permanent molar tooth sealed.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

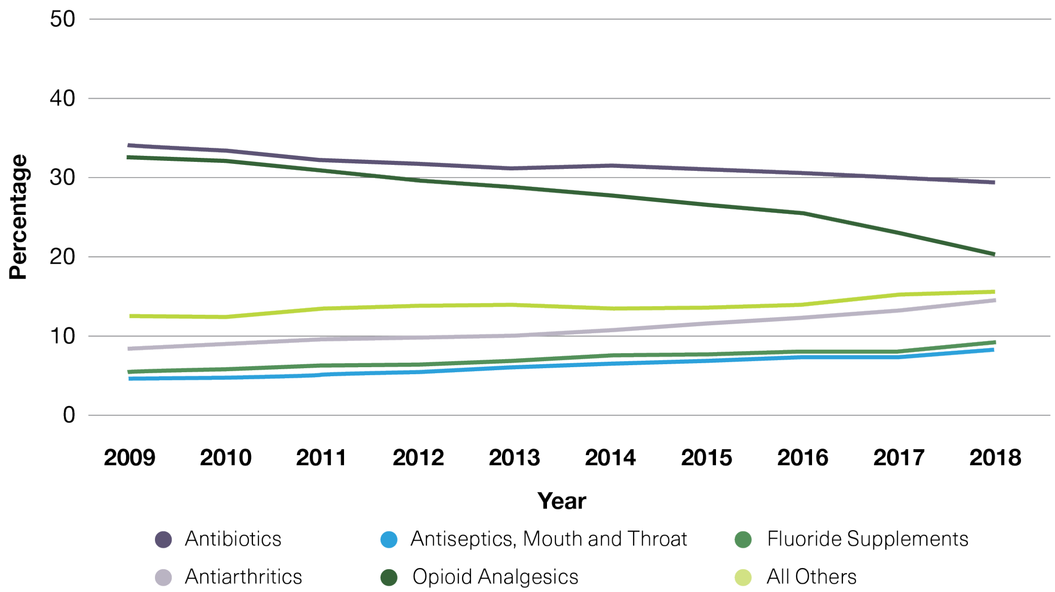
Adolescents with Disabilities and Special Health Care Needs

Although communication technologies offer opportunities to improve oral health care delivery in the adolescent population, work remains to be done to move these concepts to implementation and widespread practice. New uses of medications, such as BOTOX® to assist in neuromuscular disorders, and psychotropics, for the physical and emotional aspects of disabilities, are examples of applications that could be expanded to some adolescents with special health care needs (SHCNs) to help improve the delivery of oral health care (Dressler et al. 2017). Interprofessional care opportunities, as well as better integration of oral health into special education programs and Individualized Education Programs, offer opportunities not possible earlier. Recognition by the Commission on Dental Accreditation (Commission on Dental Accreditation 2019) of the need for the general dental community to be taught to care for persons with SHCNs is another opportunity for improvement and innovation.

Dental Insurance Coverage and Utilization of Dental Services

Since the turn of the century, there have been only small improvements in adolescents' utilization of oral health care. Among those aged 12 to 15 years, 82% have had a dental visit during the past 12 months, compared to 79% 20 years ago (Figure 15). However, substantial improvements have been seen for non-Hispanic Black and Mexican American teenagers aged 12 to 15 and for those living in poverty.

Figure 19. Ten-year proportion trend of retail prescriptions dispensed by drug class to patients ages 11–20 prescribed by dental providers: United States, 2009–2018



Source: Symphony Health PHAST Prescription Monthly. 2009–2018; extracted May 2019. Reprinted with permission.

In this age group, there was no change observed for non-Hispanic Whites or those living above 200% of the federal poverty guidelines. Although the trend has been positive for adolescents aged 16 to 19 years, the improvement was not statistically significant (70% vs. 75%) (Figure 20). Significant improvement has been observed for those aged 16 to 19 who are non-Hispanic Black, Mexican American, or living in poverty, whereas there was no change for non-Hispanic Whites or more affluent adolescents. The percentage of adolescents with any dental insurance coverage improved from 79% to 85% from 1999–2004 to 2011–2014, making adolescents the second-highest covered age group in the country, after children (see Section 2A – Figure 36). This increase in dental insurance coverage for adolescents has been driven by an increase in public insurance coverage, suggesting that Medicaid expansion and increased funding to support community health centers may be an important factor in improving the utilization of oral health services for those groups that have been underserved in the past. Importantly, this increase in utilization among these groups of adolescents is helping to reduce the historical disparities previously observed between less advantaged and more advantaged socioeconomic groups with regard to annual dental visits.

Chapter 3: Promising New Directions

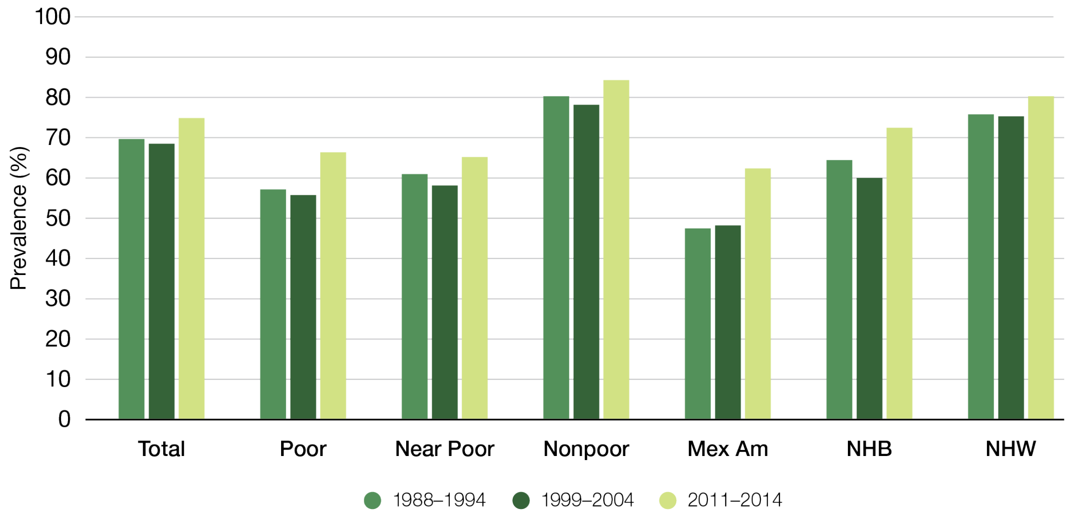
Recent high profile public health problems among adolescents—including the opioid epidemic, illness and death caused by vaping and other substance misuse, teen suicide, and cancers associated with human papillomavirus (HPV)—have revealed significant gaps in knowledge and a need to turn our attention to this critical period of the lifespan. Emerging solutions are being developed and tested to address pressing problems in this age group and set the course for positive oral health in adulthood.

High-Risk Behaviors Affecting Oral Health in Adolescents

Alcohol and Illicit Drugs

Because most adolescents who engage in risky drinking or illicit drug use will not seek treatment for these behaviors, interventions delivered through the normal course of health care, such as dental visits, may be an opportunity to intervene. Given that almost 80% of youth have seen a dentist during the past year, the dental setting is an ideal place for screening, brief treatment, and referral for tobacco cessation, alcohol, and substance use (Tomar 2001; Isett et al. 2018).

Figure 20. Percentage of adolescents ages 16–19 with a dental visit in the past 12 months by poverty status and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: FPG = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Also, adolescent oral health status may be an indicator for potential substance use. For example, dentists can detect the impact of tobacco products, including teeth stains, bad breath, and gum recession, among other negative consequences (Albert et al. 2006), as well as orofacial trauma, which often is the result of high-risk behaviors. Although national professional dental organizations have recognized the importance of screening for adolescent high risk behaviors (American Academy of Pediatric Dentistry Council on Clinical Affairs 2017), and many providers have successfully incorporated screening into medical settings (Bernstein et al. 2009; Monti et al. 2007; Newton et al. 2018), such screenings are rare when providing oral health care.

Professional standards include understanding the role of substance use in oral health and familiarity with screening and intervention options for adolescents, as well as the responsible use of anesthetics and prescribing practices in dental settings (American Dental Association 2018b). Research has shown that interventions with adolescents are improved by focusing on secondary exposure from parents or other adults (Allen et al. 2017) and monitoring the use of opiates in medical and dental settings.

Increasing awareness of the need for more education and training on opioid prescribing for dental pain (Garvin 2018) offers the promise of moving from opioids to other forms of clinical pain management and fostering research into alternative therapies. Research suggests that dentists may expose teenagers to opioids through either sedation during molar extraction or postoperatively in an effort to provide pain control (Fraser et al. 2017). Given the demonstrated efficacy of nonsteroidal anti-inflammatory drugs for pain management among molar surgery patients, consideration of opioid-sparing therapies for pain management is warranted (Fraser et al. 2017). As of 2018, the American Dental Association has established a policy guiding dentists in the use of pain medication with the intent of reducing the use of opioid medications to treat dental pain (American Dental Association 2019).

A promising practice initiated by oral surgeons is aiming to improve adolescents' oral health by reducing opioid prescriptions after wisdom tooth removal and educating them about oral cancers. Launched by the American Association of Oral and Maxillofacial Surgeons in partnership with several organizations, these programs are reducing opioid prescriptions for adolescents and raising awareness about HPV and oral cancer risk (Box 1).

Box 1. How does a professional community of oral and maxillofacial surgeons reduce oral health risks in adolescents?

Teenagers and young adults face specific oral health risks related to the removal of wisdom teeth, the experimentation with smoking and other tobacco use, and exposure to the HPV virus. Oral and maxillofacial surgeons are intervening by reducing opioid prescriptions after wisdom tooth removal and educating adolescents about oral cancers. The American Association of Oral and Maxillofacial Surgeons (AAOMS) has initiated several programs to reduce opioid prescribing. One program, made possible through partnerships with Aetna and Pacira Pharmaceuticals in 2017, enrolled 200 oral and maxillofacial surgeons who participated in a pilot program using a non-opioid pain management technique. These participants reduced by 17% the number of opioid tablets prescribed for patients undergoing the surgical removal of impacted third molars.

AAOMS also has made oral cancer awareness a priority public service topic. Recognizing that HPV is the leading cause of oropharyngeal cancer and that the fastest growing segment of the oral cancer population are nonsmokers younger than age 50, AAOMS developed messaging targeting younger patients. A comprehensive communications campaign was developed that includes press releases and television and radio spots for the general public, as well as toolkits for oral and maxillofacial surgeons and other dentists. To date, the TV and radio public service announcements have had a combined total of 109,165 broadcasts, with a broadcast audience impression of 598 million. Major partners in the communications campaign are the Oral Cancer Foundation, the Academy of General Dentistry, the American Academy of Oral and Maxillofacial Pathology, the American Academy of Oral Medicine, the American Academy of Periodontology, and the American Dental Hygienists' Association.

Tobacco Product Use

Few tobacco prevention and cessation interventions address multiple product use, the variety of tobacco products used (National Cancer Institute 2016), or how the use of multiple products affects adolescent oral health. Research that addresses these issues would go a long way toward improving the efficacy of smoking-cessation interventions in an oral health setting. Evidenced-based pharmacological and behavioral treatments that are effective in adults who smoke have not been sufficiently studied in adolescents in dental care settings. Innovative approaches for prevention and cessation currently are being developed that incorporate adolescent interests, such as gaming, social media, and virtual reality. These interventions could serve as adjuncts to dental office-based counseling (Borrelli et al. 2021) in smoking prevention and cessation among youth and young adults (Derksen et al. 2020). Digital gaming also may show promise as an intervention strategy to address health-related problems among vulnerable youths, such as HIV prevention (Hightow-Weidman et al. 2017). Similar games should also be explored for smoking prevention and cessation, and could prove to be especially effective among high risk groups. The high potential for addiction among youth that results from pod or cartridge-based e-cigarettes has been identified as an emerging threat to public health (Spindle and Eissenberg 2018). In addition, pod/cartridge-based e-cigarettes containing THC, the main psychoactive component of cannabis, have emerged. More research is needed to (1) understand the oral health consequences of vaping (with or without THC), either alone or in combination with nicotine use, and (2) outreach and prevention efforts addressed at older youth and teenagers.

Oral health professionals can play an important role in counseling adolescents to reduce or quit smoking or e-cigarette use. Resources for cessation referral that are tailored for adolescents include the local American Cancer Society, American Lung Association, or web-based programs; a school-based health center (Runton and Hudak 2016); a text messaging program (SmokefreeTXT for Teens), and a mobile-optimized website (Smokefree Teen) developed by the National Cancer Institute. The Truth Initiative also provides tools to help youth quit smoking and vaping (Truth Initiative 2021).

The dental office is a venue in which the 5As (Ask, Advise, Assess willingness, Assist in quitting, Arrange follow-up) and pharmacologic adjuncts can be effectively utilized (Tobacco Use and Dependence Guideline Panel et al. 2008; Agency for Healthcare Research and Quality 2012). Youth Tobacco Cessation: Considerations for Clinicians is a new resource that introduces an easy, 3-step model, Ask-Counsel-Treat (ACT), to guide clinical interactions around youth cessation. In addition, supplementary materials were created to support implementation of these clinical tools, including a tip sheet on how to integrate strategies within a health system's Electronic Health Record and a comprehensive list of behavioral cessation supports for youth and young adults (American Academy of Pediatrics 2021). Although the science is limited on effective ways to help youth quit tobacco use, increasing their use by oral health professionals could further reinforce societal cessation messages (Gordon et al. 2006) and help teenagers quit.

Provision of Adolescent Oral Health Care in Alternative Settings

School-Based Oral Health Programs and School-Based Health Centers

The reality that some children reach adolescence without a dental home has prompted approaches to linking children with dental care through the educational system, which offers tracking of attendance. This linkage of health care through school has been widely implemented for young children, including through Head Start programs that have helped to reduce unmet dental need for many preschool children living in poverty. Providing teenagers with opportunities to access dental care through school is a promising new direction that has great potential in reducing unmet dental need among adolescents at high risk for poor oral health. For example, when a private-public partnership opened a dental clinic within Cincinnati's Oyler Community Learning Center, a K–12 school, some of the high school students had never seen a dentist (Healthy Schools Campaign 2018 [February 15]). Using school health resources to help navigate students to needed dental care has the potential to improve oral health for many teenagers. The American Academy of Pediatric Dentistry supports legislation mandating comprehensive oral examinations before school matriculation (American Academy of Pediatric Dentistry 2017b). Several states and cities have initiated these guidelines within their school systems.

Community Partnerships

The development of partnerships between the health care system and the broader community represents an important and promising direction. Health care providers and oral health professionals encounter firsthand the impact of poor living environments on patient health and are in a position to partner with social workers, community representatives, and others to help address SDoH. One qualitative study identified programs that addressed the root causes of health disparities by creating linkages across multiple sectors of health, social, and community-based programs and services to promote health equity for adolescents (Tebb et al. 2018). For example, in tackling poverty, the health and social service sectors worked together to implement a range of approaches (e.g., job/skill preparation, housing, prescriptions, and teen pregnancy prevention efforts). Approaching patient care from a holistic perspective, which incorporates the patient's medical, dental, and psychosocial history, improves patient outcomes (Sabato et al. 2018). Also, education on SDoH is needed in dental education and is beginning to appear in dental curricula, including hands-on opportunities (Sabato et al. 2018; Tiwari and Palatta 2019). For example, some dental schools are incorporating poverty simulation into their curricula as a teaching approach in which students put themselves in situations in which they must make decisions with the resources, strategies, and limitations that challenge their low income patients (Lampiris et al. 2017).

Chapter 4: Summary

Oral health is important for overall health and well-being across the entire lifespan. Adolescence is the portal to adulthood, the time when children transform into young adults, acquiring adult capabilities, problems, and diseases, including those related to the mouth and craniofacial area. In recent years, adolescents have not always received full consideration in oral health programming, dental education, clinical practice, and research. However, there is growing recognition that opportunities exist to address issues specific to this population and to make a difference in adolescent oral health outcomes that can persist for a lifetime.

A major issue among adolescents is the prevalence of dental caries (58%), with little improvement since 2000 seen among some groups, particularly among those living in less affluent households and those who are Mexican American. Although untreated caries is declining among lower income adolescents, the prevalence of untreated tooth decay is higher than many chronic diseases but has garnered much less public health attention. Socioeconomic and racial/ethnic disparities in caries among adolescents have seen some important changes since 2000. Regarding overall caries experience, the disparity between Mexican American and non-Hispanic White adolescents is increasing, as the disparity between non-Hispanic Black and non-Hispanic White adolescents has declined. The disparity between lower income adolescents and more affluent adolescents is substantially increasing. On the other hand, earlier disparities for untreated tooth decay have been declining for Mexican Americans, non-Hispanic Blacks, and poor adolescents during the past 20 years of national oral health surveys. The changing picture of dental caries in adolescents still reflects the observation that not all teenagers benefit equally from advances in caries prevention and improved access to oral health care. Reduction of such disparities remains a priority for the oral health care community.

Oral health conditions common in adulthood take root in adolescence. For example, TMDs in adolescents are associated with the pubertal stage but otherwise are likely to have complex causes in adolescents similar to those of adults; these require further study. The third National Health and Nutrition Examination Study, conducted from 1988 to 1994, provided the last national data for adolescents on gingivitis, periodontal disease, and malocclusions. These conditions need to be included again to confirm that prevalence remains low, especially in light of recent increases in vaping and diabetes that could affect the prevalence of periodontal disease. In addition, improvements in surveillance and data collection are needed to effectively monitor the impact of developmental tooth defects and dental fluorosis in permanent teeth.

The use of alcohol and illicit drugs remain important risk factors for oral problems among adolescents, with implications for oral-facial trauma as well as for greater negative oral health outcomes as they move into adulthood. A greater understanding of how substance use and other risk factors in adolescence lead to negative oral health outcomes is needed. Although the data indicate a general decline in alcohol and illicit drug use among adolescents, other trends—the rising use of marijuana by older African American adolescents, binge drinking in males, and elevated opioid overdoses and deaths—suggest that there are pockets of populations that are uniquely vulnerable to particular substance use and should be more fully examined. The use of e-cigarettes and the vaping of nicotine and marijuana have risen dramatically, and these behaviors increase the risk for using combustible cigarettes. Consequently, vaping has become an urgent public health problem, with 1 in 5 high school students now using (Gentzke et al. 2019). Healthy People 2030 has set a target for decreasing e-cigarette use in adolescents in grades 6 through 12 to 10.5% (U.S. Department of Health and Human Services 2020b). These challenges present opportunities for oral health professionals to screen adolescent patients and deliver brief interventions, especially for those who may not otherwise have access to these services.

Minority adolescents who live in poor neighborhoods with parents of low educational background are at increased risk for poor oral health. Conceptual and theoretical models of social determinants of adolescent health need to be developed and tested to respond effectively to this population's unique risk and protective factors, as well as critical biological, cognitive, and social milestones. Identifying the mechanisms and pathways between social determinants of health (SDoH) and adolescent health can point to effective, multilevel and multisector interventions. Improving the general health and oral health of adolescents requires improving their daily lives—in school, employment, housing, and environment, thereby enhancing protective factors in the social environment and at a population level.

In addition, dental practitioners must be educated on the importance of human papillomavirus (HPV) vaccination as a cancer-prevention tool and the opportunity to promote HPV immunization during annual dental visits (Daley et al. 2019). Oral health professionals can deepen their knowledge of the etiology, progression, and prevention of HPV-associated cancers and familiarize themselves with current preventive strategies, such as HPV vaccination, among others (Brotherton and Bloem 2018; Liao and Brown 2014). These educational interventions are effective in increasing provider knowledge and awareness of HPV-related diseases and HPV immunization programs (Pampena et al. 2019; Shukla et al. 2019).

Because mobile technology is widely used by adolescents of all backgrounds, more research is needed on how to leverage this technology to promote oral health and reduce the effect of advertisements that work against oral health promotion, particularly among high risk groups.

In summary, adolescence is a paradoxical point in the lifespan; it is perhaps the least understood among age groups but offers the greatest potential for improving oral health in adulthood. During the past 20 years, a few main themes have emerged affecting oral health in adolescents in the United States (Box 2). Dental caries continues to be an important concern for adolescents, but periodontal disease, dental erosion, TMDs, and sexually transmitted infections—particularly HPV—warrant attention. SDoH affect health behaviors in adolescents and how they seek care. Finally, the adolescent transition is marked by new behaviors, including risk-taking, emotional and psychological disorders, and the use of drugs and tobacco, all of which have oral health consequences. Recognition of these issues has brought oral health providers together with medical, psychological, and social professionals to address these problems and improve health outcomes in the transition from adolescence into early adulthood.

Box 2. Key messages for Oral Health Across the Lifespan: Adolescents

- Adolescence is a critical time for establishing independent and positive lifelong oral health habits, even more so because many adolescents may lose eligibility for dental insurance as they enter adulthood.
- About half of all adolescents will experience dental caries; there has been little improvement in the past 20 years.
- Gum disease, dental erosion, and misalignment of the upper and lower teeth are concerns that first appear during adolescence. Adolescents are also prone to sports injuries affecting the mouth and face.
- Risk-taking behaviors that commonly occur in adolescence, such as tobacco and substance use, as well as the first occurrence of some mental health problems, can affect adolescents' long-term oral health.
- Adolescence is the best time for vaccination against human papillomavirus (HPV), which causes most oropharyngeal cancers. Oral health professionals are uniquely situated to provide HPV vaccinations.

Call to Action:

- Adolescence is a life stage that has been largely neglected by researchers and practitioners in oral health. Policy, education, and research opportunities should be developed to address the unique oral health challenges of this group.

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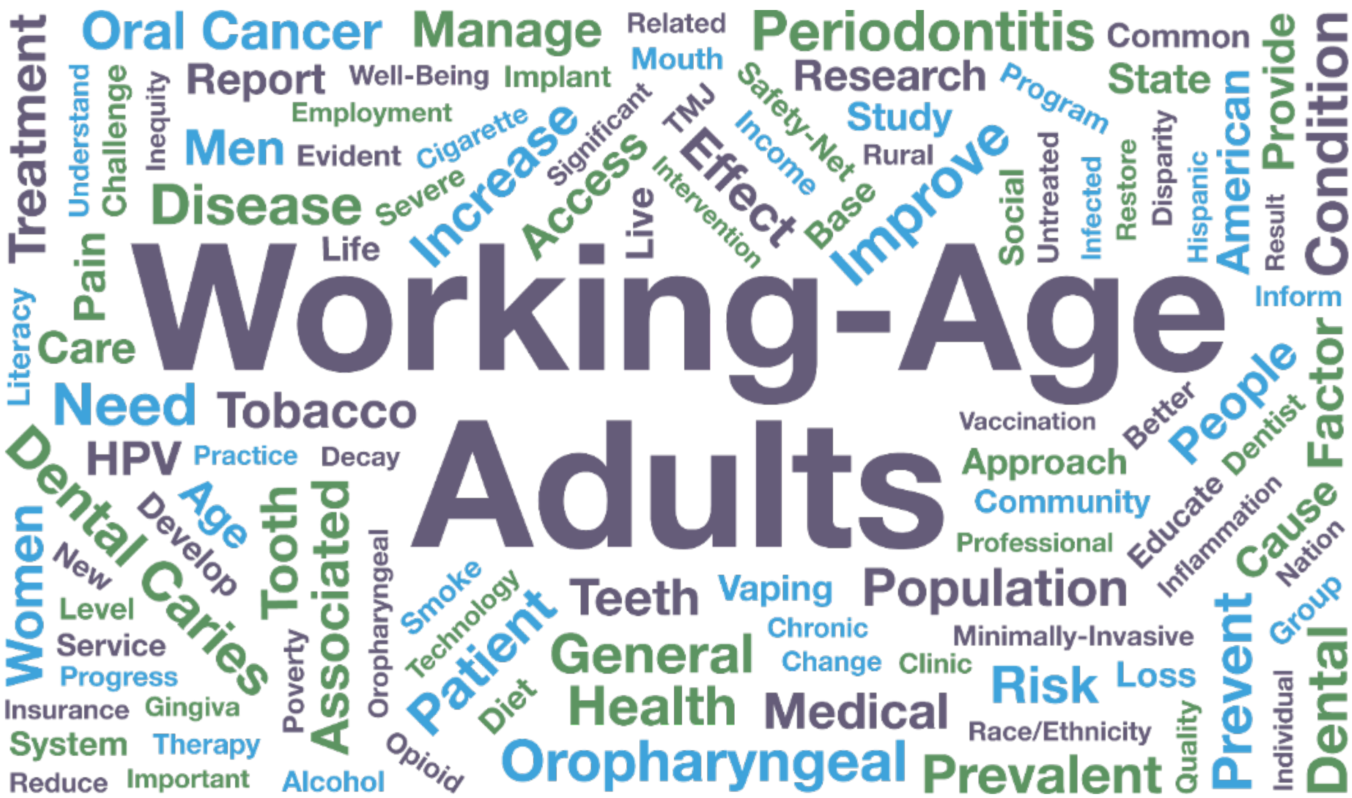
Working-Age
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Oral Cancer
Manage
Related
Periodontitis
Common
Treatment
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Well-Being
Implant
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Challenge
Inequity
Employment
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Prevent
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Health
Medical
Race/Ethnicity
Quality
Individual
System
Therapy
Opioid
Reduce
Important
Alcohol
Prevalent

Oral Health in America: Advances and Challenges

Section 3A: Oral Health Across the Lifespan: Working-Age Adults

Chapter 1: Status of Knowledge, Practice, and Perspectives

Oral health is essential for the overall health and well-being of adults, just as it is for children and adolescents. In adulthood, general health impacts oral health, and vice versa, in both the short- and long-term. The American Dental Association (ADA) defines oral health as "…a functional, structural, aesthetic, physiologic and psychosocial state of well-being and is essential to an individual's general health and quality of life" (American Dental Association 2021, p. 72). This concept is described more fully in Section 1.

The relationship between oral and general health manifests in a variety of ways. The effects of periodontal disease—a chronic disease affecting the gums, bone, and other supporting tissues around teeth—has been studied in relation to nearly 60 other adverse health conditions, including diabetes, heart disease, and Alzheimer's disease. Patients with head and neck cancer who undergo radiation therapy experience damage to salivary glands, leading to a lifelong battle with dry mouth, increased dental decay, mucosal tissue swelling, and periodontal infections. Infection from the oral human papillomavirus (HPV) increases the risk for some cancers, including oropharyngeal cancer (OPC). Finally, risky behaviors, such as smoking, drinking, and opioid use, can have a negative impact on oral health.

Oral diseases are common and can have significant impact on quality of life. Tooth loss affects the ability to eat a balanced diet, speak, chew, swallow, and smile, and is associated with more illness and earlier-than-normal death. Tooth loss, untreated tooth decay, and moderate to severe periodontal disease occur throughout the adult population and often worsen as people age. These conditions contribute to impaired oral function and impact social and emotional well-being.

Craniofacial and Tooth Development

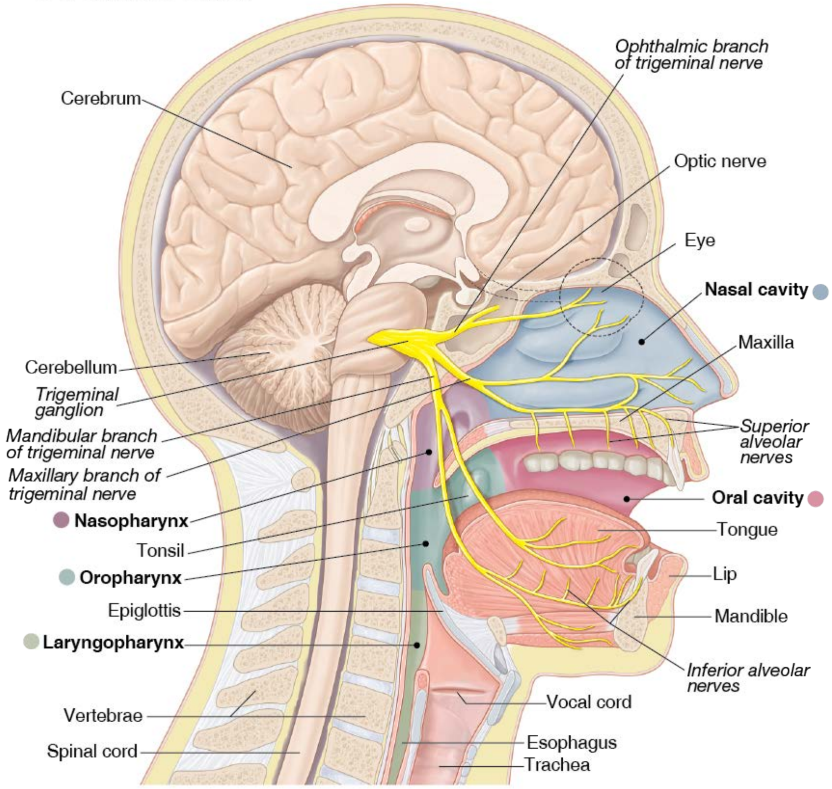
The craniofacial complex—composed of nerves, bones, and other structures—has generally reached maturity by 20 years of age (Figure 1); however, brain maturation may not be complete until closer to 25 years. The craniofacial complex includes structures of the orofacial area such as the mandible, temporomandibular joint, and mouth, that help to uniquely define the head and face (D'Souza et al. 2010). Most adults will have 32 erupted permanent teeth (see Section 2B, Figure 1), unless they are congenitally missing or have remained unerupted. Malocclusion (the misalignment of teeth and/or bones), usually diagnosed and treated in childhood or adolescence, can persist, or even emerge, in adulthood. Section 2 includes more information on craniofacial development and malocclusion.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Dental caries is a multifactorial disease process that cause demineralization of tooth enamel. If the process is not reversed through remineralization, the enamel is weakened and then destroyed, forming a cavity that, if left untreated, can cause pain, infection, and tooth loss. (Divaris 2016; Pitts et al. 2017). For more information on what causes caries, see Section 2 of this monograph, which focuses on oral health in children and adolescents. Untreated tooth decay continues to be a major cause of tooth loss in adults. In 2015, untreated tooth decay cost

Figure 1. Craniofacial complex



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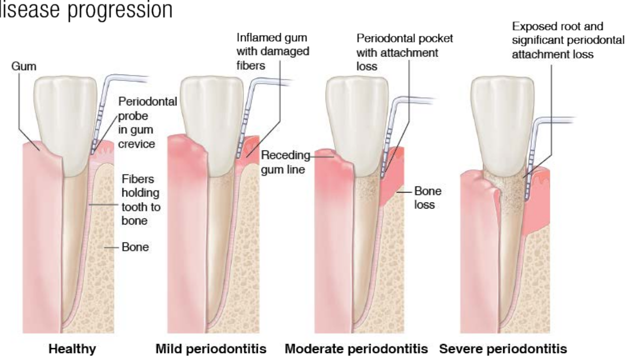
about $45.9 billion in lost productivity in the United States (Righolt et al. 2018).

Dental caries is not just a disease of childhood. At least 9 out of 10 working-age adults have experienced tooth decay in their permanent teeth (Centers for Disease Control and Prevention 2019a). Although it has decreased since the early 1970s, the prevalence of dental caries in adults remains widespread. On average, working-age adults have 9 permanent teeth decayed, missing, or filled because of dental disease. Based on data from 2011–2016, more than 1 in 4 working-age adults had untreated tooth decay (26%), with significant disparities by race/ethnicity and income. Just 22% of non-Hispanic White adults had untreated decay, compared to 37% of Mexican Americans and 40% of non-Hispanic Blacks. Among adults with a household income at least twice the federal poverty level, 18% had untreated decay, compared with 41% of adults with lower household incomes (Centers for Disease Control and Prevention 2019a). Untreated tooth decay also is highest among those aged 20 to 34 years (29%) and lowest among those aged 50 to 64 years (22%), which sets the stage for dental caries as a highly prevalent chronic disease throughout adulthood.

Periodontal Disease

Periodontitis is an oral infection characterized by inflammation of the gums and supporting structures of the teeth. As the inflammation intensifies, periodontal pockets can form (creating spaces between the teeth and gums) that lead to infection and progressive bone loss (Figure 2). In advanced stages, it can lead to sore and bleeding gums, painful chewing problems, and tooth loss. There are several forms of periodontitis, but the more common forms include aggressive periodontitis, chronic periodontitis, necrotizing periodontitis, and periodontitis manifesting as a result of systemic disease (Caton et al. 2018a; 2018b). Globally, periodontitis is the sixth most prevalent disease worldwide, affecting an estimated 740 million people (Kassebaum et al. 2014; Murray et al. 2014). Its functional impact can be measured in terms of pain, discomfort, and difficulty in chewing.

Figure 2. Important anatomical changes associated with periodontal disease progression



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Changes in facial appearance can impair social interaction, as can the halitosis (bad breath) that often accompanies the condition. Recent research shows that periodontitis and associated inflammation are risk factors for noncommunicable chronic diseases such as cardiovascular disease, diabetes mellitus, respiratory disease, and cognitive impairment (Bansal et al. 2013; Teixeira et al. 2017; Cardoso et al. 2018; Liccardo et al. 2019). The identification of periodontitis as a risk factor for these diseases has elevated its significance from a local disorder in the mouth to a more systemic disease with general health implications. Mechanisms to account for the systemic effects of periodontitis focus on the direct and indirect effects of periodontal bacteria gaining access to the body's circulation system and increasing the systemic inflammatory burden through effects on the liver or by direct infection of specific organs and tissues (Hajishengallis and Chavakis 2021).

Periodontitis is an important oral disease of adulthood, with prevalence increasing with age (Billings et al. 2018a; 2018b). An estimated 42% of the U.S. population has periodontitis, and 8% have severe periodontitis (Table 1). The prevalence of severe periodontitis is greater for men than women and is higher for Mexican Americans and non-Hispanic Blacks, compared to non-Hispanic Whites. Current smoking is an important risk factor for severe periodontitis among working-age adults. People with diabetes and those with an income below 100% of the federal poverty level also are at increased risk for both severe and moderate periodontal disease (Eke et al. 2018). Periodontitis is an important public health problem and a leading cause of tooth loss in the United States today (National Institute of Dental and Craniofacial Research 2018a).

Tooth Loss

Tooth loss affects adults of all ages, but complete tooth loss (edentulism) is rare among working-age adults in the United States today; just 2.2% of adults aged 20 to 64 years were edentulous in 2011–2016. Edentulism was higher among adults who were poor (6%), had less than a high school education (5%), and were current smokers (6%) (Centers for Disease Control and Prevention 2019a). Among older working-age adults (50–64 years of age), an estimated 6% are edentulous (without teeth), with more than 17% of those living in poverty experiencing complete tooth loss (Dye et al. 2019a). In the United States, significant tooth loss (having six or more missing teeth) affects the populations of some regions of the country more than others. For example, Appalachia, followed by the Mississippi Delta, have the highest levels of significant tooth loss among working-age adults (Gorsuch et al. 2014). An important concept that relates tooth loss to quality of life is a functional dentition, which is typically defined as having 21 or more teeth, excluding third molars. Three in four older working-age adults in the United States have a functional dentition, but substantial oral health disparities exist by socioeconomic indicators. Among those living in poverty, about 47% have a functional dentition, whereas 83% of nonpoor adults 50 to 64 years of age have a functional dentition (Dye et al. 2019a).

Oral Cavity and Oropharyngeal Cancer

Oral cavity cancers affect areas within the mouth that include the lips, the inner lining of the cheeks, the gums, most of the tongue, the area of the mouth below the tongue, and the hard bony area forming the roof of the mouth. OPCs affect the pharynx, back of the tongue, soft palate, side and back walls of the throat, and tonsils. See Figure 1 for a visual description of these areas. Some common signs of oral cavity cancer include a sore that does not heal, inflamed patches, or other changes in the lips, mouth, or cheek, such as a mass or persistent swelling (Huber and Tantiwongkosi 2014). For OPCs, the most common sign is a sore throat or enlarged lymph node (lump or mass in the neck). However, OPCs are often indolent and cannot be easily recognized (National Cancer Institute 2020a). Because these tumors reside inside the mouth and throat, dental clinicians often are the first caregivers to detect them (National Institute of Dental and Craniofacial Research 2018b).

Table 1. Percentage of adults age 30 and older with periodontitis by select characteristics: United States, 2009–2014

Characteristic		Periodontitis % (Standard Error)		
		Severe	Mild or Moderate	Total
Total		7.8 (0.5)	34.4 (1.2)	42.2 (1.4)
Age, years	30–44	4.1 (0.3)	25.3 (1.4)	29.5 (1.5)
	45–64	10.4 (0.8)	35.6 (1.4)	46.0 (1.6)
	65 or older	9.0 (1.0)	50.7 (1.9)	59.8 (2.1)
Sex	Male	11.5 (0.8)	38.8 (1.2)	50.2 (1.4)
	Female	4.3 (0.4)	30.2 (1.4)	34.6 (1.5)
Race/Ethnicity	Mexican American	13.4 (1.4)	46.4 (1.5)	59.7 (1.7)
	Other Hispanic	7.8 (0.9)	40.7 (1.5)	48.5 (1.6)
	Non-Hispanic White	5.9 (0.6)	31.1 (1.5)	37.0 (1.7)
	Non-Hispanic Black	14.7 (1.1)	42.0 (1.3)	56.6 (2.0)
	Other race, including multiracial	9.3 (1.4)	36.9 (2.3)	46.2 (2.6)
Smoking Status	Nonsmoker	4.9 (0.5)	29.5 (1.2)	34.4 (1.4)
	Former smoker	8.0 (0.7)	37.7 (1.8)	45.8 (1.8)
	Current smoker	16.9 (1.3)	45.4 (1.7)	62.4 (1.7)
Poverty Status	< 100% FPG	13.9 (1.0)	46.5 (1.5)	60.4 (1.7)
	100–199% FPG	12.1 (1.1)	41.5 (1.9)	53.6 (2.0)
	200–399% FPG	7.2 (0.8)	37.4 (1.8)	44.6 (2.0)
	> 400% FPG	4.0 (0.6)	24.6 (1.2)	28.6 (1.4)
Body Mass Index	< 25	7.6 (0.6)	31.6 (1.6)	39.2 (1.8)
	25–30	8.1 (0.7)	34.0 (1.3)	42.1 (1.4)
	> 30	7.7 (0.7)	36.7 (1.5)	44.4 (1.5)
Diabetes Mellitus	Yes	10.8 (1.3)	49.0 (2.5)	59.9 (2.2)
	No	7.5 (0.5)	32.8 (1.2)	40.4 (1.4)
Use of Dental Floss in Past 7 Days	Yes	5.8 (0.5)	32.1 (1.2)	37.9 (1.3)
	No	12.8 (1.0)	40.3 (1.6)	53.1 (1.8)

Note: FPG = Federal Poverty Guideline.

Source: Eke et al. (2018). © American Dental Association. With permission from Elsevier.

Both oral cavity and oropharyngeal cancers continue to be a public health concern because of debilitation and disfigurement, as well as high mortality rates (Mignogna et al. 2004).

In 2019, there were an estimated 54,010 cases of oral cavity or oropharyngeal cancer in the United States, with 10,850 deaths (American Cancer Society 2021). More than 38,000 of these cases were in men, and an estimated 250,000 men were survivors of this type of cancer (Miller et al. 2019). Among all cancer cases of the oral and pharyngeal areas, the most frequent age at diagnosis for adults is between 55 to 64 years of age (National Cancer Institute 2020b). The age-adjusted incidence for oral and pharyngeal cancer, about 11 per 100,000 in 2012–2016, has been increasing by an average of 0.8% per year during the last decade (Howlader et al. 2019).

Currently, the mortality rate is about 2.5 per 100,000 (Figure 3), with an age adjusted 5-year survival rate of 66% for all OPC patients (National Cancer Institute 2020b). Survival rate ranges from better than 80% if the cancer diagnosed is confined within the primary site to about 40% if the cancer has metastasized (Figure 4). Unfortunately, the majority of these cancers are diagnosed after some spread has occurred. Generally, African American adults' overall survival is lower compared to White adults for cancers of the oral cavity and pharynx (Ang et al. 2010; Zandberg et al. 2016). Although racial disparities persist in overall survival for cancers not associated with HPV, it seems that racial differences observed in overall survival for HPV-OPC are not significant (Stein et al. 2020). This suggests that other social determinants of health (SDoH) may influence overall survival in OPC caused by HPV infection.

In addition to cancers of the oral cavity and pharynx, other oral disorders with malignant potential are oral mucosal lesions and conditions with unclear etiology. They include leukoplakias, erythroplakias, and other disorders with increased malignant potential (Warnakulasuriya et al. 2007). Leukoplakias are the most prevalent among these, at approximately 1–5% (Petti 2003), and their annual risk for malignant transformation is 2–3% (van der Waal 2014).

Oral Human Papillomavirus

There are more than 100 kinds of HPV, 13 of which are considered cancer causing. HPV16 causes more than 90% of cases of HPV-related oropharyngeal squamous cell cancer (HPV-OPC) in the United States. Other HPV types (18, 33, and 35) are responsible for a smaller subset of HPV-OPC, with each detected in less than 1% of HPV-OPC cases (Stein et al. 2015).

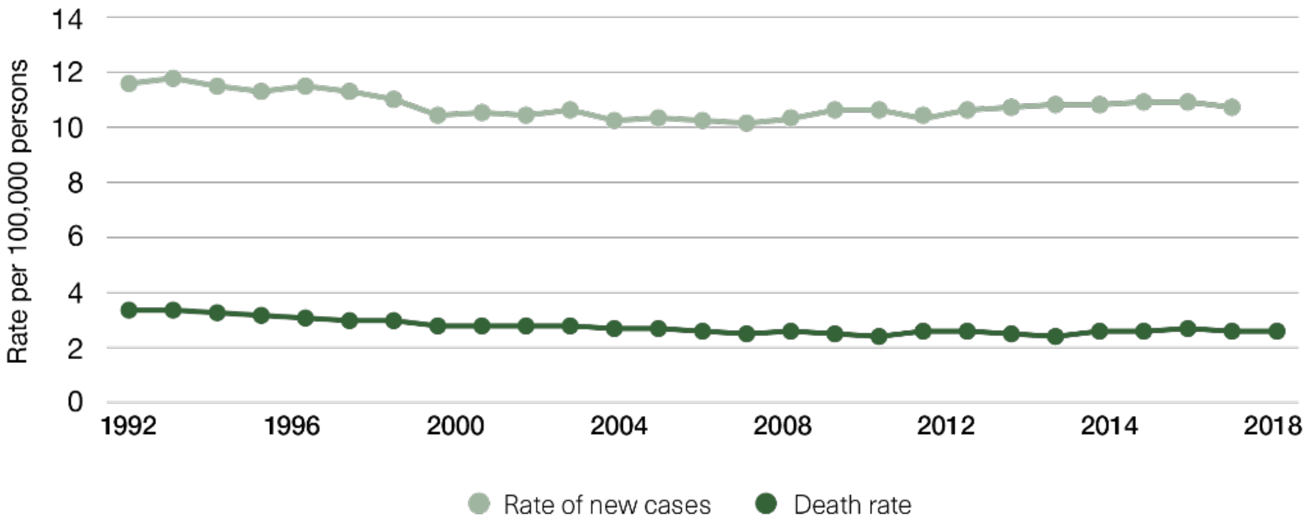
The proportion of OPC caused by HPV has increased dramatically during the past 25 years, from 35% of OPC between 1995–1999 to 75% between 2010–2012 (Chaturvedi et al. 2011; D'Souza et al. 2017a). This change is due both to a decrease in tobacco-related OPC, reflecting decreased tobacco use, and an increase in HPV-OPC. Although the vast majority of OPCs are now caused by HPV, only a small proportion (less than 5%) of oral cavity (mouth) squamous cell cancers are caused by HPV (Castellsague et al. 2016; D'Souza et al. 2017a).

HPV16 is the most common oral HPV type. Oral HPV16 DNA is detected in about 1% of U.S. adults (Gillison et al. 2012) and the lifetime risk of OPC is low (37 per 10,000) (D'Souza et al. 2017b). The primary risk factor for oral HPV is performing oral sex. The prevalence of oral HPV increases with higher numbers of lifetime oral sex partners (Gillison et al. 2012). Oral HPV is more common among men than women and among people who currently use tobacco (Chaturvedi et al. 2015; Sonawane et al. 2017). Figure 5 outlines the risk for oral HPV infection based on the key risk factors.

Evidence suggests that many people are exposed to oral HPV in their lifetime. About 5–7% of men acquire a new oral HPV infection each year (Kreimer et al. 2013; Wood et al. 2017), but incidence of oral HPV16, specifically, is about 1% in men per year and lower than that in women. The per-partner risk of oral HPV infection appears to be higher among men than women (Chaturvedi et al. 2015; D'Souza et al. 2016), although reasons for this difference are not yet understood.

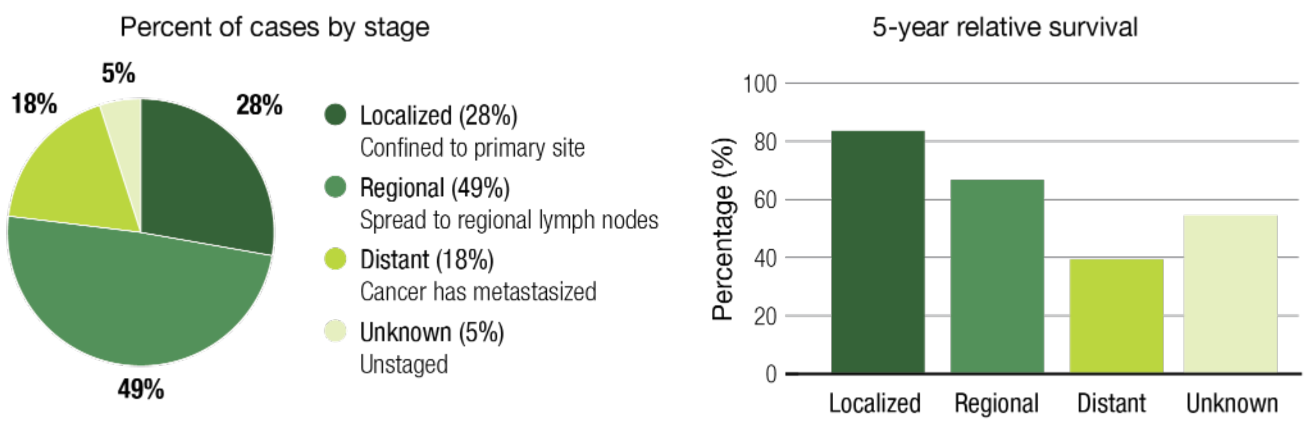
Most oral HPV infections clear on their own within 1 to 2 years, and most people are not even aware of their infection (D'Souza et al. 2016; Wood et al. 2017).

Figure 3. Incidence and mortality rates for oral cavity and pharynx cancer: United States, 1992–2018



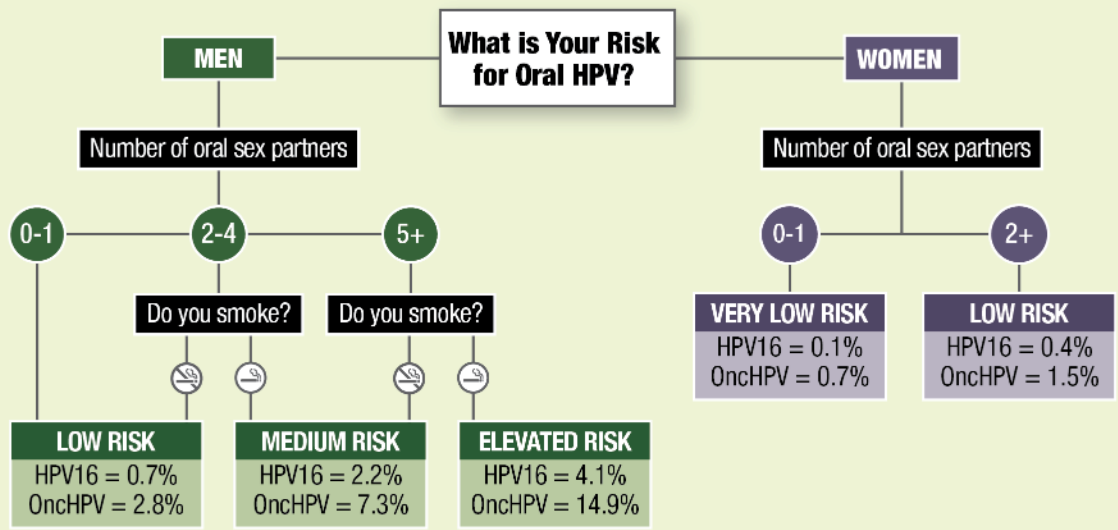
Notes: New cases come from SEER 13. Deaths come from U.S. mortality. All races, both sexes. Rates are age adjusted.
Source: National Cancer Institute (2020b).

Figure 4. Percent of cases and 5-year relative survival by stage at diagnosis for oral cavity and pharynx cancer: United States, 2011–2017



Notes: SEER 18 2011–2017, all races, both sexes by SEER summary stage 2000.
Source: National Cancer Institute (2020b).

Figure 5. What is your risk for oral HPV?



HPV = human papillomavirus; OncHPV = potentially cancer-causing HPV; HPV16 = most common high-risk type of HPV

Source: D'Souza et al. (2017). © European Society for Medical Oncology. With permission from Elsevier.

Among American men in their fifties, for example, 8.1% have a prevalent, cancer-causing oral HPV infection, and 2.1% have a prevalent oral HPV16 infection, yet only 0.7% of them will develop OPC in their lifetime (D'Souza et al. 2017b). Of the oral HPV types, HPV16 is not only the most prevalent but also is the most likely to persist (Kjaer et al. 2010; Gargano et al. 2012; Sand et al. 2019).

Although there are two HPV vaccines approved by the U.S. Food and Drug Administration, only one vaccine currently is used in the United States. The Gardasil® 9 vaccine (U.S. Food and Drug Administration 2020) is approved for people through 45 years of age. The current recommendation in the United States for HPV vaccination is for boys and girls 11 to 12 years of age. The Advisory Committee on Immunization Practices (ACIP) also recommends HPV vaccine for all adults through 26 years of age. Although vaccination is not routinely recommended for adults aged 27 to 45, a medical review and discussion with the patient could lead to a decision that vaccination would be beneficial (Meites et al. 2019). Recognizing the important role HPV has in oral health, in 2018 the ADA adopted a policy that urges dentists to support the use and administration of the HPV vaccine (American Dental Association 2018a). One year later, Oregon became the first state to pass legislation allowing dentists to provide vaccinations, including vaccinations for seasonal flu and HPV (Walker et al. 2019). More information on HPV and vaccination is discussed in Section 2B.

Orofacial Pain and Temporomandibular Joint Disorders

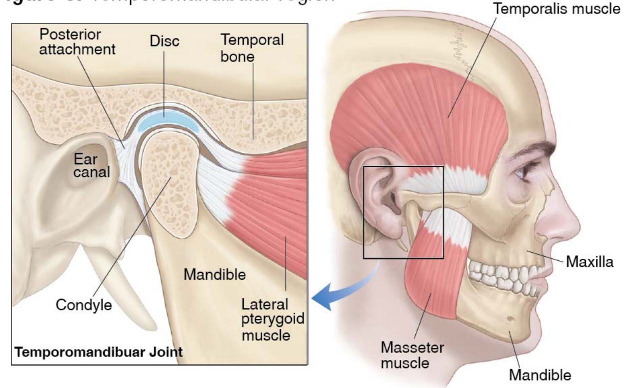
Orofacial pain can greatly reduce quality of life. This type of pain may be because of tooth-related infections, mucosal sores, or irritations, and may include burning sensations, pain in the jaw joint area, or aching pain across the face or cheek. Data from 30 years ago indicated about 12% of adults in the United States reported having a toothache and about 5% had jaw joint pain (Lipton et al. 1993). Although contemporary estimates are not available, a more recent regional study reported that 1 in 6 patients visit the dentist because of orofacial pain, with toothache being the most common, closely followed by temporomandibular joint disorder (TMD) pain (Horst et al. 2015). In general, there are three types of orofacial pain: dental-related pain, TMD pain, and non-TMD pain (Okeson 2019). Dental-related pain includes pain associated with the tooth's pulp or surrounding periodontal structure. TMD pain is broadly defined as musculoskeletal pain affecting the masticatory system (jaw), is most commonly of either joint or muscle origin, and can be classified into five groupings: masticatory muscle disorders, TMD, inflammatory disorders, chronic mandibular hypomobility, and growth disorders (Okeson 2019). Non-TMD pain represents a large category of orofacial pains that include migraine and trigeminal neuralgia (TN), among others.

Temporomandibular joint and muscle disorders are conditions characterized by pain affecting the temporomandibular jaw joint and masticatory muscles in the temporomandibular region (Figure 6) (Dworkin and LeResche 1992). They also involve such functional problems as jaw opening limitations, deviant jaw patterns, and joint sounds (Laskin et al. 1983). The personal and societal impact of TMD is primarily because of its status as a chronic/recurrent pain condition, and pain is the main reason that patients seek treatment for TMD (Dworkin et al. 1990).

In one study, the prevalence of adults reporting pain in the temporomandibular region over the previous week was approximately 5% (Lovgren et al. 2016), while about 12% of adults reported such pain in the previous 6 months (Von Korff et al. 1988). Among older adolescents and adults, the prevalence of TMD pain rises with age, peaking at 18–25% of the population (Dworkin and LeResche 1992) at about 40 years of age, and then declining. The few available studies on racial/ethnic differences suggest that TMD incidence (Slade et al. 2013a) and age-specific prevalence patterns (Plesh et al. 2011) may differ for African Americans and Hispanics, with later age of onset than for Whites.

TN is a less common pain syndrome but is reportedly one of the most painful facial conditions. Symptoms are severe shooting or jabbing pain that often is described as feeling like electrical shocks. Little is known about the etiology of this condition. Its prevalence ranges from 0.03–0.3%, with women having a three times higher prevalence than men, and those aged 37 to 65 years having the highest prevalence (De Toledo et al. 2016). The cost of treating TN in the United States exceeded $94 million between 2003 and 2013 (Holland et al. 2015). Additional information on orofacial pain is provided in Section 5.

Figure 6. Temporomandibular region



Source: Created by Jonathan Dimes for this NIH Report.

Dental Fear and Anxiety

Fear and anxiety related to dental care are distressing emotional responses, typically characterized by a combination of physiological reaction (e.g., increased heart rate, perspiration), worry or rumination, feelings of apprehension or dread, and avoidance of treatment (McNeil et al. 2011). Causes and manifestations of dental fear/anxiety are highly individualized, with experiences along a continuum, ranging from fearfulness to phobia (McNeil et al. 2011).

Nearly 20% of U.S. adults experience moderate to high dental fear/anxiety, and an estimated 7% experience high fear/anxiety (White et al. 2017). These estimates are relatively consistent with those documented since the 1950s (Smith and Heaton 2003). It is somewhat discouraging that even as dental care access and quality have increased, fear/anxiety has persisted in the United States, while decreasing in other countries (Svensson et al. 2016).

Dental Erosion and Tooth Wear

Ongoing damage to a tooth's enamel is not limited to the dental caries process alone. Tooth wear as a result of erosive or abrasive etiological factors is not uncommon among adults, with a global prevalence for any form of tooth wear in permanent teeth ranging from 20–45% (Bartlett and O'Toole 2020). Dental erosion is the irreversible, acid-induced loss or wear of dental hard tissues, not involving bacterial-secreted acids associated with dental caries (Ganss 2014). Dental erosion can result from extrinsic factors (acidic diet) or from intrinsic factors (acidic content of the stomach). In children, dental erosion is most often caused by dietary acids from juice, soda, fresh fruit, and sour candies. In adults, although dietary acids also may cause dental erosion, it more often is associated with gastroesophageal reflux disease (GERD), especially if it affects molar occlusal surfaces (Pace et al. 2008; Ranjitkar et al. 2012; Al-Zwaylif et al. 2018). Identifying GERD is important because the risk of developing esophageal adenocarcinoma later in life is approximately 43 times greater in individuals with untreated GERD than in those without GERD (Lagergren et al. 1999).

Other forms of tooth wear (abrasion) can result from intrinsic factors (tooth grinding) or from extrinsic factors, such as frequent use of highly abrasive oral care products or frequent consumption of a diet high in abrasive foods. Tooth wear is associated with increasing age in adults (Van't Spijker et al. 2009). Findings from a practice-based research network in the Northwestern United States reported that among adult participants, about half had at least four teeth with some indication of moderate tooth wear (Cunha-Cruz et al. 2010). Those who were older, male, and had some periodontal bone loss were more likely to have moderate or severe tooth wear. Although there is sufficient evidence to support our understanding of the etiology of erosive and abrasive tooth wear, there is little evidence to support clinical decision making on when to intervene or what the long-term effectiveness of interventions may have on oral health-related quality of life (OHRQoL) (Bartlett and O'Toole 2020).

Dental Trauma

Dental trauma can occur in different forms, from injury that has caused the tooth to become displaced from its normal position but retained in the jaw bone with some mobility, tenderness, or pain, to full avulsion (in which a tooth has been "knocked out"). In addition, injury could cause the tooth to have a complete fracture, resulting in portions of the dental crown or root experiencing a complete break (Figure 7, D, F, G). Incomplete or uncomplicated crown fractures affecting permanent teeth (often known as a cracked tooth) are the most common type of dental injury among adults (Figure 7, B, C, E). Because incomplete tooth fracture often is difficult to assess and often is perceived as not requiring attention, epidemiologic assessments most likely substantially underreport dental trauma (Lam 2016) and when reported, can lead to far-ranging prevalence estimates. For example, cracked teeth (or incomplete tooth fracture) has been previously reported to be between 34–74% (Cameron 1964; Hiatt 1973).

Figure 7. Tooth cracks and fractures

Notes: Examples of typical cracks and fractures affecting teeth.
(A) Small visible fracture lines in coronal area only (Craze lines) in central incisor.
(B) Small crack extending from the occlusal (chewing) surface of a premolar but not extending beyond the cemento-enamel junction (CEJ) into the tooth root.
(C) Cracked tooth extending from the occlusal surface of a molar into the tooth root without separation of tooth fragments.
(D) Large tooth fracture in a molar extending from the occlusal surface through the tooth root resulting in separation between the tooth fragments.
(E) Vertical tooth root fracture involving a single molar tooth root.
(F) Cracked molar cusp resulting in a portion of the enamel separating from the remaining coronal portion of the tooth.
(G) Injury to a central incisor resulting in fracture and loss of a portion of the remaining tooth.

Source: Created by Jonathan Dimes for this NIH Report.

Teeth can develop cracks from a variety of causes, including biting down too strenuously on a very hard food item or object, tooth grinding, physical trauma, and oversized dental restorations (Table 2) (Hasan et al. 2015). Cracks are difficult for dentists to diagnose because many of them are hard to detect, even while employing a variety of techniques using magnifying lenses, a dental explorer, a periodontal probe, dyes, vitality tests, or transillumination. Radiographs enable a dentist to eliminate other pathologies and are useful in detecting cracks that run from the cheek (buccal) to the tongue (lingual) sides of the tooth (Hasan et al. 2015). Although tooth cracks are common and most are harmless, others may cause symptoms that require treatment. These symptoms can include pain when chewing; sensitivity to cold, heat, and sweets, and swelling in the gums around the tooth. Pain also can occur when pressure from biting is relieved ("rebound" pain). Painful symptoms characterize a condition called "cracked tooth syndrome" (Nguyen and Palmer 2010). Depending on the size and location of the crack, treatments vary from no treatment (Hilton et al. 2020), to minor adjustments of the biting surface of the tooth, to restorations that vary in size and materials. If the crack is extensive, removal of the tooth may be the only possible option (Bader et al. 1995; Nguyen and Palmer 2010).

Complete tooth fractures occur when the fractured parts of the tooth move independently of one another and can result from the same situations that cause cracked teeth

Table 2. Etiological factors in cracked tooth syndrome

Classification	Factors	Examples
Restorative procedures	Inadequate design features	Over-preparation of cavities Insufficient cuspal protection in inlay/only design Deep cusp-fossa relationship
	Stress concentration	Pin placement Hydraulic pressure during seating of tightly fitting restorations Physical forces during placement of restoration, e.g., amalgam or soft gold inlays (historical) Non-incremental placement of composite restorations (tensile stress on cavity walls) Torque on abutments of long-span bridges
Occlusal	Masticatory accident	Sudden and excessive biting force on a piece of bone
	Damaging horizontal forces	Eccentric contacts and interferences (especially mandibular second molars)
	Functional forces	Large untreated carious lesions Cyclic forces
	Parafunction	Bruxism
Developmental	Incomplete fusions of areas of calcification	Occurrence of cracked tooth syndrome in unrestored teeth
Miscellaneous	Thermal cycling	Enamel cracks
	Foreign body	Lingual barbell
	Dental instruments	Cracking and crazing associated with high-speed handpieces

Source: Hasan et al. (2015).

(Hasan et al. 2015). They usually require treatments similar to those used for cracked tooth syndrome, but an estimated 15% involve the tooth pulp and can result in extractions (Bader et al. 1995).

High-Risk Behaviors Affecting Oral Health in Adults

Many American adults use tobacco, opioids, and alcohol. Although smoking cigarettes and pipe tobacco has declined during the past 20 years, the use of electronic cigarettes and other tobacco products has increased, particularly among young adults. The opioid crisis that began in the 1990s continues to be a public health problem. These high-risk behaviors impact oral health and general health.

Tobacco Product Use

Based on data from 2019, an estimated 50.6 million U.S. adults (20.8%) were using a tobacco product (cigarettes; cigars, cigarillos, or filtered little cigars; waterpipe tobacco; e-cigarettes; and smokeless tobacco), with 14% exclusive cigarette smokers and 18.6% using two or more tobacco products. Among those who were using tobacco products, most (80.5%) reported using combustible products (cigarettes, cigars, or pipes) (Cornelius et al. 2020). Comparing age groups, cigar use was higher among young adults (18–24 years of age) at 14%, primarily driven by flavored cigars. Males (13%) were more likely to smoke cigars than females (3%), as were non-Hispanic Blacks (12%) and non-Hispanics of two or more races (15%). Furthermore, some subgroups of the lesbian, gay, bisexual, transgender, and queer population (16% bisexual; 11% gay/lesbian) were more likely to smoke cigars than their heterosexual counterparts, at 8% (Kasza et al. 2017).

The prevalence of waterpipe tobacco smoking (WPS), or hookah use, is gradually rising in the United States. The combination of water-cooled and flavored tobacco smoke, as well as an incorrect perception of safety, has contributed to this increase (Smith-Simone et al. 2008; Cobb et al. 2010; Maziak et al. 2011; Jaff and Kumar 2016). WPS prevalence among adults increased from 0.6% to 1% between 2013 and 2019 (Hu et al. 2016; Cornelius et al. 2020). In 2019, WPS was the most commonly used tobacco product after e-cigarettes among younger people aged 18 to 24 years, and current cigarette smokers, as well as men, non-Hispanics, and sexual minorities also were more likely to use waterpipe tobacco (Cornelius et al. 2020).

Meanwhile, e-cigarette use among adults in the United States has fluctuated since their introduction in the early 2000s. Current e-cigarette use, for example, grew from 0.3% in 2010 to 6.8% in 2013 (McMillen et al. 2014), before falling to 3.7% in 2014 and climbing to 4.5% in 2019 (Delnevo et al. 2016; Cornelius et al. 2020). Data from 2017 suggest that 30% of U.S. adult combustible tobacco users also used e-cigarettes. The prevalence of exclusive e-cigarette use was nearly 3% that year, with relatively higher use among young adults, sexual minorities, and those living in the Midwest and South (Wang et al. 2018). Users of e-cigarettes are nearly three times more likely to have gingivitis than nonsmokers (Vora and Chaffee 2019). Other reported oral health consequences of e-cigarettes include oral-facial injuries resulting from overheating and explosion of e-cigarette devices, including tooth fractures and separation of teeth from the gums, as well as other conditions that often require considerable cosmetic and functional corrective surgery (Brownson et al. 2016; Harrison and Hicklin 2016; Rogér et al. 2016; Brooks et al. 2017). However, because use of e-cigarettes is so new, there are uncertainties about the impacts of long-term use on oral health and general health.

As use of these new products has increased, conventional cigarette smoking has decreased, largely because of considerable effort in tobacco prevention and cessation public health initiatives during the past 40 years. In 2018, 13.7% of adults smoked cigarettes, the lowest rate since monitoring began in 1965 (Creamer et al. 2019). Nonetheless, cigarette smoking remains the leading preventable cause of disease (including oral diseases), disability, and death in the United States (U.S. Department of Health and Human Services 2014; Tomar et al. 2019). For example, the number of cigarettes smoked per day is tied to an increased risk for cancer of the oral cavity and pharynx (Figure 8).

Cigarette smoking contributes to the burden of periodontal diseases. A recent systematic review and meta-analysis of 12 prospective studies reported that smokers had an 85% higher risk for periodontitis than nonsmokers (Leite et al. 2018). Smoking is associated with poor periodontal treatment outcomes and implant survival rates (Warnakulasuriya et al. 2010). Quitting is associated with improved periodontal disease outcomes (Preshaw et al. 2005; Heasman et al. 2006; Leite et al. 2018). Relatively fewer studies have shown an association between smoking and dental caries (Vellappally et al. 2007; Benedetti et al. 2013) or tooth loss (Warnakulasuriya et al. 2010). Additional information on tobacco use including use of e-cigarettes is discussed in Section 5.

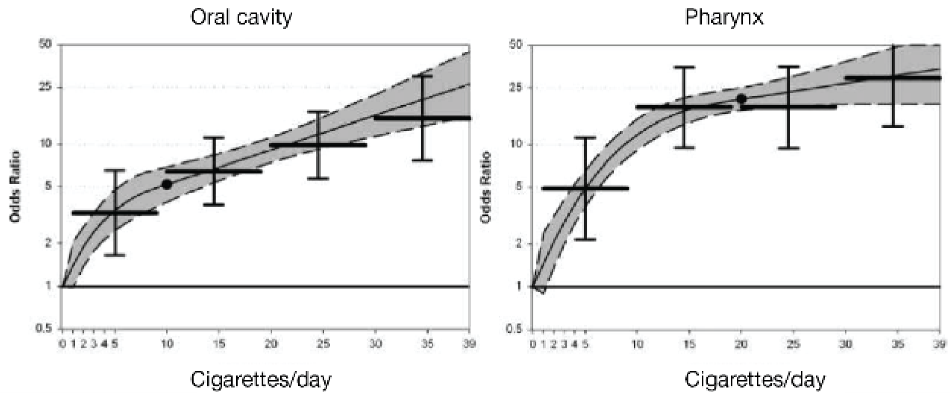
Cannabis Use

Cannabis describes the different products that come from the cannabis plant. They include marijuana and hemp, both of which contain cannabinoids, a group of active chemical compounds, such as tetrahydrocannabinol. Cannabis products are used for a wide range of putative medicinal effects, as well as a euphoric "high." Increasing public acceptance of medical marijuana and the relaxation of state marijuana laws has left the public, health care providers, and legislators with multiple unanswered questions about the safety of the products derived from this plant and its effectiveness for therapeutic purposes.

High-quality studies examining the effects of cannabis use on oral health are lacking. Because of its classification as a Schedule 1 drug, there are restrictions on federal research with marijuana that contribute to the paucity of data on this topic. Legislation has been proposed to loosen these research restrictions (U.S. Department of Justice 2019). What is known about the oral implications of cannabis products is summarized in Table 3. Numerous case reports have linked smoked cannabis to oral cancer, and there also is evidence of a possible link between smoked cannabis, HPV infection, and OPC. However, large population-based studies and a comprehensive review conducted by the National Academies of Sciences concluded that cannabis use has not been associated with oral, head, or neck cancers (Rosenblatt et al. 2004; National Academies of Sciences, Engineering, and Medicine 2017), nor with HPV infection (Ortiz et al. 2018).

Darling and Arendorf (1993) found three significant oral conditions more frequently in adults who smoked cannabis and tobacco or used methaqualone (which is no longer legally manufactured) than in those who only smoked cigarettes or in nonsmoking controls.

Figure 8. Cigarette use and risk for developing oral cavity and pharynx cancer



Notes: Odds ratios with 95% Confidence Intervals presented. Prediction estimates for tobacco smoking were obtained using cubic regression spline models. The reference category was defined as never smokers for the spline models.
Source: Polesel et al. (2006). © Wiley-Liss, Inc. With permission from John Wiley & Sons.

These conditions were leukoedema (a filmy, opalescent-to-whitish gray, wrinkled buccal epithelium), xerostomia (dry mouth), and traumatic oral ulcers. In a 2009 study, cannabis users 18 to 25 years of age had significantly more decayed surfaces, consumed more sugar-containing drinks, and had significantly fewer daily tooth brushings and dental visits than tobacco users (Schulz-Katterbach et al. 2009). In addition, some data support a positive association between cannabis use and periodontitis prevalence and severity, with deeper pockets and more clinical attachment loss (which signifies more severe disease) in people who used cannabis more frequently (Shariff et al. 2017; Chisini et al. 2019). Cannabis studies often have involved participants who also smoke cigarettes and/or use alcohol or other drugs, making it difficult to control for confounding variables (Darling et al. 1990; D'Amore et al. 2011). Additional information on marijuana use is provided in Section 5.

Methamphetamines

Methamphetamine (meth) is a highly addictive stimulant that has been used as a recreational drug since the 1990s and can have a significant impact on OHRQoL among adults (Mukherjee et al. 2018). Methamphetamine is ingested by smoking, nasal inhaling, or through intravenous injection. In a 2018 survey, it was found that 0.7% of the U.S. population 18 to 25 years of age and 0.8% of those 26 years or older reported having used methamphetamine during the past year (Substance Abuse and Mental Health Services Administration 2019).

The use of methamphetamine has a significantly negative impact on oral health. This impact is demonstrated by a rampant dental disease that is characterized as "meth mouth" (Clague et al. 2017). Methamphetamine users report pain and discomfort. Their teeth are decayed, broken, loose, and often heavily worn down. The maxillary anterior teeth are most affected by rampant tooth decay, especially in users who inject the drug (Shetty et al. 2016). Methamphetamine users also have more missing and untreated decayed teeth than age- and sex-matched non-users (Shetty et al. 2010; Shetty et al. 2016). Methamphetamine-induced bruxism (tooth grinding) results in loss of tooth structure through tooth wear, as well as tooth and restoration fracture. Tooth grinding also leads to TMD, particularly in female methamphetamine users (Donaldson and Goodchild 2006). Additional information on methamphetamine use is provided in Section 5.

Alcohol

Globally, alcohol use was ranked as the seventh leading risk factor for premature death and disability in 2016. A known cancer-causing agent and contributing cause of injury, alcohol is also an important contributor to oral cancers, periodontal disease, tooth loss, and other oral health conditions (Rehm et al. 2017; World Health Organization 2020).

Table 3. Oral implications of cannabis products

Oral Implications of Regularly Smoked or Vaporized Cannabis	Associated Outcomes
Periodontitis (a,b,c) (highest level of evidence for an association between cannabis use and oral health)	Contributing but not causing periodontitis; greater clinical attachment loss, deeper periodontal pockets, more severe periodontitis
Xerostomia (dry mouth) 1–6 hours after smoked (d, e)	Increased risk of dental caries due to lack of buffering and clearance
Leukoedema (d, e)	Multi-factorial: co-use of alcohol, tobacco; genetics
Increase in candida carriage (e)	Increased risk of a candida infection
Smooth surface caries (f)	Multi-factorial: poor oral health activity
Poor oral hygiene activity and seeking dental care (f)	Increased risk of dental caries, gingivitis, periodontitis
Oromucosal cannabis spray (THC and CBD) (g) (approved in Canada and the United Kingdom, used to relieve pain in multiple sclerosis)	Stinging sensation, oral mucosal white lesions in the floor of the mouth

Sources:
a. Shariff (2017)
b. Chisini (2018)
c. Meier (2017)
d. Darling et al. (1993)
e. Darling et al. (1990)
f. Schulz-Katterback (2009)
g. Scully 2007 (small open observational study)

Excessive alcohol use, in the form of binge drinking (five or more drinks per occasion for men, or four or more for women) and heavy drinking (15 or more drinks per week for men and 8 or more for women), is associated with an increased risk for many health problems, including oral diseases and facial injuries. Males 18 to 35 years of age often are seen in hospital emergency departments or oral and maxillofacial surgery departments with alcohol-related injuries sustained during an assault or a fall. Heavy alcohol consumption also has been associated with tooth loss in men (Copeland et al. 2004). Oral hygiene and periodontal conditions tend to be worse in people with alcohol use disorder, likely also because of poor dental care, accidents, and violence-related injuries.

The cancer-causing effects of alcohol extend to head and neck cancers (Hashibe et al. 2007), including cancers of the oral cavity, as well as pharyngeal, laryngeal, and esophageal cancers, especially when alcohol is used with tobacco (Bagnardi et al. 2001; Tramacere et al. 2010). The risks related to alcohol consumption begin at less than one drink per day and increase with heavy drinking or tobacco use (Scully and Bagan 2009). In the United States, these cancers account for the majority of alcohol-related deaths among men (Nelson et al. 2013). Other related issues include light drinkers, who were 1.17 times more likely to develop oral cancer and 1.23 times more likely to develop pharyngeal cancer, compared to non-drinkers or occasional drinkers. Cancer risk for heavy drinkers was 4.64 and 6.62, respectively (Tramacere et al. 2010). *The Lancet* recently published a study on global alcohol use and burden that found unequivocally that “alcohol use is a leading risk factor for [the] global disease burden and causes substantial health loss” (GBD 2016 Alcohol Collaborators 2018). The study also noted that for populations 50 years of age and older, cancers accounted for a large proportion of total alcohol-attributable deaths in 2016, constituting 27.1% of total alcohol-attributable female deaths and 18.9% of alcohol-attributable male deaths. Alcohol is considered a cause of squamous cell carcinomas in the head, neck, and esophagus, as well as subsites within the head and neck, including lip, oral cavity, pharynx, and nasopharynx. The study demonstrated that any level of alcohol consumption, even one drink per day, increases the relative risk of developing each of these cancers (GBD 2016 Alcohol Collaborators 2018).

In addition, alcohol use affects the prevalence of periodontal disease. Clinical attachment loss, a measure of periodontal disease, has been found to have a significant relationship with the number of drinks consumed per week (Tezal et al. 2004). Plausible explanations include alcohol's effects on host defense, clotting mechanisms, bone metabolism, healing (e.g., protein deficiency), and direct toxic effects on periodontal tissues. Despite strong evidence to the contrary, a longitudinal study of dental health in a Swedish population sample (Jansson 2008) found no association between alcohol consumption and periodontal disease. Additional information on alcohol use is provided in Section 5.

Dietary Behaviors

Sugar-sweetened beverages (SSBs)—drinks with added sugars, including carbonated, fruit, sports and energy drinks (Park et al. 2016)—are the most common sources of dietary sugars in adults (Kim et al. 2017). In addition to the general deleterious health effects of added dietary sugar, such as increasing the risk for diabetes and cardiac disease, oral effects are known (World Health Organization 2003; Bernabé et al. 2014). Bernabé and colleagues (2014) reported a significant positive association between intake of SSBs and caries in adults and their findings were further supported by the results of a meta-analysis (Moynihan and Kelly 2014). Furthermore, Bernabé and colleagues (2014) reported that the number of SSBs adults drink per day is positively associated with the number of decayed, missing, and filled teeth (DMFT). They found that adults (30 years of age or older) who drink 1 to 2 and 3 or more SSBs daily had, respectively, 31% and 33% more DMFT than those who did not drink SSBs.

Tooth decay is a known precursor to tooth loss, and tooth loss is positively associated with intake of SSBs (Zhu and Hollis 2014; Kim et al. 2017). Young adults who drink SSBs one to two times a day have twice as great a risk of losing six or more teeth (OR 2.2) than those who do not drink SSBs. The risk is even greater for those who drink SSBs more than twice a day (OR 2.8) (Kim et al. 2017).

Social Determinants of Health

Inequities in oral health that have been well documented for children also characterize the health of adults. To fully understand the root causes of oral diseases and the factors contributing to oral health disparities and inequities across the lifespan, it is necessary to recognize the role of SDoH. The World Health Organization (WHO) defines SDoH as "the conditions in which people are born, grow, work, live and age" (World Health Organization 2011, p. 2). These determinants can be organized into five key areas: economic stability, education, social and community context, health and health care, and the neighborhood and built environment (see Figure 3 – Section 1). They are shaped by families and communities and by the distribution of money, power, and resources at the worldwide, national, and local levels, as well as by policy choices at each of these levels. Consequently, WHO has provided recommendations advocating for better social conditions to improve health (Commission on Social Determinants of Health 2008). SDoH can either enhance or impair health and are applicable to both communicable and noncommunicable diseases, including oral diseases.

Oral diseases share many of the same SDoH as some of the most common chronic diseases affecting U.S. adults. For example, where a person lives determines their access to healthy food, as well as dental and medical care (Sheiham and Watt 2000). Some neighborhoods are food deserts that lack grocery stores selling fresh fruits and vegetables, while tobacco products, alcohol, fast food, and high-calorie snacks are readily available. The residents of these neighborhoods face great challenges in accessing healthier dietary choices and are, as a result, at greater risk for diabetes, heart disease, and oral diseases such as OPC and tooth decay. High unemployment rates and transportation barriers also negatively affect access to health care and oral health care. As previously described in 1971 by Tudor-Hart, this unfortunate paradox suggesting that people at the greatest risk for disease also faced the greatest barriers to getting the care they needed is very relevant to dentistry (Tudor Hart 1971). The factors behind these barriers, moreover, lead us to confront the structural racism that limits opportunities for individuals in minority communities to engage in a range of activities that sustain oral health—from conveniently obtaining healthy foods to accessing prevention strategies and professional care in their communities. Section 1 provides more information on this topic.

Some populations experiencing poor oral health outcomes, such as Native Americans, appear to be negatively impacted in a variety of ways by factors attributed to SDoH. American Indian/Alaska Native (AI/AN) adult dental patients have a substantially higher prevalence of untreated caries than the general U.S. population. For example, among adults aged 35 to 49 years, 64% of AI/AN dental patients have untreated caries, compared with 27% of the general U.S. population (Figure 9). AI/AN adults also have almost three times as much untreated tooth decay as non-Hispanic Whites and almost 50% more than non-Hispanic Blacks.

One reason for these differences lies in restricted access to dental care, because many AI/AN adults live in geographically isolated areas with a shortage of dental professionals. As shown in Figure 10, fewer than 35% of adults aged 18 to 34 years and only 25% of those aged 35 to 49 years accessed dental care in 2018. Perhaps more significantly, dental care access decreased among those aged 35 to 49 years from 2001 to 2018. Although there is an increasing trend of access by AI/AN adults aged 50 to 64 years, only about 26% of them accessed dental care in 2018.

Income, race, and ethnicity also are especially important social determinants for oral health in the working-age adult population, and these determinants were described in the 2000 Surgeon General's report on oral health. Using that report as a baseline, income disparities in untreated dental caries among adults aged 20 to 64 years have remained stable, with those in the lowest income groups experiencing prevalence of untreated decay more than twice as high, compared to those living at least 200% or more above the federal poverty guideline. Disparities in untreated caries among racial and ethnic groups are notable, with non-Hispanic Blacks faring worse than any other race/ethnic category. Untreated dental caries among non-Hispanic Black working-age adults is 40% compared to 22% for non-Hispanic Whites (Centers for Disease Control and Prevention 2019a).

Women's Oral Health

Menstrual Cycle

During the menstrual cycle, women experience hormonal fluctuations that influence the periodontium, which are specialized tissues (including the gums) that surround and support the teeth (Markou et al. 2009). These fluctuations, mainly in estrogen and progesterone, cause changes in the gingival and periodontal tissues (Machtei et al. 2004; Becerik et al. 2010; Shourie et al. 2012). Different phases of the menstrual cycle do not appear to correlate with the condition of the gingiva in orally healthy women. However, a significant exacerbation of pre-existing gingivitis during menstruation has been observed (Markou et al. 2009). Similarly, although ovarian hormones have just a slight effect on clinically healthy periodontium (Becerik et al. 2010), they may worsen pre-existing inflammation in gingival tissues (Shourie et al. 2012). These effects usually occur a day or two before menstruation starts and clear up shortly after (Markou et al. 2009).

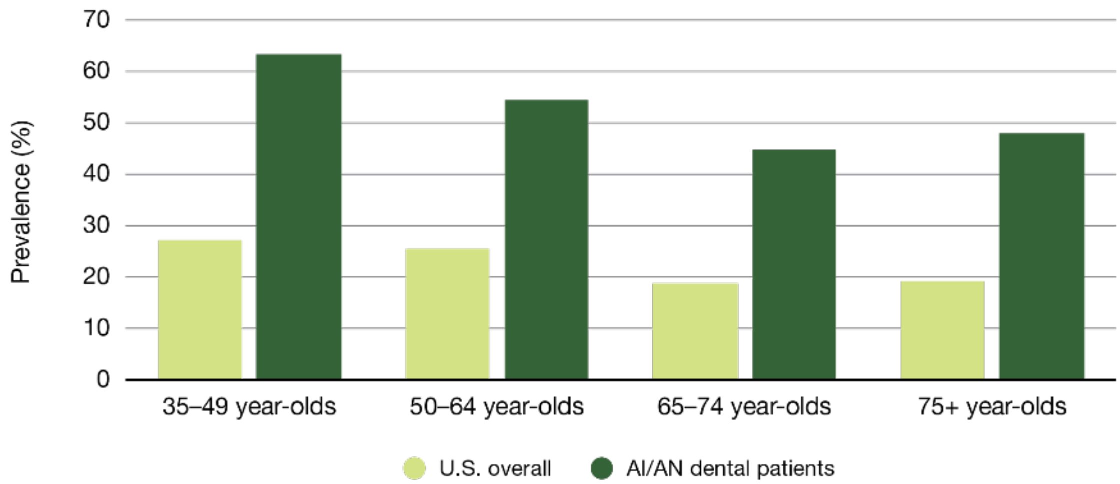
Hormonal changes during the menstrual cycle cause some women to experience oral changes that may include redness of gums, bleeding gums, swollen gums, swollen salivary glands, and canker sores. These hormones affect blood supply to the gum tissue and the body's response to toxins from plaque buildup. Sex hormones also increase the rate of folate metabolism in the oral mucosa. Because folate is necessary for tissue maintenance, increased metabolism may diminish folate stores and prevent tissue repair (Markou et al. 2009).

Oral Contraceptives

Oral contraceptives are one of the most widely used prescription medications in the United States, with about 11 million users (DeRossi and Hersh 2002). Oral contraceptives contain varying levels of progesterone and estrogen and mimic a state of pregnancy to prevent ovulation (Mascarenhas et al. 2003). Research suggests that prolonged use of contraceptives may detrimentally affect the periodontium (Saini et al. 2010) and increase risk for periodontitis (Kessler 2017).

There are several factors that could cause this. Changes in women's hormone levels, as discussed above, have systemic influences that affect the gums. For example, higher levels of progesterone increase blood flow to the gum tissue, causing gums to be more sensitive and vulnerable to irritation and swelling. Changes in progesterone and estrogen levels affect collagen production in the gingiva, reducing the body's ability to repair and maintain gingival tissues (Ali et al. 2016).

Figure 9. Percentage of adults age 35 years and older with untreated dental caries by age group for American Indians and Alaskan Natives (AI/AN) during 2015 and the overall U.S. population during 2011–2012



Notes: AI/AN adult Indian Health Service dental clinic users in 2015; Overall U.S. population information represents the noninstitutionalized, civilian population (data sourced from NHANES 2011–2012).
Source: Phipps and Ricks (2016).

Furthermore, oral and other hormonal contraceptive users experience changes in saliva composition and decreased saliva production, which can lead to oral health problems, ranging from irritated gingiva to aggressive periodontitis. Contraceptives can increase inflammation and the quantity of gingival fluids, which increase the prevalence of healing complications (dry socket conditions) after tooth extractions. Thus, tooth extractions should take place on days 23–28 of the menstrual cycle (Kessler 2017). Finally, women using oral contraceptives have a higher prevalence of *Streptococci mutans*, the primary organism responsible for dental caries, in their oral cavities and consequently experience a higher incidence of dental decay (Ali et al. 2016).

Hormones and Aging

As women age, their estrogen levels fall, with consequences across body systems, including the oral-craniofacial complex. Menopause is defined as 12 consecutive months without a menstrual cycle. Perimenopause is the period around menopause in which hormone levels fluctuate. Hypoestrogenism, or a reduction in estrogen, can lead to decreased saliva production in postmenopausal women (Chaveli et al. 2011). Falling estrogen levels also can affect the oral mucosa, resulting in oral health problems that may include burning mouth syndrome, xerostomia (dry mouth), atrophic gingivitis (inflammation and swelling of the gums), periodontitis, and dysesthesia (Friedlander 2002; Cao et al. 2007). Xerostomia is a common symptom in menopausal women (Minicucci et al. 2013).

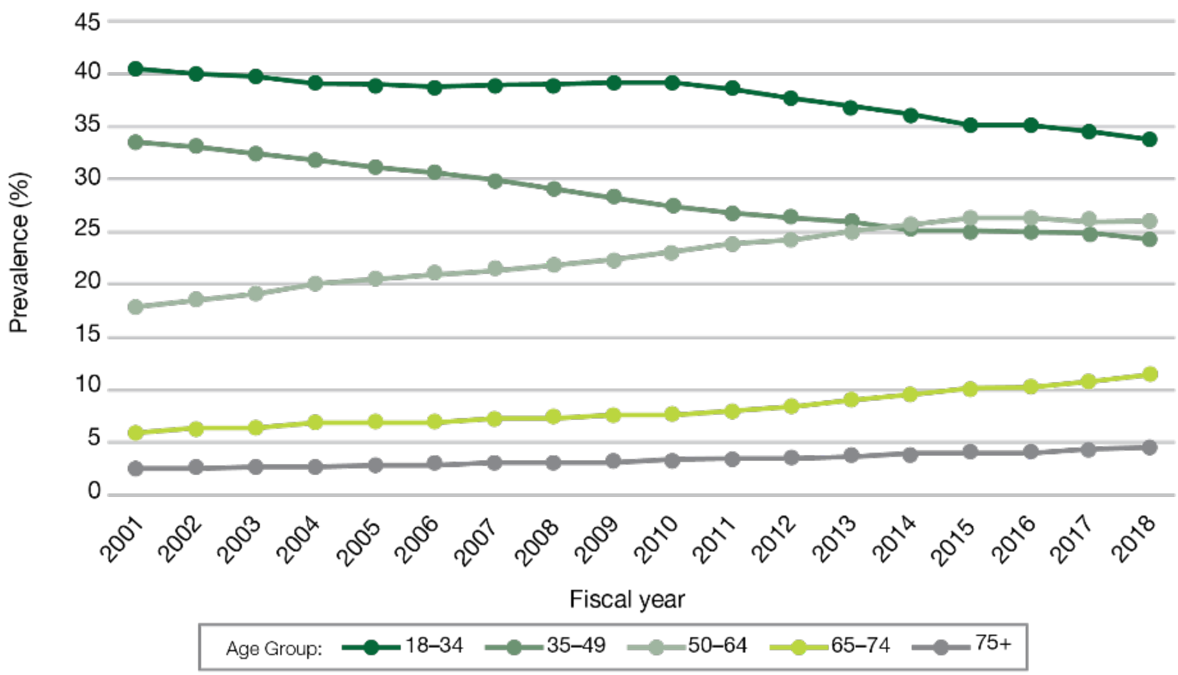
Menopause is a leading cause of osteoporosis (Becker 2006), which can affect the jawbone and reduce bone mineral density (BMD), contributing to periodontal disease progression. One study found that postmenopausal women had a higher prevalence and severity of periodontal disease (Yalcin et al. 2006).

Several studies have investigated the effect of hormone replacement therapy on oral health among perimenopausal and postmenopausal women. The results have been mixed, with some studies indicating improvements in dental pain, tooth mobility, depth of periodontal pockets (Lopez-Marcos et al. 2005), and tooth retention (Taguchi et al. 2004). However, a systematic review reported that hormone replacement therapy has no effect on the oral health of women (Meurman et al. 2009).

Pregnancy and Oral Health

Oral health is critical for pregnant women. During pregnancy, women may experience tooth decay, gingivitis, periodontitis, tooth loss, and erosive tooth wear.

Figure 10. Percentage of American Indian/Alaska Native adults ages 18 and older accessing dental care from 2001 to 2018



Source: Indian Health Service Office of Public Health Support, Division of Program Statistics, 2020.

Numerous studies have revealed that as levels of pregnancy-related hormones rise, the chances of gingivitis and periodontal disease increase in expectant mothers (Wu et al. 2015). As pregnancy progresses, levels of estrogen and progesterone produced in the ovaries and placenta rise. By the third trimester, these hormones peak and may induce immune responses that boost bacteria and inflammation, causing gingivitis and periodontal disease (Centers for Disease Control and Prevention 2019b).

Poor oral health during pregnancy has been linked to adverse health outcomes. For example, studies have shown that maternal periodontal disease is associated with increased risk for preeclampsia (Boggess et al. 2003), as well as preterm birth (Offenbacher et al. 2006; Corbella et al. 2016) and low birth weight (Gomes-Filho et al. 2016). Other factors, such as blood glucose levels, also affect these relationships. In addition, pregnant women are at higher risk of tooth decay because of factors that include an increase of acid in the oral cavity, dietary cravings for sugar, and limited attention to oral health care. Periodontitis in pregnant women is associated with a significantly increased risk for gestational diabetes, compared with women without periodontitis (Abariga and Whitcomb 2016). Experts recognize the importance of good oral hygiene and professional oral health care to reduce complications during pregnancy and at birth (Niessen et al. 2013).

Dental treatment during pregnancy may include dental examinations, radiographs, dental prophylaxis, local anesthetics, restorative care, and, if necessary, dental surgery (Silk et al. 2008). Because of possible patient discomfort, especially late in pregnancy, elective treatment is sometimes postponed until after delivery. Additional counseling by oral health providers should include instructions regarding proper oral hygiene, use of fluoride toothpaste, and dietary education about the adequate quality and quantity of nutrients for the mother-to-be and the unborn child. Providing timely educational information and preventive therapies to pregnant women also has been shown to reduce risk for dental caries in their children (Lucey 2009; Meyer et al. 2010).

Despite the importance of having good oral health during pregnancy, even with proper referrals, pregnant women often do not seek or receive dental treatment when it is needed, and those who do may face dentists who are hesitant or unwilling to provide care (Huebner et al. 2009). Rocha and colleagues (2018) conducted a systematic review of the use of dental services during pregnancy and reported that the prevalence of dental visits during pregnancy ranged from 33–68% in the United States and Canada. The authors also found that income, education, and race/ethnicity were significantly associated with visiting the dentist. Those with lower income and education and ethnic minorities were less likely to visit the dentist. Lee and colleagues (2021) obtained similar findings in a study in 31 states and New York city using cross-sectional data from the Pregnancy Risk Assessment Monitoring System (2012–2015), which collects information on the use of dental services (Stephens et al. 2020). They found that 19.7% of respondents reported having a dental problem during pregnancy, and 51.7% had at least one dental visit while pregnant. Non-Hispanic Black and Hispanic women were less likely to visit a dentist during pregnancy compared to non-Hispanic White women. In a study of the Virginia Pregnancy Risk Assessment Monitoring System 2012–2014 data (Naavaal et al. 2019), only 47% of women reported having a dental visit. Having dental insurance, knowledge of the importance of dental care during pregnancy, and counseling by a health provider were significant predictors of dental service utilization during pregnancy.

A study in California (Marchi et al. 2010) investigated use of dental services during pregnancy using data from the Maternal Infant Health Assessment, an annual population-based survey of mothers delivering live infants in California during February through May of each year. Only one-third of the women reported receiving any dental care during pregnancy, and 62% of those who reported dental problems did not receive care. As with other studies, this study found that ethnic minorities, low income, and less-educated women were at greater risk of not receiving dental care.

Interrelated Effects of Oral Health with General Health

Just as general health conditions—including some medications used to treat them—can affect oral health (Table 4), the opposite also is true: oral health conditions can affect general health. Although the research community has advocated for additional clinical trials of these relationships, several U.S. insurers have taken the initiative to implement cost-saving dental benefits for patients with chronic diseases, such as type 2 diabetes, coronary artery disease, and cardiovascular disease.

Atherosclerotic Cardiovascular Disease

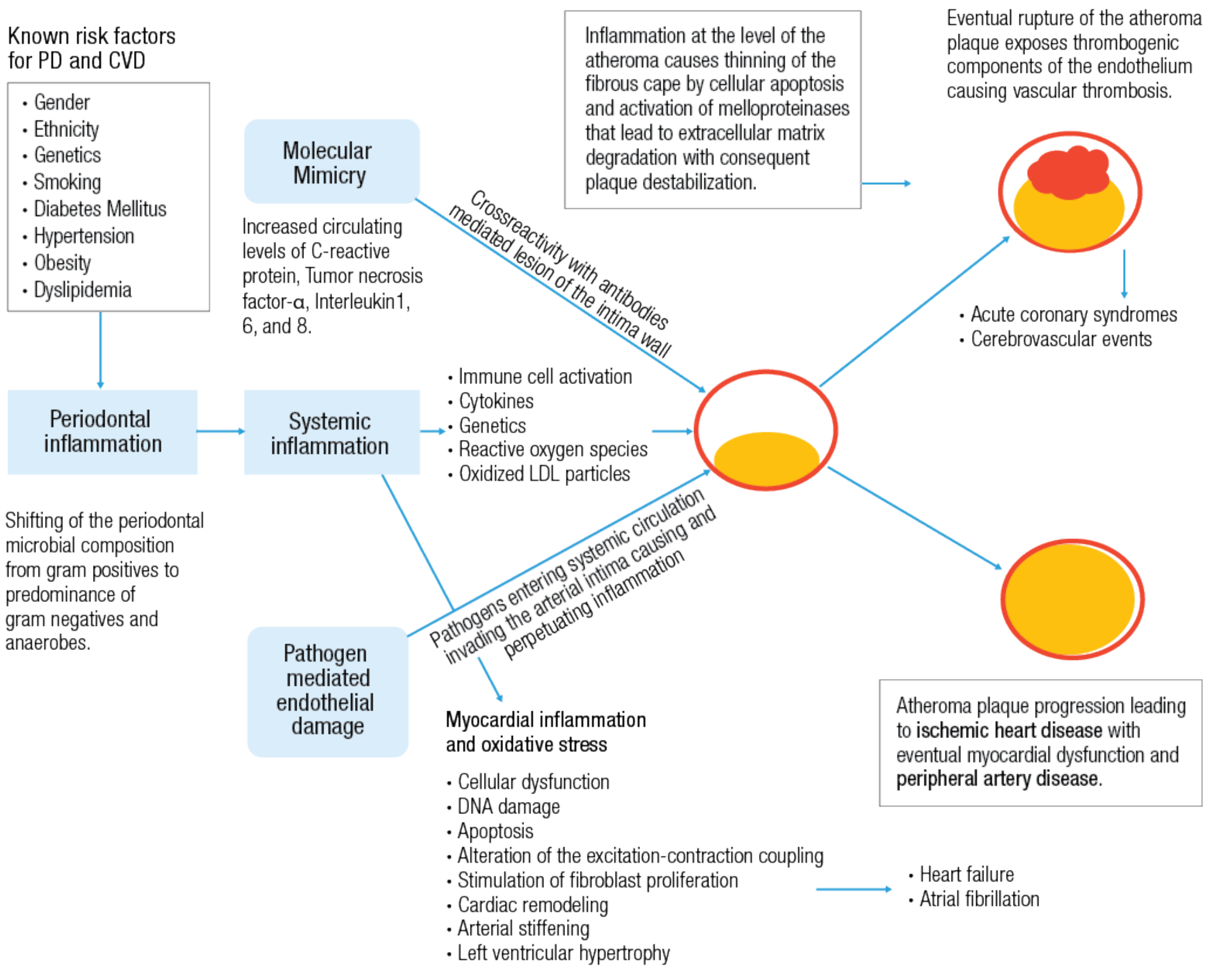
Periodontal disease is associated with atherosclerotic cardiovascular disease, including coronary heart disease, cerebrovascular disease, and peripheral arterial disease, although the risks are not the same for all age groups. These associations are currently thought to operate indirectly through systemic inflammatory pathways that can facilitate a series of cascading events causing vascular damage, or more directly via pathogenic exposure (Figure 11).

It is unclear if treating periodontal disease can prevent the onset of cardiovascular disease or secondary events. A 2017 systematic review found no studies on the topic (Li et al. 2017). However, when patients received nonsurgical periodontal treatment versus no treatment, there was a significant decrease in their C-reactive protein and leukocyte levels, which are blood serum markers for inflammation. In addition, periodontal treatment had a beneficial effect on some biochemical measures, such as blood lipid levels that can affect cardiovascular risk (Buhlin et al. 2009). Furthermore, a recent systematic review indicates that periodontitis may be a modifiable risk factor for cardiovascular disease (Sanz et al. 2020). These authors state that "severe periodontitis is independently and significantly associated with all-cause and cardiovascular mortality in several different populations." On the other hand, a Cochrane review found that there is presently little substantive evidence that treatment for periodontitis can prevent or improve cardiovascular disease (Liu et al. 2019).

Cerebrovascular Accident and Transient Ischemic Attack

It has been suggested that certain types of inflammation, including periodontal disease, could be risk factors for stroke (Syrjanen et al. 1986). Periodontal disease is considered an independent risk factor for cerebral ischemia in men and younger individuals (Grau et al. 2004; Fagundes et al. 2019; Lee et al. 2019). People with severe periodontitis had a 4.3 times higher risk of cerebral

Figure 11. Relationship of periodontal disease (PD) to cardiovascular diseases (CVD)



Source: Carrizales-Sepúlveda et al. (2018). © Australian and New Zealand Society of Cardiac and Thoracic Surgeons (AZNSCTS) and the Cardiac Society of Australia and New Zealand (CSANZ). With permission from Elsevier.

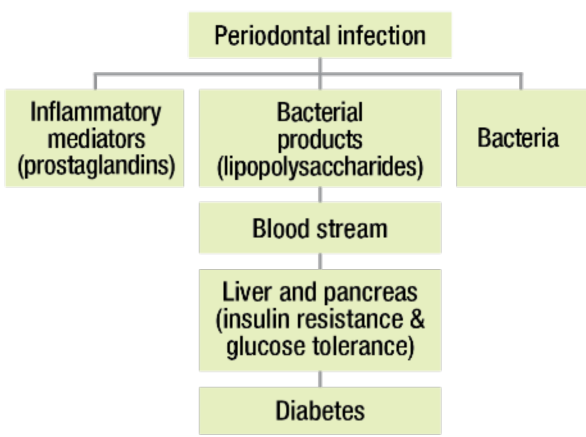
ischemia than those with mild or no periodontitis (Grau et al. 2004). Severe periodontitis was found to be a risk factor in men but not women, and in adults younger than 60 years of age, but not for older people. One recent study has reported that gender and age (40–59 years) may be an effect modifier between severe periodontal disease and incident myocardial infarctions (Cho et al. 2021).

Diabetes and Glycemic Control

Diabetes is an important risk factor for periodontitis, and the prevalence of periodontitis is three times higher in individuals with diabetes than in those without diabetes (Preshaw et al. 2005). Conversely, moderate to severe periodontitis is a predictor for the development of type 2 diabetes (Demmer et al. 2008; Winning et al. 2017). Figure 12 shows a potential link between the two diseases.

Systematic reviews of randomized controlled trials (RCT) on periodontal therapy and glycemic control in people with diabetes have been conflicting. A 2015 systematic review by Mauri-Obradors and colleagues (2015) of 21 RCTs on periodontal therapy and diabetic glycemic control concluded that the research literature does not support periodontal treatment as a means to improve serum glycated hemoglobin (HbA1c) levels in patients with type 1 diabetes. Conversely, a 2017 systematic review by Madianos and Koromantzos (2018), containing seven RCTs regarding periodontal therapy and diabetic glycemic control, concluded there was a statistically significant reduction in HbA1C levels at 3 and 6 months post-treatment. Most systematic reviews have reported some additional glycemic benefit when adjunctive antibiotics were used with periodontal therapy (Grellmann et al. 2016; Teshome and Yitayeh 2016; Souto et al. 2018). However, more consistent homogenous studies are needed because conflicting reports exist (Salvi et al. 2008; Lira Junior et al. 2017). Additional research to resolve inconsistencies in prior reports would be useful. People with diabetes are more likely to have periodontal disease, and treatment is extremely important.

Figure 12. Pathway showing link between periodontal disease and diabetes



Source: Babu and Gomes (2011).

Osteopenia and Osteoporosis

Osteopenia and osteoporosis are characterized by decreased BMD and bone microarchitecture, increasing the risk of bone fracture. An estimated 50% of the population in the United States aged 50 years and older will suffer from decreased BMD in their lifetimes (Wright et al. 2014). Low BMD in females (50%) is more prevalent than in males (20%) (Cosman et al. 2014). Non-Hispanic White and Hispanic populations have a higher prevalence of low BMD than do African Americans (Wright et al. 2014).

The impact of low BMDs on tooth loss and of periodontal disease on bone loss continues to be of interest. Although association between low BMD and periodontal disease has been shown (Iwasaki et al. 2013; Gil-Montoya et al. 2020), it is not clear what effect osteopenia and/or osteoporosis may have on periodontal disease. Among postmenopausal women, chronic periodontitis is more prevalent and severe in those with osteoporosis than in those with normal bone density (Wang and McCauley 2016). Normal levels of vitamin D and medication to treat osteoporosis may improve the periodontal status of these women (Penoni et al. 2017). In a systematic review and meta-analysis, Penoni and colleagues (2017) found that postmenopausal women with low BMD had greater clinical attachment loss—a sign of irreversible periodontal disease—than those with normal BMD. One study in Japan indicated that mandibular cortical width and extent of erosion seen on panoramic radiographs was significantly correlated with BMD, as measured using ultrasound densitometry, and held the potential for predicting osteoporosis risk (Ohtsuki et al. 2017). However, additional work is needed to verify this finding, establish the mechanism by which osteoporosis contributes to periodontal disease, and determine if advanced densitometry devices could be used to screen for osteopenia/osteoporosis.

Sickle Cell Disease

Sickle cell disease (SCD) is the most common inherited hematological disease in the United States. Though the actual prevalence of SCD is unknown, it is thought that sickle cell anemia or Hemoglobin SS (the most severe form), is the most prevalent form of the disease, occurring most frequently in African Americans and increasingly found in Hispanics (Hassell 2010). Other forms of SCD found in the United States include hemoglobin SC disease and hemoglobin Sβ thalassemia.

Certain dental conditions that are seen more often in people with SCD than in the general population include dental caries, orofacial or dental pain usually of undetermined origin, pulpal necrosis (death of dental pulp cells), periapical (at the root of the tooth) infections, osteomyelitis of the mandible (jaw bone infection), neuropathy (nerve pain), medullary hyperplasia with abnormal trabeculae spacing in the mandible and maxilla (abnormal bone and tissue growth in the jaw), and hypomineralization of the teeth (discoloration of tooth enamel) (Demirbas Kaya et al. 2004; Laurence et al. 2006; da Fonseca et al. 2007; Mulimani et al. 2016).

Table 4. Medical conditions with oral health consequences

Medical condition	Oral health consequences
Alzheimer's disease and other progressive dementias	Poor oral hygiene, periodontal disease, dry mouth, dental caries risk (Delwel et al. 2018)
Anemias	Pale mucosa, atrophic glossitis, angular stomatitis, oral candidiasis, aphthous-like ulcers (Adeyemo et al. 2011; McCord and Johnson 2017)
Bulimia nervosa	Dental erosion, dental caries, dry mouth, parotid enlargement (Bretz 2002)
Chronic kidney disease	Periodontitis (Deschamps-Lenhardt et al. 2019)
Diabetes	Periodontitis (Kocher et al. 2018)
Gastroesophageal reflux disease (GERD)	Dental erosion (Lee et al. 2017)
HIV, other immune-suppressing conditions, sexually transmitted diseases	Mucosal disease (oral hairy leukoplakia, oral candidiasis, oral warts, oral Kaposi sarcoma, aphthous stomatitis, oral herpetic ulcers), herpes zoster lesions, salivary gland enlargement, necrotizing gingivitis, periodontitis (Shiboski et al. 2009)
Inflammatory bowel disease (ulcerative colitis and Crohn's disease)	Cobblestoning and mucogingivitis, indurate mucosal tags, pyostomatitis vegetans, aphthous stomatitis and angular cheilitis, deep linear ulcerations and lip swelling with vertical fissures (Muhvić-Urek et al. 2016)
Interpersonal violence	Oral and dental trauma (mandible fracture, facial contusion and laceration, dental concussion) (Ferreira et al. 2014)
Medications that impact the mouth (including antidepressants, antihistamines/decongestants, antihypertensives, herbal products)	Salivary gland dysfunction, gingival overgrowth, angioedema, oral pigmentation, lichenoid lesions, dysgeusia/taste changes, bleeding/petechiae, alveolar bone loss, mucositis/stomatitis, neuropathy, chemo-osteonecrosis (Ciancio 2004)
Methamphetamine and other illicit substance use/abuse	Dry mouth, gingival inflammation, tooth wear, rampant caries—commonly called "meth mouth" (Stanciu et al. 2017)
Neoplastic hematologic disease, including leukemia, multiple myeloma, lymphoma, and cancer chemotherapy	Mucositis, leukemic gingival infiltrates and inflammation, opportunistic infections, oral petechiae-ecchymosis, ulcers, tumor growth, periodontitis (McCord and Johnson 2017)
Osteoarthritis	Poor oral hygiene, temporomandibular joint pain (Kelsey and Lamster 2008)
Osteoporosis	Periodontitis, tooth loss (Kelsey and Lamster 2008)
Pregnancy	Gingival hyperplasia, morsicatio buccarum, oral candidiasis, pyogenic granuloma (Bett et al. 2019)
Radiation therapy for head and neck cancers	Oral mucositis, rampant caries, osteoradionecrosis, trismus of muscles of mastication, taste change (Sciubba and Goldenberg, 2006)
Sjögren's Syndrome (and other autoimmune diseases)	Dry mouth/mucosa, salivary gland enlargement, oral candidiasis, rampant caries, oral ulcerations, taste changes/dysgeusia (Cartee et al. 2015)
Sleep disorders	Gingival inflammation, lower masticatory function (Carra et al. 2017)
Stroke and acquired brain injury	Poor oral hygiene, dental caries, dysphagia, xerostomia, tooth loss, gingivitis/periodontitis (Pillai et al. 2018)
Systemic sclerosis	Microstomia, caries, dry mouth, periodontal disease, gingival recession, mandibular bone resorption (Veale et al. 2016)
Thrombocytopenia and hemophilia	Petechiae and hemorrhagic bullae of mucosa, bleeding gingiva, spontaneous gingival bleeding (Adeyemo et al. 2011; McCord and Johnson 2017)

Sources: Adapted from Akinkugben et al. (2017) and Weintraub et al. (2019).

In medullary hyperplasia, the hyperplasia and compensatory expansion of the facial bones can result in changes in craniofacial bone structure, increasing the likelihood of dental malocclusion (Costa et al. 2015). Although there is little evidence of a causal pathway leading to dental caries, people with SCD may experience more dental caries and poor oral health because they prioritize other aspects of health care (Laurence et al. 2006; Laurence et al. 2013). Moreover, dental clinicians may be reluctant to treat people with SCD because they do not know how to address the potential complications (Passos et al. 2012). African Americans with SCD are more likely to be unemployed and less likely to have dental insurance (Laurence et al. 2006). These inequities, including the potential reluctance of dental providers to provide care, a low priority placed on oral health among patients with SCD, and the high cost of dental treatment may all be factors that contribute to the higher prevalence of dental caries in patients with SCD.

Cancer Treatment

The oral cavity can be at risk for a range of toxicities from cancer treatment, principally involving the mucosa (oral mucositis) and, to a lesser extent, in order of prevalence, salivary glands, bone forming the mandible or maxilla, and periradicular sites (National Cancer Institute 2020c). The various effects of cancer treatments on oral health are shown in Table 5. Unlike high-dose head and neck radiation, which causes irreversible damage to oral tissues, the long-term impact of high-dose chemotherapy on teeth and surrounding periodontium (Raber-Durlacher et al. 2004) or salivary glands (Wolff et al. 2017) is limited. The principal oral toxicity associated with high-dose chemotherapy is oral mucosal injury, called oral mucositis (Peterson et al. 2012). Oral mucositis can be extremely painful and debilitating. It often appears as red, burn-like sores or as ulcer-like sores ranging in size from 0.5 centimeters (cm) to 4 cm (National Cancer Institute 2020c).

Medications and Oral Health Complications

Osteonecrosis of the Jaw (ONJ) and Medication-Related ONJ

ONJ is an oral complication from cancer radiation treatment to the head or neck. Medication-related osteonecrosis of the jaw (MRONJ) is an oral complication from cancer treatment with either antiresorptive or antiangiogenic drugs (Ruggiero et al. 2014; Migliorati et al. 2019; Nicolatou-Galitis et al. 2019). The pathologic mechanisms that drive development of the MRONJ lesion have not been fully delineated (Migliorati et al. 2019). MRONJ is associated with both bone-modifying agents (BMAs), such as bisphosphonates and denosumab, and anti-angiogenics, such as bevacizumab. Since the first report of MRONJ in 2002, there have been important, consensus-level advances in the staging and clinical management of these lesions (Ruggiero et al. 2014; Nicolatou-Galitis et al. 2019). A diagnosis of MRONJ requires:

- Current or previous treatment with a BMA;
- Exposed bone or bone that can be probed through an intraoral or extra-oral fistula in the maxillofacial region, which has persisted for longer than 8 weeks; and
- No history of radiation therapy to the jaws or metastatic disease to the jaws.

MRONJ is an infrequent complication in oncology patients, ranging from 1-5% (Otto et al. 2018). The most likely people to be at risk for MRONJ are those whose clinical treatment has included BMAs or anti-angiogenics to reduce the risk for pathologic fractures attributable to skeletal metastases. This includes people with multiple myeloma, as well as advanced solid tumor cancers, such as prostate, breast, or colon cancer.

MRONJ also occurs in people taking oral BMAs, most often to treat osteoporosis. A systematic review revealed that the mean age at onset of MRONJ was 69.7 years, give or take 5.2 years. MRONJ is more common in females than in males and is more common in the mandible. Alendronate was the most common agent used; the duration of intake was 50.4 months, give or take 19 months, and 86.7% took the drug orally (Aljohani et al. 2017). Longer duration of use seems to increase the risk of development of MRONJ. Paradoxically, use of these medications for osteoporosis may improve the periodontal status of postmenopausal women with osteoporosis (Penoni et al. 2016).

Gingival Hyperplasia

People taking certain long-term medications, including immunosuppressants for solid organ transplants, calcium channel blockers for cardiovascular disease, and phenytoin for epilepsy may develop gingival hyperplasia (overgrowth) (Aral et al. 2015; Hatahira et al. 2017).

Table 5. Prevalence of oral complications from cancer treatments

Condition	Mean Prevalence Estimate
Bisphosphonate osteonecrosis	6.1%
Dysgeusia	76%
Oral fungal infection	32.6%
Oral viral infection	With oral ulcerations/sampling oral ulcerations = 33.8–49.8% **RT** only/sampling oral ulcerations = 0% **RT** and adjunctive **CT**/sampling oral ulcerations = 43.2%
Dental caries	28.1%
Severe gingivitis	20.3%
Salivary gland hypofunction and xerostomia	68–91% > 2 years post **RT**
Trismus	25.4% for conventional **RT** 5% for **IMRT** 30.7% for combined **RT** and **CT**
Osteoradionecrosis	5.2–7.4%

Notes: RT = Radiation Therapy; CT = Chemotherapy; IMRT = intensity-modulated radiation therapy.
Source: Adapted from National Cancer Institute (2020c).

Although the lesion is not typically painful, the resulting periodontal pocket formation can compromise the ability to maintain oral hygiene and the gingival sites may become infected.

Xerostomia (Dry Mouth)

The oral health of adults with chronic conditions may be affected if they take some types of medications or multiple medications. The most common side effect of medications is decreased salivary flow, which causes xerostomia (dry mouth), a condition of not having enough saliva to keep the mouth moist. Chronic dry mouth makes chewing, swallowing, and even talking difficult. Saliva plays multiple roles—it facilitates digestion, lubricates soft tissues, and has antibacterial properties—and its decrease can increase the risk for dental caries. Medications that have anticholinergic properties, such as antidepressants and antipsychotics, and antihypertensive medications, such as angiotensin-converting enzyme inhibitors, calcium channel blockers, beta-blockers or diuretics, can cause dry mouth. Chronic dry mouth can be caused by:

- *Side effects of some medicines:* Hundreds of medicines can cause the salivary glands to make less saliva. For example, medicines for high blood pressure, depression, and bladder-control issues often cause dry mouth.
- *Disease:* Sjögren syndrome, HIV/AIDS, and diabetes can all cause dry mouth.
- *Radiation therapy:* The salivary glands can be damaged if they are exposed to radiation during cancer treatment.
- *Chemotherapy:* Drugs used to treat cancer can make saliva thicker, causing the mouth to feel dry.
- *Nerve damage:* Injury to the head or neck can damage the nerves that tell salivary glands to make saliva.

Sleep Apnea

People of all ages can have sleep apnea. It is normal to stop breathing for a few seconds during sleep, but it can be detrimental to health if it occurs too frequently (more than once per hour in children and 5–10 times per hour in adults) and lasts more than 10 seconds. Sleep apnea is a combination of apnea (cessation of breathing), hypopnea (reduction of breathing strength), and hypoxia (reduction in oxygen to the brain). Sleep apnea occurs in about 2–4% of the general population. With increasing age and obesity, the prevalence increases to 15% and 40%, respectively, depending on gender. Males are more at risk, and premenopausal females appear to be protected (Peppard et al. 2013; Heinzer et al. 2015).

Cessation of breathing during sleep can be caused by obstruction of the upper airway (big tonsils, large tongue, fat in throat and tongue [because of obesity], and small and narrow jaws) or it can be central, attributable to brain or lung altered reactivity or a weaker reflex to reopen the airway. Supine sleep position, alcohol use, and medications for anxiety (benzodiazepines) or pain (opioids) can also contribute to worsening the condition in some vulnerable people.

Sleep apnea can cause altered concentration and memory, as well as lower vigilance and attention. In adult women, fatigue is a dominant complaint and men complain of sleepiness. Sleep apnea is often associated with other health conditions, such as insomnia, snoring, high blood pressure, diabetes, headache, tooth grinding, low libido, and depression. These are not always the direct cause of sleep apnea; however, the coexistence of apnea can be an important aggravating factor. For example, having obstructive sleep apnea can increase an individual's risk for hypertension.

Oral health professionals can screen patients for sleep apnea; however, formal diagnosis and assessment of its risk on function and health are the responsibility of a sleep physician who may order a sleep test with a device to measure sleep breathing activity (Kapur et al. 2017; Veasey and Rosen 2019). Only sleep physicians can diagnose and assess sleep breathing. They may then provide a continuous positive airway pressure (CPAP) device or refer the patient to a dentist who can provide an oral appliance. Some dentists work collaboratively with primary care physicians and sleep specialists as part of multidisciplinary care teams.

The first choice of treatment is a CPAP machine, which is prescribed by a physician. A CPAP machine reduces the health risks when it is used on a regular basis during sleep. The second choice is a mandibular advancement dental device or appliance that prevents backward movement of the jaw to prevent the upper airway closure. This device has been available for more than 30 years and its efficacy is proven (Marklund et al. 2019; Uniken Venema et al. 2020), although it may not work for everyone (Remmers et al. 2017; Sutherland et al. 2017). Dentists who have had special training and are qualified through the American Academy of Dental Sleep Medicine (American Academy of Dental Sleep Medicine 2021) are trained to provide these appliances (Gauthier et al. 2012; Haviv et al. 2014; Levine et al. 2018).

Based on recent evidence, both treatments have a similar effect. However, currently available data suggest that the mandibular advancement device is less effective in reducing apnea frequency and must be used for more hours per night and for more nights per week than the CPAP to achieve the same health benefit (reduction of morbidity/presence of disease or disorder and mortality) over time (Anandam et al. 2013; de Vries et al. 2018; Schwartz et al. 2018; Sutherland and Cistulli 2019). To reach the best efficacy with CPAP or dental devices, risk factors should be addressed by offering advice on how to improve sleep quality, lose weight, correct supine sleep position, initiate oropharyngeal exercise programs to increase muscle tone during sleep, and reduce alcohol use (Hsu et al. 2020; Lavigne et al. 2020).

Dentists also can provide orthodontic treatment or jaw surgeries to correct a narrow lower and upper jaw to prevent sleep apnea (Lin et al. 2020). Physicians can remove large tonsils and nasal obstructions, perform bariatric surgery, or stimulate nerves to push the tongue forward. Sleep apnea treatment has a better likelihood of succeeding by using a multidisciplinary team care approach that includes physicians, dentists, psychologists, speech therapists, and sleep specialists (Lavigne et al. 2020).

Prevention and Management of Oral Diseases and Conditions

Efforts directed at preventing and controlling orofacial diseases and other adverse conditions in adults are focused on dental caries, periodontitis, and oral cancer. Primary prevention interventions for dental caries are aimed at preventing the occurrence of tooth decay. These activities often include health promotions that focus on improving poor dietary habits and encouraging better oral hygiene for teeth and periodontal health. The use of fluoride-containing toothpaste, either purchased over the counter or provided by a dentist as a prescription, also is an important primary prevention activity. Other primary prevention efforts include: (1) providing mouth guards to prevent sports injuries to teeth, (2) tobacco cessation interventions and substance misuse counseling to prevent periodontitis and other harms to the mouth, and (3) vaccinating young adults to prevent HPV-associated cancers, including OPC.

Secondary prevention efforts are intended to detect early signs of disease, generally through receiving regular care, and thereby to reduce the impact of early disease onset. Silver diamine fluoride (SDF) is a chemotherapeutic approach that aims to reduce the impact of dental caries when the caries process has been limited to a small cavity. A different chemotherapeutic approach for helping to control the progression of gingival inflammation and periodontitis is the use of anti-inflammatory antibacterial mouth rinses, such as chlorhexidine, which is by prescription only.

The focus of tertiary prevention is controlling the disease after diagnosis to prevent progression to tooth loss or to provide rehabilitation to restore some function that supports quality of life. For controlling advanced caries progression in adults, a variety of restorative options are available. In controlling periodontitis, the objective is to prevent bone loss using a variety of nonsurgical therapies and if necessary, periodontal surgery.

Management of Dental Caries

Modern management of dental caries emphasizes prevention, with personalized risk assessment, a preventive care plan, and disease management based on early detection. Although caries risk assessment has proven useful with children, its use in adults continues to be problematic. This is an important issue for facilitating patient-centered care, given that a person's prognosis is dependent on a robust caries risk prediction modelling (Fontana et al. 2020). This work remains underdeveloped.

With greater attention to earlier detection and intervention, noninvasive or nonsurgical management of dental caries that preserves tooth structure is becoming more frequently utilized in adults (Slayton et al. 2016). These approaches are designed to arrest the caries process and allow remineralization of the carious lesion. Topical fluorides for adults, such as fluoride varnish, remineralize the tooth structure and prevent the caries process. SDF, mentioned above, also can be used in adults to arrest the caries process. A systematic review examined the use of SDF in adults with exposed root surfaces and found SDF to be effective in arresting the caries process on root surfaces of teeth (Oliveira et al. 2018). For dental caries in which minimal structure has been destroyed, minimally invasive restorative treatment can be provided with a goal of preserving as much tooth structure as possible to attain better long-term results. For teeth more severely affected by the caries process, restorative procedures, such as restorations (fillings) or crowns may be needed.

Management of Periodontal Disease

Periodontal disease prevalence increases with age and the incidence rises steeply in adults aged 30 to 40 years. It is estimated that the burden of periodontitis will continue to increase globally as working-age adults and older adults continue to retain more of their natural dentition (Tonetti et al. 2017). As the relationships between oral infection/oral inflammation and the risk for noncommunicable diseases—primarily cardiovascular diseases, diabetes, respiratory diseases and cognitive impairment—continue to be identified (Liccardo et al. 2019), the need to prevent and/or eliminate or reduce the adverse effects of severe periodontitis assumes greater significance.

Prevention of periodontal disease, similar to dental caries, requires an understanding of risk factors and the tailoring of prevention programs to individual needs through diagnosis and risk assessment. A new Periodontal Classification system (Caton et al. 2018a) identifies the stage of the disease based on severity and complexity of management and the grade of the disease that rates the risk of progression. These variables enable the clinician to identify the level of severity of periodontal disease, along with an individual's comorbidities, thus enabling better targeting of preventive services. The removal of subgingival calculus remains a critical component to decrease inflammation and prevent and control periodontal disease. Adherence to recommendations about self-care is essential too, beginning with oral hygiene care to reduce plaque. Because periodontitis shares risk factors with other systemic diseases, such as heart disease and diabetes, WHO has strongly advocated for the use of the Common Risk Factor Approach to include self-performed oral hygiene as part of healthy lifestyles (Tonetti et al. 2017).

The goal of periodontal treatment is to "control gingivitis and periodontitis, avoid disease progression leading to tooth loss, retain a functional dentition for a lifetime, preserve self-esteem and improve quality of life" (Tonetti et al. 2017, p. 459). Adults need to be informed of the importance of seeking regular care if periodontitis is present. To achieve this goal, medical and dental health professionals need to be aware of the relationships between severe periodontitis and certain systemic diseases, and refer patients with a suspected problem for treatment. Adults with limited access to oral health care or limited funds to pay for care, however, may struggle to afford preventive measures or treatment of periodontal disease.

Management of Tooth Loss

Although adults have seen improvements in the number of teeth lost because of caries and periodontal disease, tooth loss in adults remains a problem today. Tooth loss can lead to such problems as poor diet, which can result in weight loss or weight gain, limited social contact, impeded speech, lowered self-esteem, or reduced employment opportunities (U.S. Department of Health and Human Services 2000). Adults missing their front teeth do not have the same employment opportunities as those with a complete smile. Chronic medical conditions, many of which begin in adulthood, can contribute to poor oral health. People with chronic conditions are more likely to have untreated dental disease, which can lead to tooth loss.

According to data from the 2011–2016 National Health and Nutrition Examination Survey, among adults older than 50 years of age who had a dental examination, the prevalence of edentulism (no teeth), severe tooth loss (less than eight teeth remaining), and lacking functional dentition (less than 20 teeth) were 10.8%, 16.9%, and 31.8%, respectively. In addition, those who reported select chronic conditions were significantly more likely to have severe tooth loss than were people without chronic conditions (Parker et al. 2020). The increase of tooth loss in adults with chronic conditions speaks to the importance of referrals between physicians and dentists to ensure that oral health problems are diagnosed and treated early to prevent tooth loss.

The replacement of missing teeth can be accomplished with a variety of dental procedures. Traditionally, a fixed bridge or a removable partial denture were the treatment options for missing teeth. With advancements in implant designs, surfaces, and treatment protocols during the past 20 years, implant success has improved; consequently, more adults are selecting implants as the treatment of choice to replace their missing teeth. In fact, data from the National Health and Nutrition Examination Survey shows that between 1999–2000 and 2015–2016, the largest relative increase in implant use occurred among adults aged 55 to 64 years (Elani et al. 2018). The costs of this tooth replacement choice, however, can be high, with estimates of replacing one tooth with an implant ranging from $3,000 to $6,000 (Alderman 2010; Healthline 2019).

With the increase in the use of implants, peri-implant disease has increased. The new classification system for peri-implant health and disease, including infections and other problems that may occur following the placement of implants, provides definitions for peri-implant health, peri-implant mucositis, and peri-implantitis. Evidence for the latter two suggest the role of bacterial plaque and plaque control measures as important in managing these conditions (Caton et al. 2018a).

Oral Health Literacy

With an estimated 90 million adults having limited health literacy, a large proportion of our population either cannot benefit from oral health advances or do not have the ability to navigate our complex health care and reimbursement systems (Kutner et al. 2006). Because adults are the primary caregivers for both children and older adults, health literacy is critical to their ability to access and use oral health services appropriately.

Health literacy is defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Ratzan and Parker 2000, p. vi). Adults with higher health literacy make better choices about their care, disease prevention activities, health behaviors, and interactions with the health care system. It is reasonable to conclude that adults with limited health literacy are likely to experience worse oral health outcomes than their peers. However, the specific mechanisms underlying these associations and the roles that practitioners and clinic settings play require further exploration.

Many working-age adults face challenges as they attempt to make decisions affecting their oral health. For preventive interventions to succeed in reducing the prevalence and severity of oral diseases in adults, oral health literacy programs are needed to better inform and guide decision making on issues related to oral health care. In addition, conscious and unconscious biases pose barriers to oral health prevention and treatment services for racial/ethnic minorities and immigrant populations (Lamster and Northridge 2008; Northridge et al. 2017a; Bastos et al. 2018; Hebert-Beirne et al. 2018). Oral health risks in immigrant communities are compounded by the difficulties these populations experience related to linguistic, cultural, economic, and social barriers that can interfere with accessing health care.

Hispanic subpopulations may continue to face health literacy challenges in the next few decades as their population grows (Vespa et al. 2018). According to the 2003 National Assessment of Adult Literacy, 41% of Hispanics have below basic levels of health literacy (Kutner et al. 2006). Research is needed to clarify the demands that will be placed on the oral health care system and to understand how the health care needs of this growing population can best be met with respect to health-literate practices.

Recent efforts in the state of Maryland to improve oral health following the death of Deamonte Driver (a young boy who died from an untreated toothache), included the development of a health literacy program for Medicaid-eligible pregnant women. Focus groups conducted with pregnant women found that they often do not get dental care during pregnancy for several reasons: they were not aware that they are eligible for dental care during pregnancy, they believed incorrectly that it is unsafe for women to see a dentist while pregnant, and some were afraid to go to the dentist (Horowitz et al. 2016). Additional studies on the health literacy of adults in Maryland have found many adults to have little knowledge or incorrect knowledge on how to prevent dental caries (Horowitz et al. 2013; Horowitz et al. 2015). See Section 1 for more detailed information on oral health literacy.

Special Needs Populations

Adults with Disabilities and Special Health Care Needs

Adults with disabilities represent a diverse population, with some having developmental or physical disabilities from birth, while others acquire disabilities as children or adults. Similarly, their living arrangements are as varied, with some living in the community, while others may require community homes or assisted living. Overall, the percentage of people with disabilities in the U.S. civilian population slightly increased from 12% in 2010 to about 13% in 2016. As the U.S. population ages, the percentage of people with disabilities will increase as well. In 2016, for adults aged 18 to 64 years, the rate of disability was estimated to be 11%, while in people 65 years of age and older the rate of disability was 35%. Among the population with disabilities, more than half (51%) were people aged 18 to 64 years, while 2 in 5 (41%) were aged 65 years and older. In 2016, 36% of people with disabilities aged 18 to 64 years, living in the community, were employed (Kraus et al. 2018).

Adults with special health care needs (SHCNs) often have underlying chronic conditions with associated risk factors, such as poor hygiene, dry mouth, increased inflammatory load, and poor systemic health. The combination of chronic conditions with SHCNs has a profound effect on oral health; although some people may lack the dexterity or cognitive ability to maintain oral hygiene, others may have to take medications that compromise their oral health. Systemic changes that accompany certain chronic conditions can interfere with oral health. The opposite also is true—poor oral health can have a lasting impact on general health and well-being. For example, non-functional dentition that results from dental disease or missing teeth could compromise an individual's ability to eat, affecting their nutritional intake and overall health (Chavez et al. 2018). An adult with a spinal cord injury or multiple sclerosis may be more susceptible to oral diseases, such as periodontal disease and dental caries, because of the inability to perform daily oral care. Adults with disabilities and SHCNs also face enormous barriers in accessing dental care compared to their healthier counterparts (Glassman and Miller 2003).

Although children with SHCNs have public or private health insurance and hence, relatively better access to care as they transition to adulthood, a vast majority of them risk losing coverage once they become young adults (Fishman 2001).

Incarcerated Populations

Inmates have higher rates of substance abuse, psychological disorders, and chronic and communicable diseases than the general population. For example, rates of diabetes, chronic respiratory conditions, and liver disease are more than twice that of the general population (Trotter II et al. 2018). The incidence of prior substance abuse, pharmacologic treatment for psychiatric and chronic diseases, and effects of chronic disease all negatively affect oral health. Indeed, the prevalence of dental caries, periodontal disease, and other oral diseases is higher in inmates than in the general population (Treadwell and Formicola 2008). Violence in incarcerated environments frequently involves facial trauma, with mandibular and facial fractures being the most common injuries (Henning et al. 2015). Incarceration also engenders stress and anxiety that can lead to increased incidence of such habits as grinding the teeth (Cavallo et al. 2014). Access to appropriate dental and medical care while incarcerated is limited; the only articulated standard of care is that inmates should be merely "free from deliberate indifference to serious medical needs" (Makrides and Shulman 2017, p. S1). Although it is generally understood that inmate oral health status is poorer than that of the general U.S. population, there is insufficient data to guide oral health policy or clinical guidance for this population (Treadwell and Evans 2019).

Veterans

Most data regarding the oral health of veterans are derived from veterans eligible for dental care provision through the U.S. Department of Veterans Affairs (VA). The median age of veterans is 65 years for men and 51 years for women, making this an older population group (U.S. Department of Veterans Affairs 2019). Studies demonstrate that this group of veterans are more dentally and medically complex than the general population. In addition, VA medical centers have unique treatment centers, such as spinal cord injury centers, rehabilitation centers, or substance abuse centers. Patients receiving treatment for these chronic debilitating conditions are at high risk for oral diseases and may have worse oral health than the general population. An evaluation of veterans receiving services for the first time from VA Dentistry found that 13% were edentulous (toothless) and that 58% of dentate veterans required caries-related treatment. Veterans are more likely to have periodontitis or to have more teeth affected by dental caries, but military service appears to only be associated with an increase in dental restorations (Schindler et al. 2021). With a mean of 2.2 teeth per person treated for caries, this group had a higher caries level than the general U.S. population (Jurasic et al. 2019). VA Dentistry has emphasized preventive care and has shown that the increased use of fluoride for high caries risk patients has led to fewer restorations placed (Jurasic et al. 2014). More information on veterans is provided in Section 1.

Victims of Abuse

Interpersonal violence may be physical, sexual, or psychological and includes intimate partner violence, sexual assault, sex trafficking, child maltreatment, and family violence. More than 18 million women and more than 4 million men experience physical violence, rape, or stalking in the context of intimate relationships (Smith et al. 2018). Sexual violence reportedly impacts 1 in 3 women and 1 in 4 men during their lifetimes (Basile et al. 2014), and an estimated 20% of women and 2% of men have reported that they have been victims of sexual assault (rape or attempted rape) (Basile et al. 2014). It is hard to find reliable statistics related to human trafficking because of the hidden nature of the crime and challenges in identifying individual victims (U.S. Department of State 2021). In addition, little is known about the oral health of these individuals and the degree to which it increases the general burden of disease in this country.

In a study of 304 women seeking oral treatment in a community setting, the majority (67%) were found to have experienced some form of domestic psychological or physical violence (Kundu et al. 2014). These women reported that the abuse they experienced also affected their oral health practices and was linked to their oral health. Clearly, it is likely that an oral health professional will come into contact, knowingly or unknowingly, with a survivor of interpersonal violence. Dental professionals should remain committed to understanding these problems in order to identify and respond appropriately to them. Professional training on the indicators of human trafficking and the importance of using a survivor-centered, trauma-informed approach is recommended (Office on Trafficking in Persons 2020).

Some injuries may be visible to an oral health professional—oral and facial trauma, including injuries to the mouth, head, neck, jaw, teeth, and gums (Ellis et al. 2019). Other signs of abuse may include missing or chipped teeth, fractures, soft tissue injuries, and trauma in nerves to the mouth and jaw (Kundu et al. 2014; Mukherji 2015; Ellis et al. 2019). However, abuse may not always be apparent. Obvious signs of physical harm, and fearfulness and anxiety in the dental setting are potential signs of traumatic or abusive experiences.

Violence also can affect a victim's ability to maintain oral health in terms of regular tooth brushing and preventive care. Oral health issues stemming from inadequate nutrition and proper dental care have also been identified among victims of violence (Fischer et al. 2017), as have infectious complications associated with HIV, other sexually transmitted diseases, and oral cancers (Mukherji 2015; Fischer et al. 2017).

Oral Health and Quality of Life

OHRQoL is a person-centered measure that takes into account all aspects of an individual's life, including health status. Over the years, studies have sought to determine the impact of oral health on quality of life. In 2003–2004, 15% of U.S. adults reported one or more impacts on their oral health that occurred "fairly often" or "very often" (Sanders et al. 2009). OHRQoL varied according to levels of tooth loss, perceived dental treatment needs (for example, relief of pain), reasons for dental visit, dental insurance coverage, and income. Poorer OHRQoL has been associated with lack of financial support, although not with lack of social support (Maida et al. 2013). Results of a U.S. national survey showed that greater income inequality was associated with poorer OHRQoL (Moeller et al. 2017).

Many studies have shown that certain dental treatments improve patients' OHRQoL. For example, a review of routine nonsurgical therapy for periodontal disease concluded that the treatment produced improvements in OHRQoL (Shanbhag et al. 2012). In one clinical trial, implant-supported dentures provided significantly better OHRQoL than conventional dentures in people who had lost all teeth in at least one jaw (Slade 2012). Other trials have evaluated treatment interventions for a range of dental conditions, including xerostomia (Niklander et al. 2018), dental fluorosis (Meireles et al. 2018), dentin hypersensitivity (Lima et al. 2017), and oral hygiene in stroke patients (Dai et al. 2017), with all showing some improvement in OHRQoL. Although clinical trials have shown that treatment for dental caries improved OHRQoL in children (Antunes et al. 2013; Abanto et al. 2016; Arrow and Klobas 2016), similar trials for adults are conspicuously absent. Nevertheless, the general consensus is that the existing body of knowledge clearly supports the importance of OHRQoL in general health and well-being (Sischo and Broder 2011).

Dental Service Utilization

One in three working-age adults typically have had a dental visit in the past year (Nasseh and Vujicic 2016). As a group, working-age adults utilize dental care at a lower visit rate than children, adolescents, and older adults. However, utilization does vary among working-age adults from those aged 19 to 34 years (lower) to those aged 50 to 64 years (higher) (29% vs. 42%). Working-age adults living in poverty utilize the oral health care system at the lowest level, with about 1 in 5 having a dental visit in the past 12 months. Among adults aged 19 to 64 years, dental utilization strongly correlates with dental insurance coverage. About half of working-age adults with private dental insurance have had a dental visit in the past 12 months, whereas only 1 in 5 with public dental insurance and 1 in 6 with no insurance had a dental visit. Among working-age adults, 20% indicated they needed dental care but did not get it in the past 12 months and the main reasons reported were related to financial concerns (Gupta and Vujicic 2019 (November)).

Since their inception, the national Healthy People objectives have emphasized the importance of having regular dental care. Both the Healthy People 2020 and the latest Healthy People 2030 objectives have included utilization of dental services as a Leading Health Indicator (LHI), thereby representing a high priority objective. For Healthy People 2030, the objective of "children, adolescents and adults who use the oral health care system" remains an LHI (U.S. Department of Health and Human Services 2020a). The Healthy People 2030 objectives also include "Increase the proportion of people with dental insurance" from a baseline of 54.4% to the target of 59.8%, and "Reduce the proportion of people who are unable to obtain or delayed in obtaining necessary dental care" from a baseline of 4.6% to the target of 4.1%.

Provision of Adult Oral Health Care in Alternative Settings

Community-Based Interventions

Although many community-based oral health care programs have been developed for children, there is a paucity of similar community-based programs for working-age adults. The burden of unmet oral health needs on adults' quality of life is substantial (Institute of Medicine 2011a; Benzian and Williams 2015), especially for racial/ethnic minorities and immigrants in underserved communities (Institute of Medicine and National Research Council 2011). Community-based interventions to prevent oral diseases and lower risk are needed for adults in group homes or assisted living facilities with chronic diseases that increase their risk for oral diseases.

Interprofessional Care

Interprofessional health care has been extensively discussed, particularly regarding preventive, diagnostic, and emergency procedures within medical care settings. To assist in the implementation of interprofessional dental care, the U.S. Department of Health and Human Services published a report, "Integration of Oral Health and Primary Care Practice," which provided interprofessional oral health core clinical competencies for primary care providers. These primary care providers include nurse practitioners, nurse-midwives, medical doctors, doctors of osteopathic medicine, and physician assistants (Health Resources and Services Administration 2014). Subsequently, the National Academies of Sciences, Engineering, and Medicine evaluated active interprofessional programs. Most of those programs involved preventive care for children and elders and emergency care for specific adult groups, such as people with diabetes or pregnant women (Atchison et al. 2018). Although these programs currently are limited, efforts are being made to expand training and structures for physicians to carry out preventive dental treatments, as well as for dentists to carry out limited preventive primary care (Giddon et al. 2013).

Chapter 2. Advances and Challenges

During the past 20 years, our understanding and appreciation of the role that oral health plays in maintaining overall health and well-being throughout adulthood have significantly advanced. Because of an expanded body of research on the interrelationships between oral health and general health from the past 2 decades, it is now clear that certain diseases are associated with poorer oral health and, conversely, that oral diseases and conditions affect general health. Although there is certainty of associations and risk factors, the causal nature of these associations remains unclear.

Overall, changes in the oral health status of working-age adults in the United States since 2000 reflect an inconsistent pattern; many oral diseases and conditions remain prevalent, and inequities in oral health and care persist among racial/ethnic minority and low-income populations. Important progress made in adult oral health during the past 20 years has been mostly focused on individual care. Dental technology is advancing rapidly, allowing for better use of restorative materials and improved outcomes, although at a higher cost to patients. Advances in oral disease management for adults are making prevention the dominant theme for disease management leading to less tooth loss among working-age adults. The development of improved technologies for dental implants to replace lost teeth has led to a reduction in complications and improved outcomes for these procedures. However, despite advances in preventive and restorative treatments, barriers that stem from the lack of access to dental care, health insurance policies that have little to no dental coverage, and the fact that many people must pay out-of-pocket for their care, are all factors that continue to hinder access to dental care for many Americans and to create significant inequities in dental health among specific populations.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Although prevalence of caries slowly decreased from approximately 95% to 91% since the 2000 publication of *Oral Health in America* for working-age adults (20–64 years of age) (Figure 13), Americans continue to be challenged by the near-ubiquitous prevalence of lifetime tooth decay experience through adulthood, regardless of poverty status or race/ethnicity. This small decrease was driven by data for adults aged 20 to 34 years, a group who experienced a significant decrease in caries prevalence from 92% to 82% during the same time period. Dental caries experience represented a unique oral health paradox 20 years ago, in which health disparities between high- and low-income groups actually favored lower-income groups (96% vs. 86%) (Figure 14). Today, dental caries has increased for those living in poverty, while decreasing for those whose incomes were at least twice the federal poverty guideline (FPG) or higher; the result has been elimination of the health disparity between these groups of working-age adults.

Although the overall percentage of Americans experiencing dental caries has changed little in the past 20 years, the actual number of tooth surfaces affected by dental caries has substantially decreased. There are 128 tooth surfaces potentially at risk for dental caries among adults. Twenty years ago, working-age adults had a mean of 42 dental surfaces affected by caries. Now the mean is 28 dental surfaces (Figure 15). Overall, this decrease was experienced by all working-age adults, regardless of poverty status. However, the decrease was more pronounced for those living at 200% of the FPG or higher (41 vs. 26 affected surfaces) compared to those living in poverty (43 vs. 35 surfaces) (Figure 16). The decrease in mean number of dental surfaces affected by dental caries for all age groups during the past 20 years can generally be attributed to a decline in the number of tooth surfaces receiving dental treatment for caries. In other words, fewer surfaces are filled and fewer surfaces are lost because of tooth extractions.

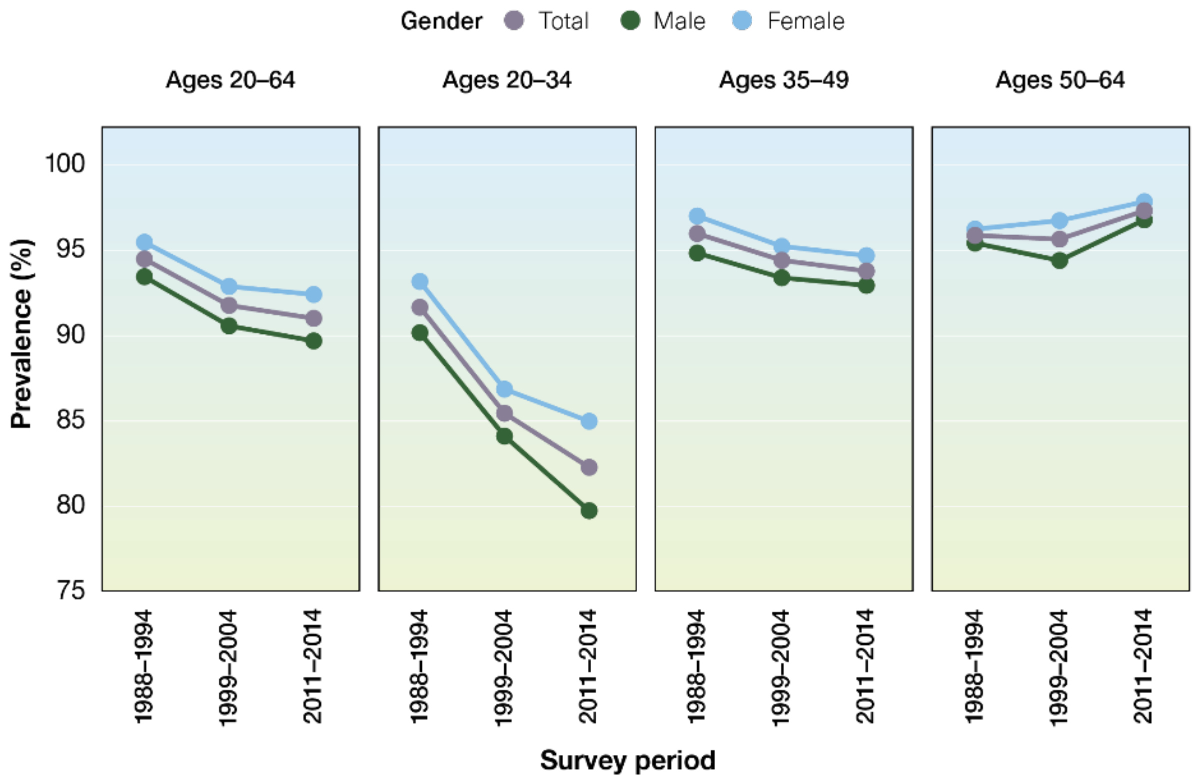
A greater challenge for working-age adults is untreated caries. Unlike the progress seen in younger children, there has been little change in untreated dental caries in working-age adults during the past 2 decades (28% vs. 29%) (Figure 17). More important, the disparities for untreated caries continue to be substantial. For example, more than half of working-age adults living in poverty have untreated caries (52%), whereas only 1 out of 5 adults with incomes of twice the FPG or higher have untreated caries (20%) (Figure 18). Twenty years ago, a typical working-age adult living in poverty had about four tooth surfaces affected by untreated caries, whereas a more affluent adult had only one tooth surface affected by untreated caries (Figure 19). Now, the mean number of surfaces affected by untreated caries has increased by 50% for working-age adults, regardless of poverty status.

Periodontal Disease

Although the prevalence of periodontal disease in American adults seems to have remained consistent during the past 20 years, there have been important changes in how the disease is measured, monitored, and reported based on our evolving understanding of the etiology and natural history of the disease (Dye and Thornton-Evans 2007; Holtfreter et al. 2015). Consequently, there are new standards for periodontal disease case definitions for population-based surveillance activities (Eke et al. 2012) and new disease case definitions for individual classification purposes (Caton et al. 2018a; 2018b). Both of these initiatives have the potential to improve understanding of prevalence trends, effective preventive interventions, and better treatment modalities in the future. However, an important challenge remains—maintaining an effective surveillance system for periodontal disease.

It is estimated that the prevalence of periodontitis increased globally by more than 50% from 1990 to 2010 (Marcenes et al. 2013). Currently, 1 in 10 Americans aged 45 to 64 years has severe periodontitis, with men nearly three times more likely to have the disease than women (Eke et al. 2018). Severe periodontal disease affects 1 in 8 Mexican Americans, non-Hispanic Blacks, and those living in poverty. Because these individuals have reduced access to oral health care services (Seo et al. 2019), health disparities likely will continue to persist in these groups. More important, given that the prevalence of periodontitis increases with age, as demographic changes in the United States continue to shift towards more people living longer, periodontitis will continue to increase as an aging population retains more teeth.

Figure 13. Percentage of adults ages 20–64 with dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



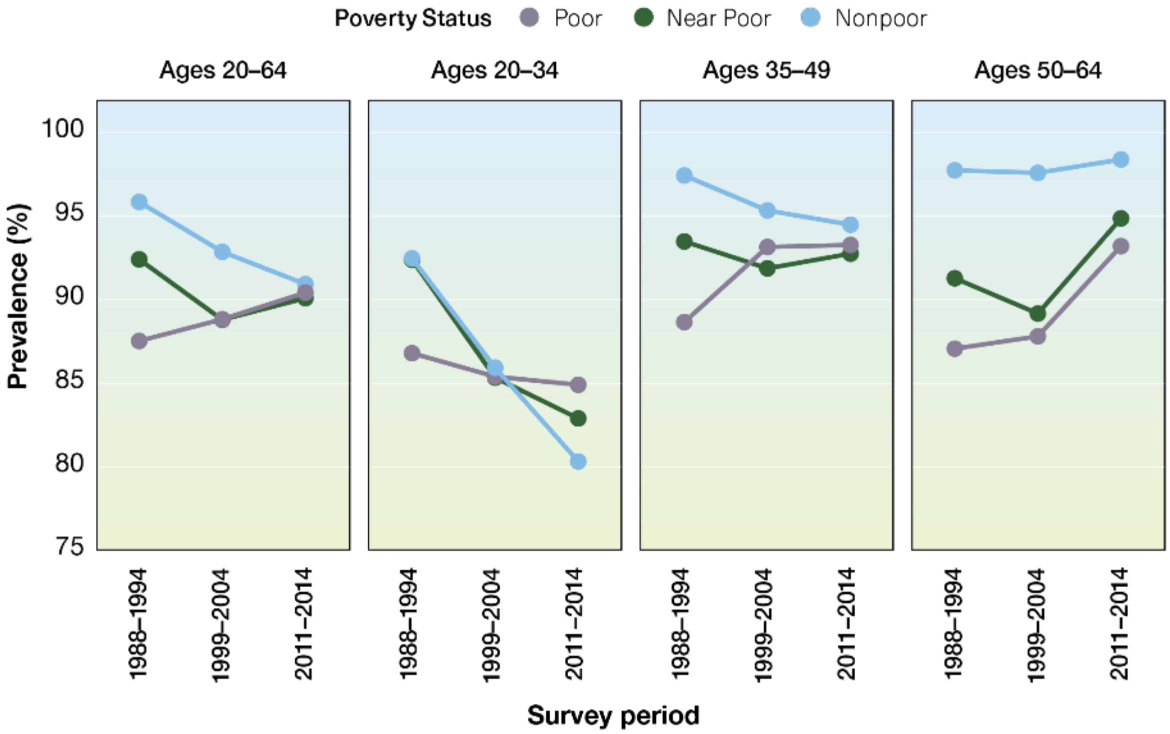
Note: Prevalence of dental caries in permanent teeth (DMFT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Given the significance of this disease, it is an important public health problem that must be addressed (Tonetti et al. 2017). Nonetheless, there are virtually no public health programs for periodontal disease prevention and control (Janakiram and Dye 2020).

Smoking represents the greatest risk factor for developing severe periodontitis. Among adults aged 45 to 64 years, 1 in 4 current smokers has severe periodontitis, and nearly 75% of smokers have some form of periodontal disease (Eke et al. 2018). This suggests that ongoing efforts to reduce tobacco use have great potential to reduce the prevalence of periodontal disease in the United States. Although there have been substantial improvements in the past 20 years in our understanding of how periodontal disease is measured and progresses across a lifetime, prevention and control of periodontal disease has primarily been focused on the individual, using patient-focused approaches, such as smoking cessation interventions offered by health professionals (Janakiram and Dye 2020). Although individual approaches used for tobacco cessation activities do work, smoking quit rates remain low (3–5%) (Lancaster and Stead 2017).

Because periodontitis shares several risk factors, such as smoking, with other noncommunicable diseases, such as cardiovascular disease, the use of a Common Risk Factor Approach (CRFA) may have the greatest potential for preventing periodontal disease in populations. However, challenges in implementing a CRFA for periodontal disease need to be addressed before substantial reductions in the prevalence of periodontitis can be realized (Janakiram and Dye 2020). These challenges include the need to build the appropriate evidence to help inform guidelines for implementation and to strengthen reporting guidelines for periodontal disease surveillance, including the evaluation of interventions.

Figure 14. Percentage of adults ages 20–64 with dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of dental caries in permanent teeth (DMFT > 0). Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

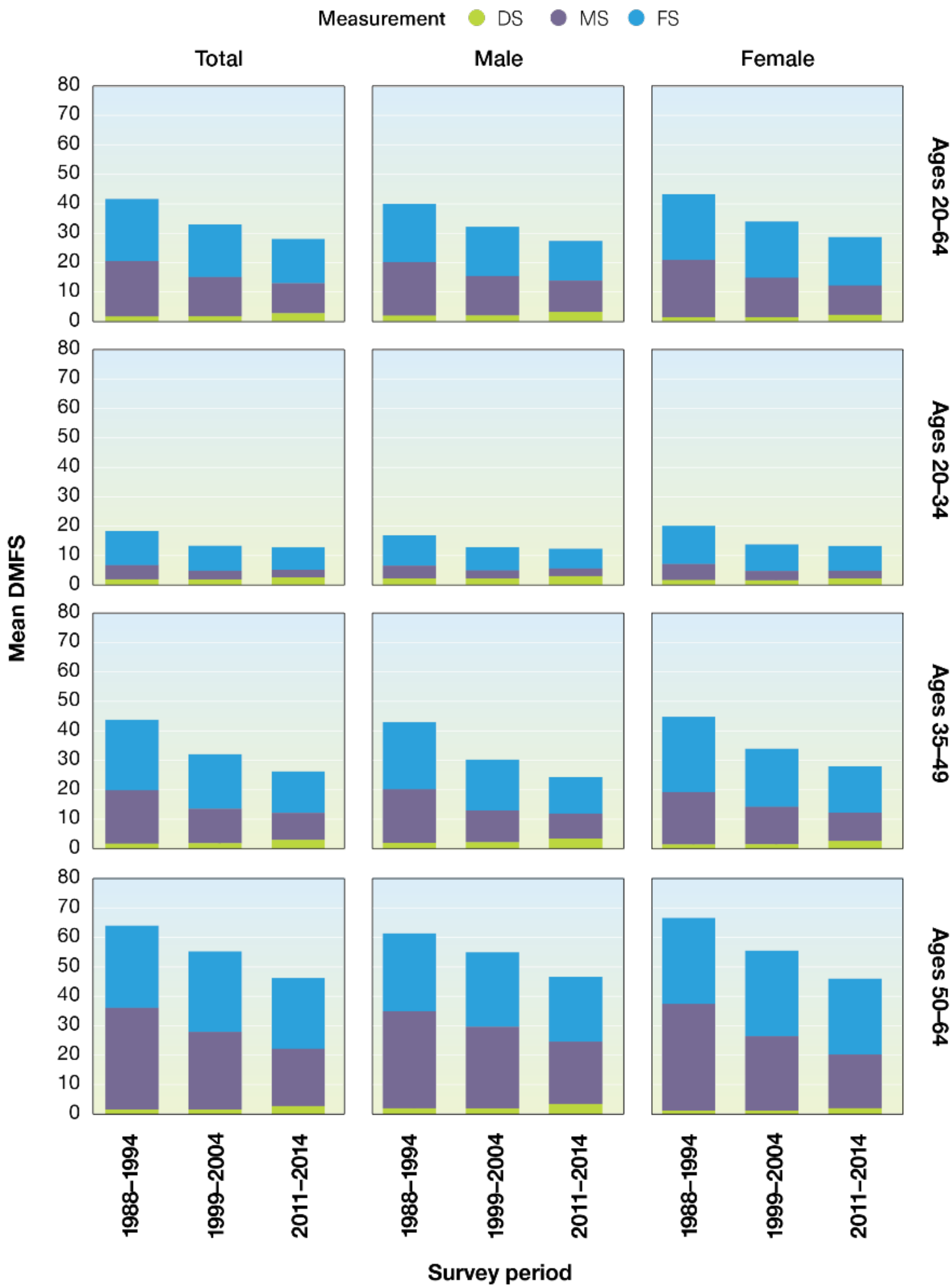
Overcoming some of these challenges will require new initiatives to communicate the adverse health impacts of periodontal disease and improve capacity to monitor effectiveness of prevention and control activities.

Tooth Loss

Tooth loss in adults has decreased significantly since the turn of the century, and this reflects important progress in improving oral health among working-age adults. The percentage of all working-age adults retaining a full dentition (28 teeth) increased from 31% to 47% during the past 20 years (Figure 20), reflecting an important trend that is likely to continue. This increase was substantially consistent across all age groups regardless of poverty status—except for adults aged 50 to 64 years, among whom was no change for those living in poverty (Figure 21). Those aged 20 to 34 years experienced the greatest increase in tooth retention, and this increase also was observed across race/ethnic and poverty subgroups.

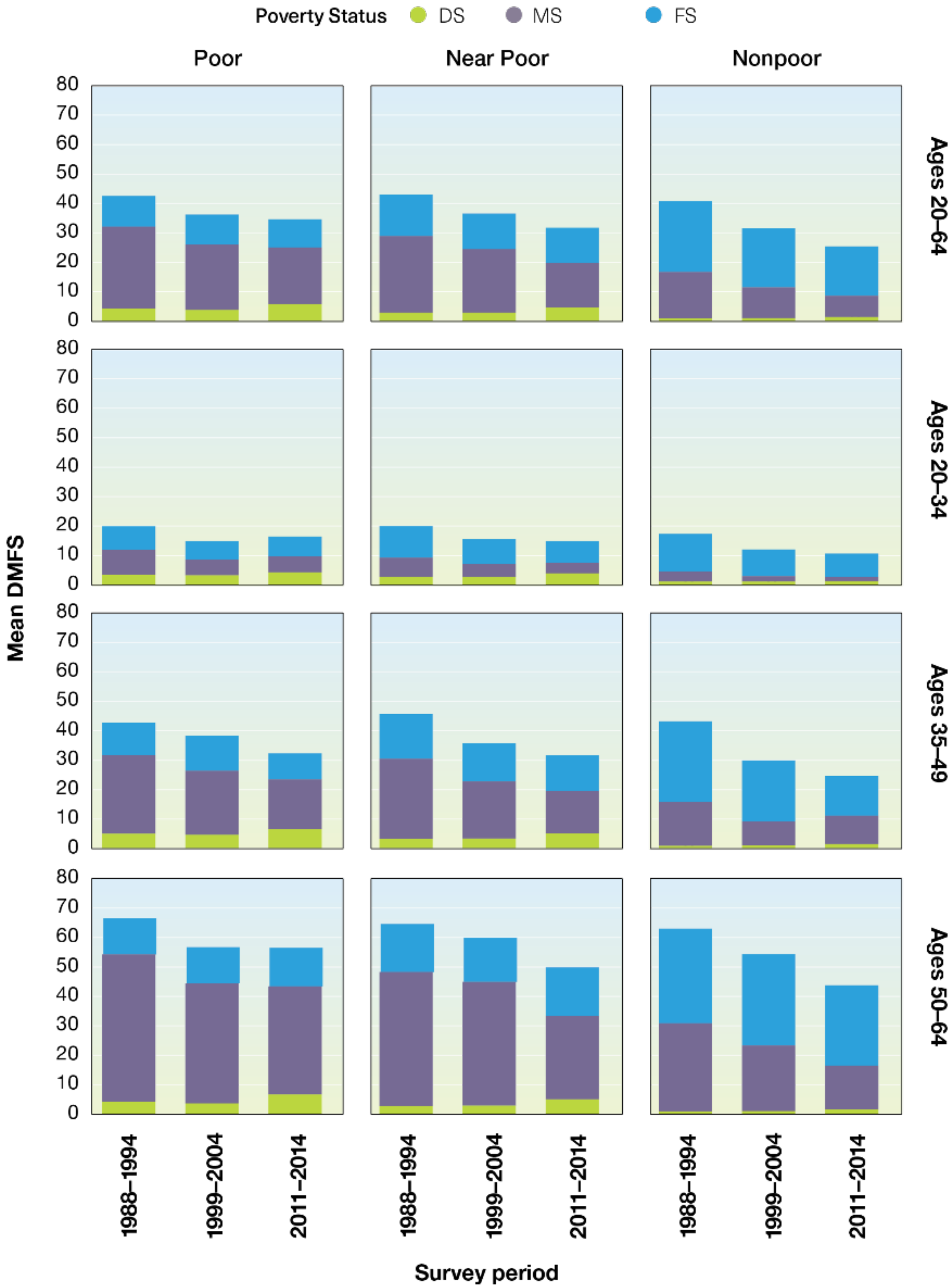
The percentage of working-age adults with a functional dentition (having 21 or more natural teeth) increased from 80% to 91% in the past 20 years (Figure 22). Although all subgroups experienced substantial increases in functional dentition, non-Hispanic Whites and Mexican Americans remain more likely than non-Hispanic Blacks to have a functional dentition and those more affluent are also more likely to have a functional dentition, compared to those living in poverty (Figures 23-24). Those aged 50 to 64 years experienced the greatest increase in a functional dentition (80% vs. 60%) during the past 20 years. Although this increase also was observed across all major subgroups, health disparities for this oral health measure also were the greatest in this age group.

Figure 15. Mean number of decayed (DS), missing (MS), or filled surfaces (FS) of permanent teeth in adults ages 20–64 by gender and age group: United States, 1988–1994, 1999–2004, 2011–2014



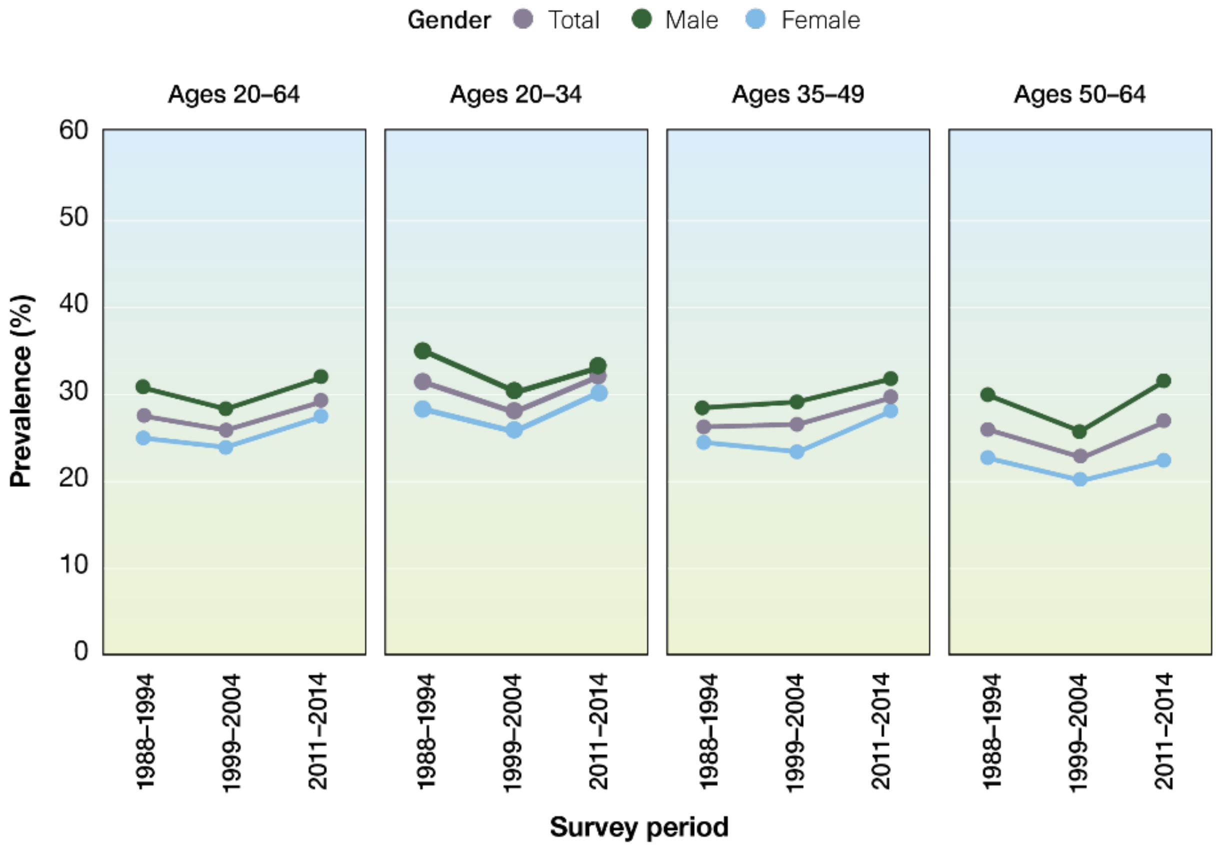
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 16. Mean number of decayed (DS), missing (MS), or filled surfaces (FS) of permanent teeth in adults ages 20–64 by poverty status and age group: United States, 1988–1994, 1999–2004, 2011–2014



Note: Federal Poverty Guideline (FPG): < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 17. Percentage of adults ages 20–64 with untreated dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014

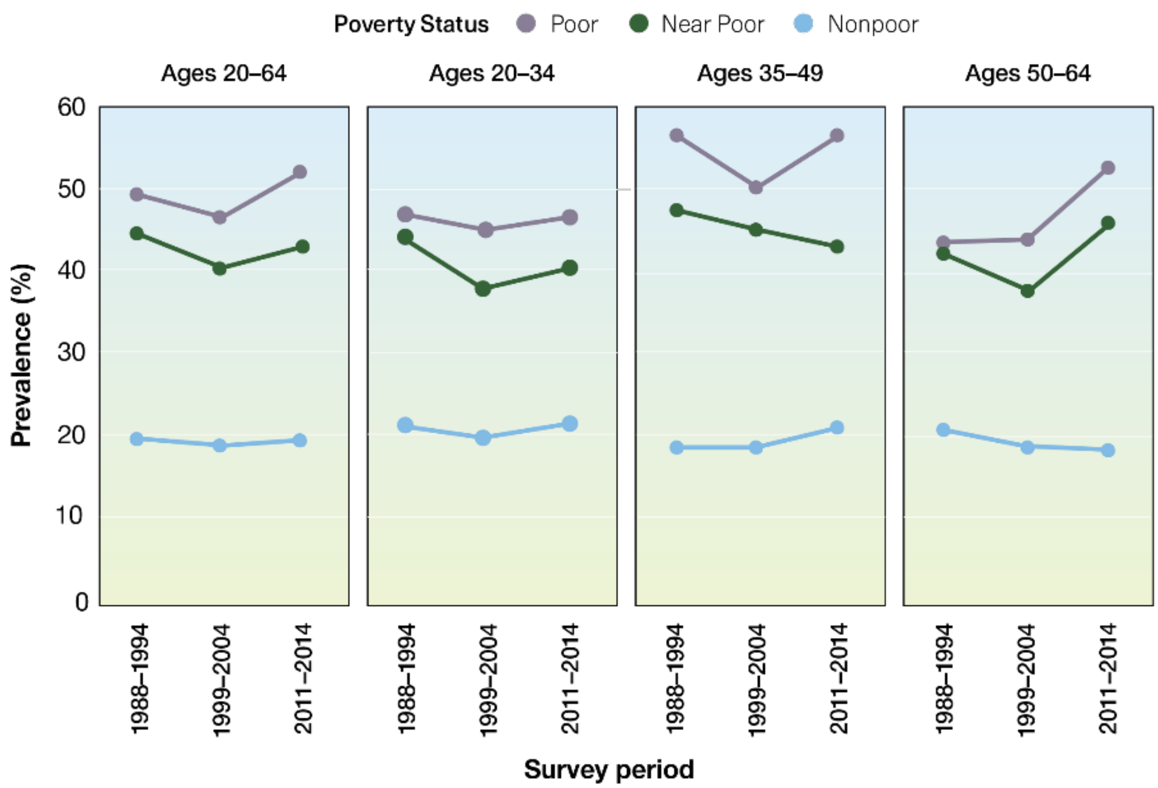


Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Trends in edentulism (complete tooth loss) among working-age adults also have shown major improvement since 2000. Slade and colleagues (2014) examined 5 decades of population-based surveys on edentulism in people 15 years of age and older and found that the prevalence of edentulism in U.S. adults declined from 18.9% to 4.9%. The authors noted that the rapid decline is in large part a function of higher edentulism in birth cohorts born earlier than the 1930s, so that the rate of decline in edentulism has slowed with their passing. They also found that for the birth cohorts of 1954–1963 and 1965–1973, incidence rates were equivalent to about 1% per decade. However, socioeconomic disparities have become more pronounced, to the extent that “edentulism is now virtually unknown in the highest quartile of the income distribution” and “… is concentrated in low-income households located in states with a long history of poverty” (Slade et al. 2014).

This finding confirmed the results of Wu and colleagues (2012) from the National Health Interview Survey data. These researchers examined edentulism trends between 1999 and 2008 among adults aged 50 years and older in five racial/ethnic groups in the United States: Asians, African Americans, Hispanics, Native Americans, and non-Hispanic Whites. They found that in 2008, Native Americans had the highest predicted rate of edentulism (24%), followed by African Americans (19%), Whites (17%), Asians (14%), and Hispanics (14%). From 1999–2008, the survey identified an overall significant downward trend in self-reported edentulism.

Figure 18. Percentage of adults ages 20–64 with untreated dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of untreated dental caries in permanent teeth (DT > 0); Federal Poverty Guideline (FPG): < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

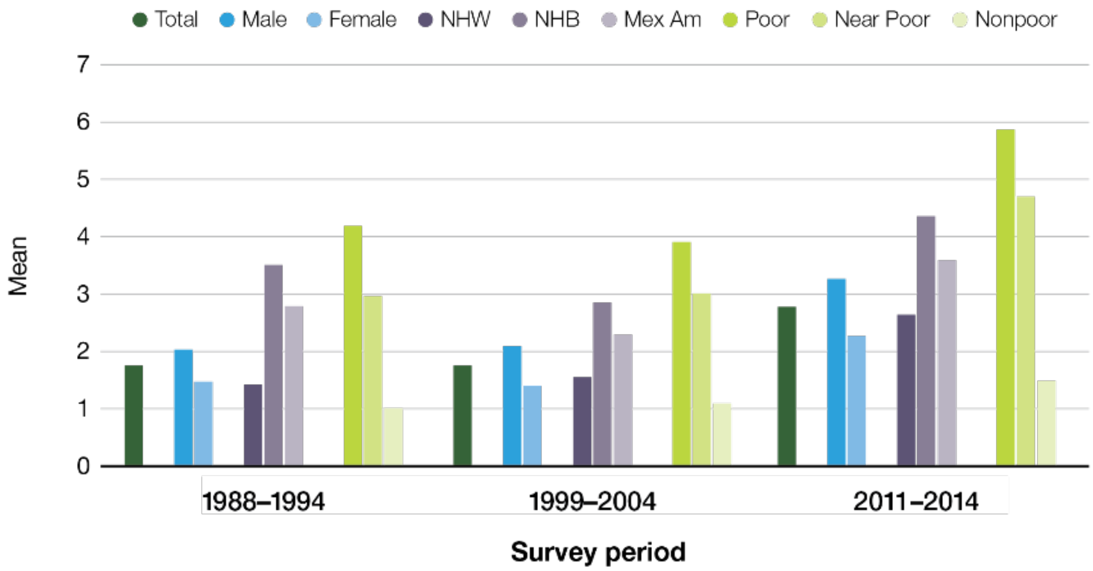
However, this decline varied by ethnic group, with Native Americans experiencing a much slower rate of decline in edentulism during this period.

Orofacial Pain and Temporomandibular Disorders

The past 20 years have seen a continuing evolution in the diagnostic classification of temporomandibular disorders (TMD), including their differentiation from other orofacial pain problems. TMD is now widely recognized as a chronic pain condition, similar to other chronic pain problems in its psychosocial impact. The emphasis in treatment has shifted from invasive surgical approaches to more conservative and holistic options. Although trauma to the jaw or temporomandibular joint plays a role in some TMD, in most cases the exact cause of the disorder is not clear. Equally important, the range of symptoms can vary, and pain may not always be site specific. Because the exact causes and symptoms frequently are not clear, identifying these disorders can be difficult and confusing. There also is sometimes an underlying emotional or psychological component to the development and persistence of TMD. In fact, the presence of other painful conditions is a strong predictor of new cases of TMD (Von Korff et al. 1993; LeResche et al. 2007; Bair et al. 2013), as well as of higher levels of disability in people with TMD (John et al. 2003). The clinical importance of viewing TMD in the context of other pain problems is increasingly clear. See Section 5 for more information on oral pain and TMD disorders.

Because TMD pain often can be heterotopic—that is, the location of the pain and the source of the pain are not the same—TMD pain can present diagnostic challenges.

Figure 19. Mean number of dental surfaces affected by untreated dental caries in permanent teeth among adults ages 20–64 by gender, race/ethnicity, and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Federal Poverty Guideline (FPG): < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

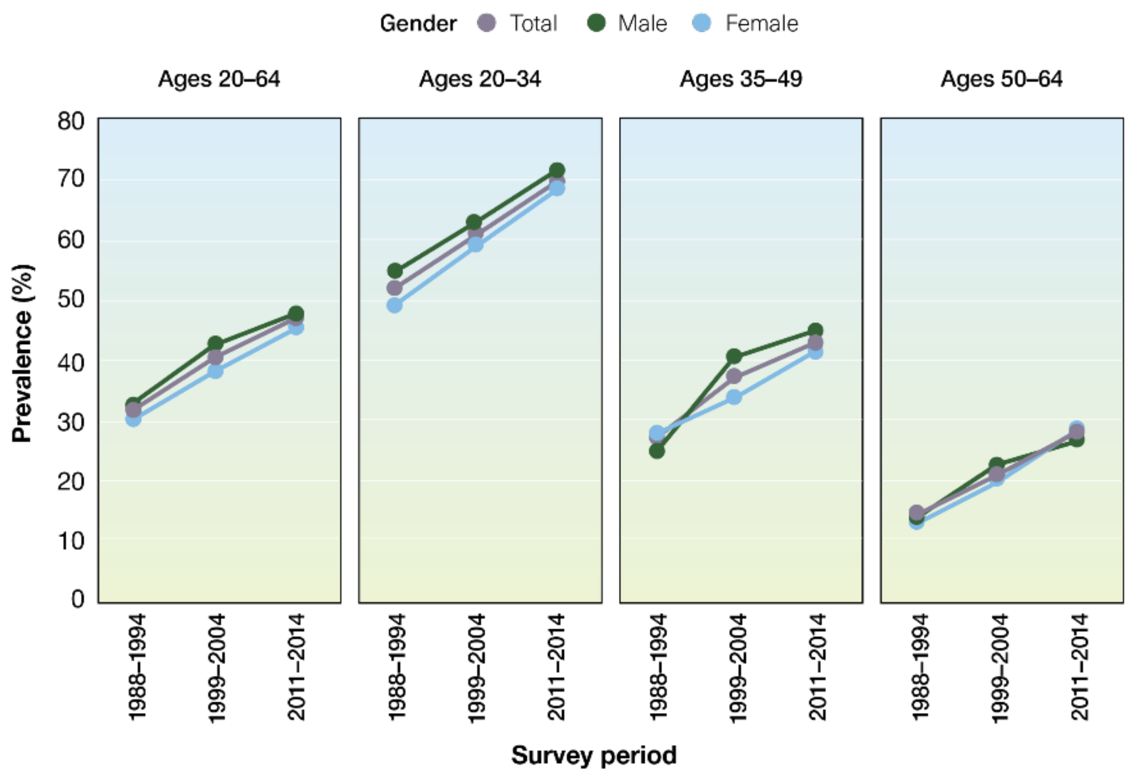
Without the correct diagnosis, successful management of TMD pain is unlikely. Furthermore, clinicians often under-recognize the wide variability in TMD's impact on individuals, its association with psychosocial factors, or that it sometimes is associated with chronic pain and other conditions elsewhere in the body. For example, one study reported that orofacial pain was the only complaint during a heart attack in 6% of patients (Kreiner et al. 2007). Consequently, oral health providers frequently need to collaborate with other health care providers to help inform decision making that leads to better outcomes for adults experiencing TMD pain.

Evidence-based dental education can best address the challenges of diagnosing and managing this condition. Predoctoral teaching about the causes and treatment of TMD has progressed, but some schools do not address the topic adequately, and some others still are teaching outdated concepts. Standards are needed to ensure that all predoctoral dental students learn how to diagnose and treat nondental orofacial pain problems (Klasser and Greene 2007).

Oropharyngeal Cancer and Human Papillomavirus

Although the prognosis for cancer of the oral cavity and pharynx has gradually improved during the past 20 years (National Cancer Institute 2018), the prevalence of oropharyngeal squamous cell cancer (OPC) caused by the human papillomavirus (HPV) has increased dramatically during the past 25 years. HPV-associated oral cancers have doubled, with men having 3.5 times more OPCs than women (Figure 25) (Van Dyne et al. 2018). Seven out of ten OPCs in the United States are caused by HPV and the number of new cases is increasing each year (National Cancer Institute 2020d). The increasing incidence of HPV-OPC now has surpassed other HPV-associated cancers and become the most common of these cancers (Van Dyne et al. 2018), an increase that appears to be driven by generational changes in sexual behavior (D'Souza et al. 2014). Research suggests that oral sexual behavior explains some of the differences in oral HPV16 prevalence. The influence of other factors remains unknown.

Figure 20. Percentage of adults ages 20–64 with a complete permanent dentition by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014

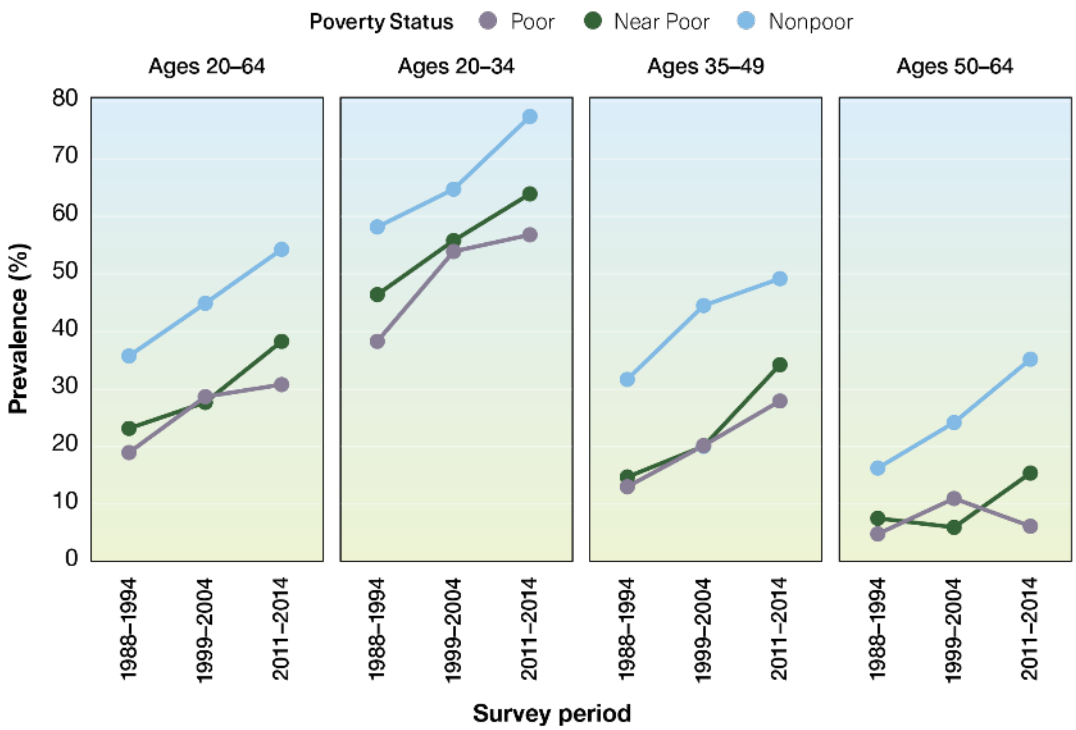


Note: Complete dentition is having all natural teeth remaining (total = 28), excluding third molars (wisdom teeth).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Although many people are likely exposed to oncogenic oral HPV infection in their lifetimes, most do not develop HPV-related OPC. The reason that some individuals develop OPC, while most clear HPV infections without developing HPV-related OPC, is not well understood. Improvements in understanding the pathogenesis would offer potential for improving risk assessment and early detection. In areas where pathogenesis remains uncertain, innovative research methods are needed to leverage approaches other than the traditional randomized clinical trials to address these unanswered questions.

Another challenge is attributable to the limited ways available to help reduce HPV infection in adults. Preventive (prophylactic) HPV vaccination was first approved in 2006 for all females aged 9 to 26 years in the United States and expanded in 2009 for use in males aged 9 to 26 years for the prevention of genital warts caused by HPV 6 and 11. Although the Advisory Committee on Immunization Practices (ACIP) recommends HPV vaccination for preteens and adolescents, as well as for adults through 26 years of age, ACIP does not recommend vaccination for adults aged 27 to 45 years in most circumstances. The Gardasil® 9 (Merck) vaccine, which was discussed in Chapter 1, is licensed for the prevention of oropharyngeal and other head and neck cancers. In addition, the vaccine prevents those anogenital cancers caused by the HPV types included in the vaccine. Consequently, in 2020 the U.S. Food and Drug Administration (FDA) approved the vaccine for the prevention of oropharyngeal and other head and neck cancers caused by HPV types 16, 18, 31, 33, 45, 52, and 58 for both males and females aged 9 through 45 years (U.S. Food and Drug Administration 2020). Additional information pertaining to the Gardasil® 9 (Merck) vaccine and adolescents is provided in Section 2B. National health and survey data is showing that the

Figure 21. Percentage of adults ages 20–64 with a complete permanent dentition by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Complete dentition is having all natural teeth remaining (total = 28), excluding third molars (wisdom teeth); Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

prevalence of oral HPV16/18/6/11 infections is significantly lower in vaccinated versus unvaccinated individuals (0.11% vs. 1.61%; Padj = 0.008) (Chaturvedi et al. 2018). Although these data are promising, the impact of the vaccine on HPV-OPC will not be realized for at least 30 years, given that HPV-OPC is typically diagnosed in people in their forties and fifties.

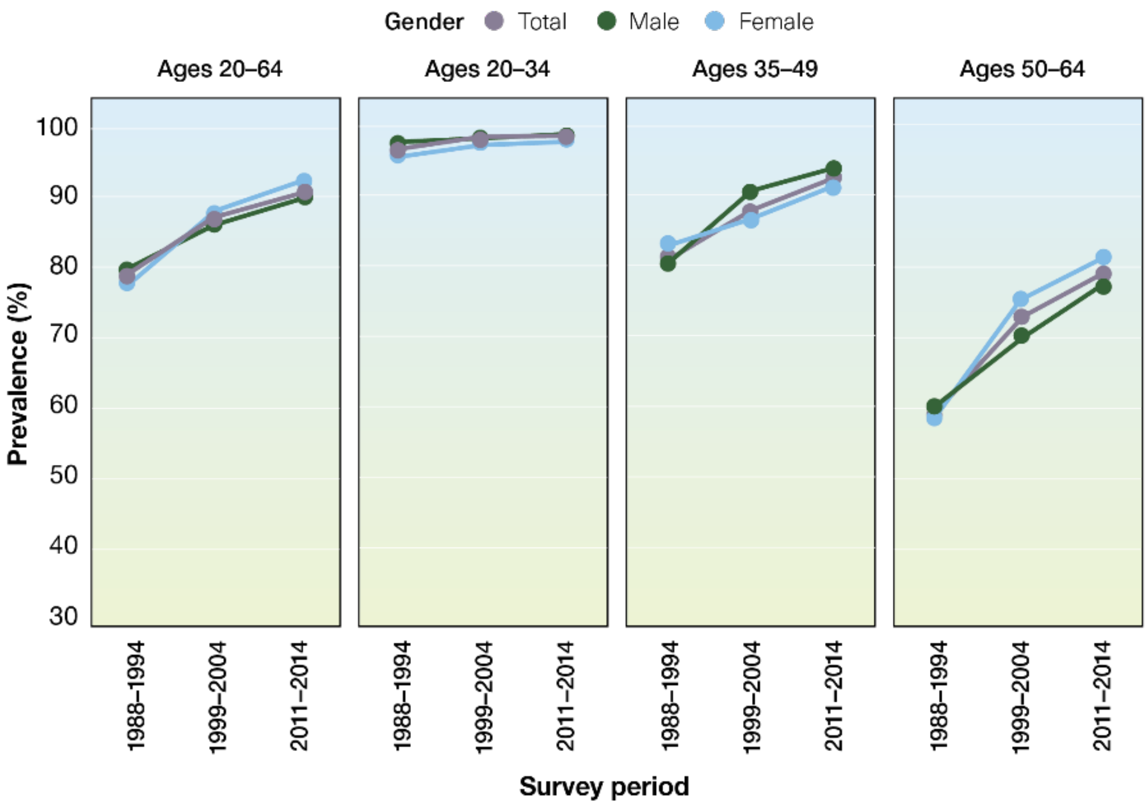
Moreover, determining the best method to screen for HPV-related OPC remains a challenge, especially because these lesions often are difficult to diagnose in the earliest stage. A premalignant state for HPV-related OPC is not acknowledged by pathologists because premalignant lesions have not been observed (Lewis et al. 2018). In addition, there is a lack of validated biomarkers suitable for screening for HPV-related OPC. However, if acceptable biomarkers are identified, their benefit must be weighed against the potential harm of identifying individuals without detectable cancer for whom surveillance and risk are unclear (D'Souza et al. 2019).

Dental Fear and Anxiety

As noted in Chapter 1, 20% of U.S. adults experience moderate to high dental fear/anxiety, and an estimated 7% experience high fear/anxiety (White et al. 2017). These estimates are relatively unchanged from those documented since the 1950s (Smith and Heaton 2003). Even as dental care access and quality have increased, fear/anxiety has persisted in the United States while decreasing in other countries (Svensson et al. 2016).

Dental fear/anxiety strongly impacts utilization of dental care—even among those with access to care—predicting delayed appointment scheduling, canceled or missed appointments, and avoidance of necessary treatment (Armfield et al. 2007; Meng et al. 2007). A total of 5–10% of adults report delaying or avoiding necessary dental care because of fear/anxiety (Milgrom et al. 2010).

Figure 22. Percentage of adults ages 20–64 with a functional dentition by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Greater fear/anxiety is associated with more decayed and missing teeth, and with fewer functional teeth (Schuller et al. 2003), as well as with dissatisfaction with one's mouth, lower perceived quality of life, and poorer self-esteem (Locker 2003; Crofts-Barnes et al. 2010). Although onset during childhood is most frequent, dental fear/anxiety can develop at any age and typically remains stable across the lifespan (Locker et al. 1999; Thomson et al. 2009). Additional knowledge is needed to understand how dental fear develops and to identify effective approaches for preventing and managing dental fear and anxiety.

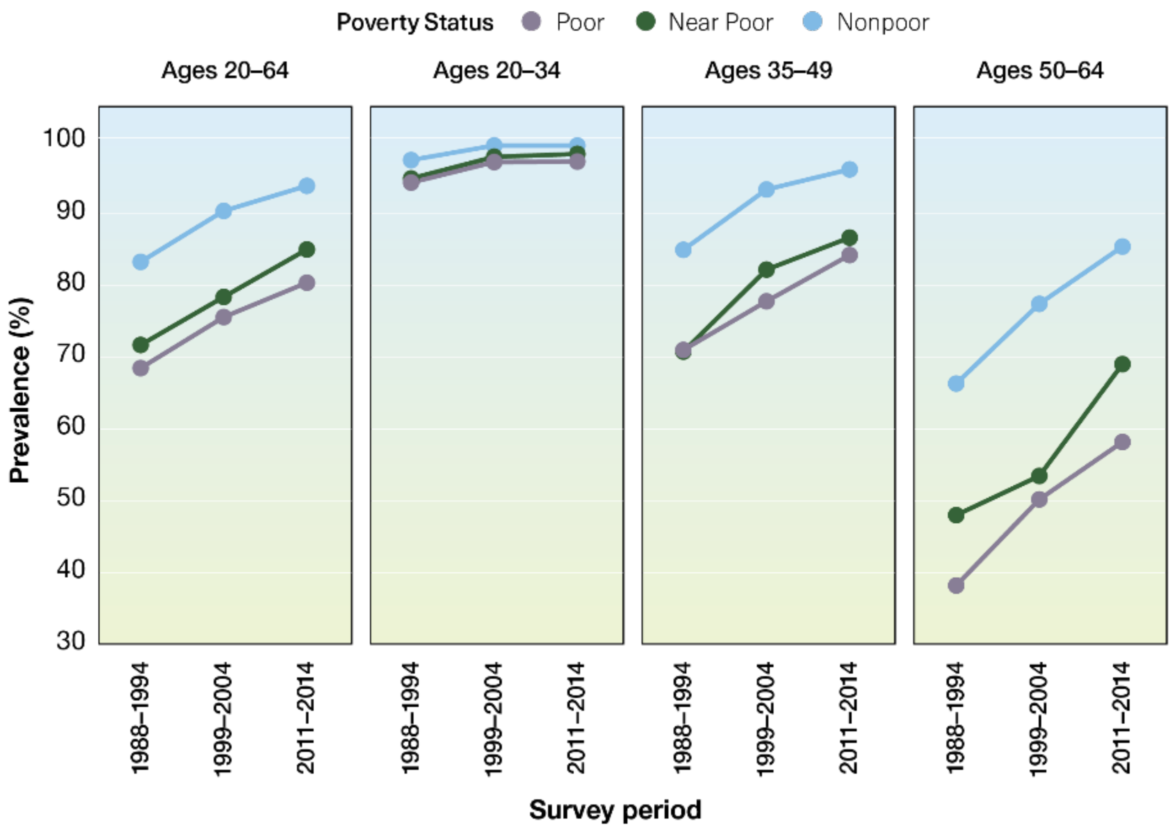
High-Risk Behaviors Affecting Oral Health in Adults

Tobacco Product Use

Since 2000, evidence has confirmed that tobacco use is a risk factor for OPC and potentially malignant oral disorders. Despite a reduction in tobacco use in the United States (Centers for Disease Control and Prevention 2018), the incidence of oral and pharyngeal cancers has steadily risen (Ellington et al. 2020). This change is attributed to an increase in OPCs, largely driven by oral HPV infection and its association with tongue and tonsillar cancers, for reasons not well understood, but probably unrelated to tobacco use (Tota et al. 2017). Yet, there has been a significant decrease in the incidence of some oral cavity cancers, notably on the floor of the mouth (Howlader et al. 2019), which is likely explained by the reduction in smoking.

Considerable effort has gone into, and success achieved in, curbing the cigarette smoking epidemic during the past 50+ years (U.S. Department of Health and Human Services 2020b). Adult cigarette smoking prevalence of 13.7% in 2018, represents the lowest recorded estimate

Figure 23. Percentage of adults ages 20–64 with a functional dentition by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



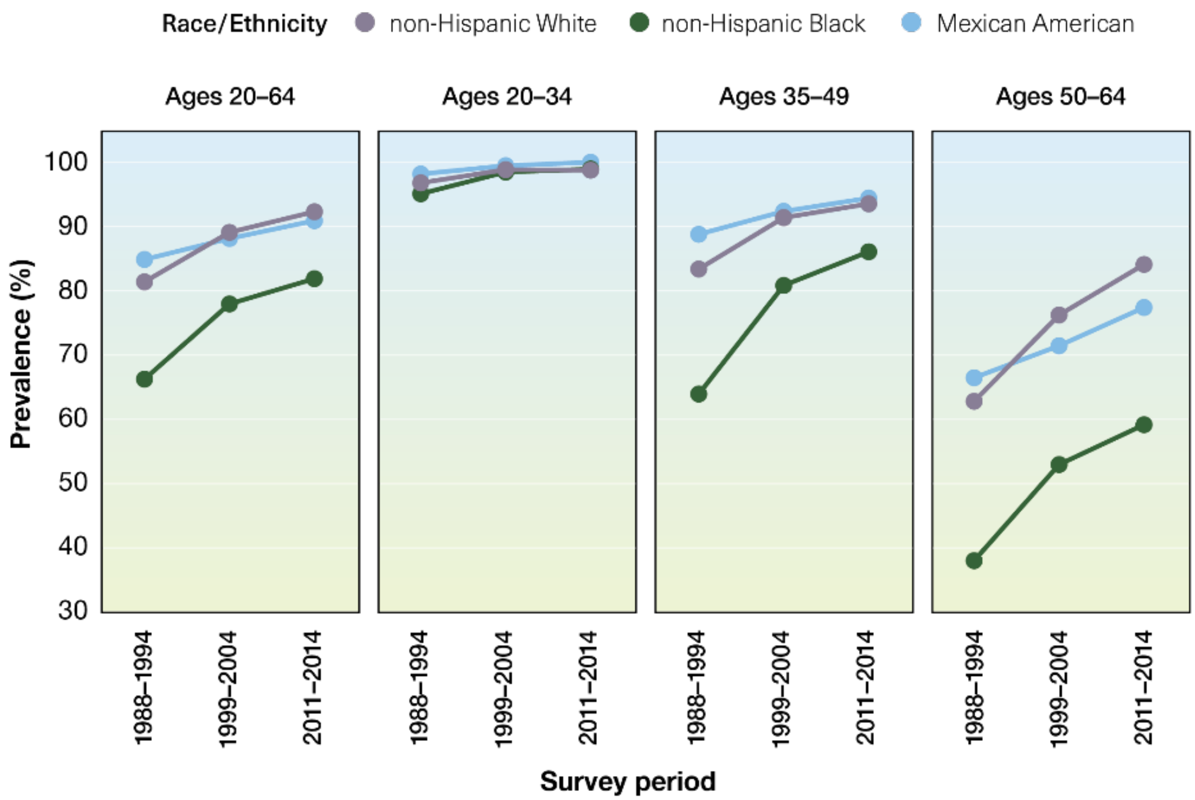
Notes: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth); Federal Poverty Guideline (FPG): < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

and a 65% decline since monitoring began in 1965 (Creamer et al. 2019). Nonetheless, cigarette smoking remains the leading preventable cause of disease, including oral diseases, disability, and death in the United States (Warnakulasuriya et al. 2010; U.S. Department of Health and Human Services 2014; Tomar et al. 2019). However, encouraging oral health professionals to incorporate tobacco cessation programs into their practice is challenging. Little progress has been made in promoting tobacco cessation in the dental setting. Further identification of barriers and the development of strategies to overcome this problem are needed.

During the past 20 years, waterpipe tobacco, e-cigarettes, and spit-free (American snus and dissolvable tobacco) oral tobacco products have become available in the United States and collectively pose significant potential risks to oral health. Important disparities in tobacco use remain in the U.S., despite significant declines in overall cigarette smoking during the last 2 decades (U.S. Department of Health and Human Services 2020b). This has the potential to widen disparities in oral health over time, given the sociodemographic and geographic differences in the use of these tobacco products. The increased use of e-cigarettes is a significant concern and presents a new challenge that may impact oral health. Daily use of e-cigarettes has been associated with higher rates of tooth loss (Huilgol et al. 2019) and gingival disease in people who use them, compared to people who have never used a tobacco product (Vora and Chaffee 2019). However, because many e-cigarette users are

Figure 24. Percentage of adults ages 20–64 with a functional dentition by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



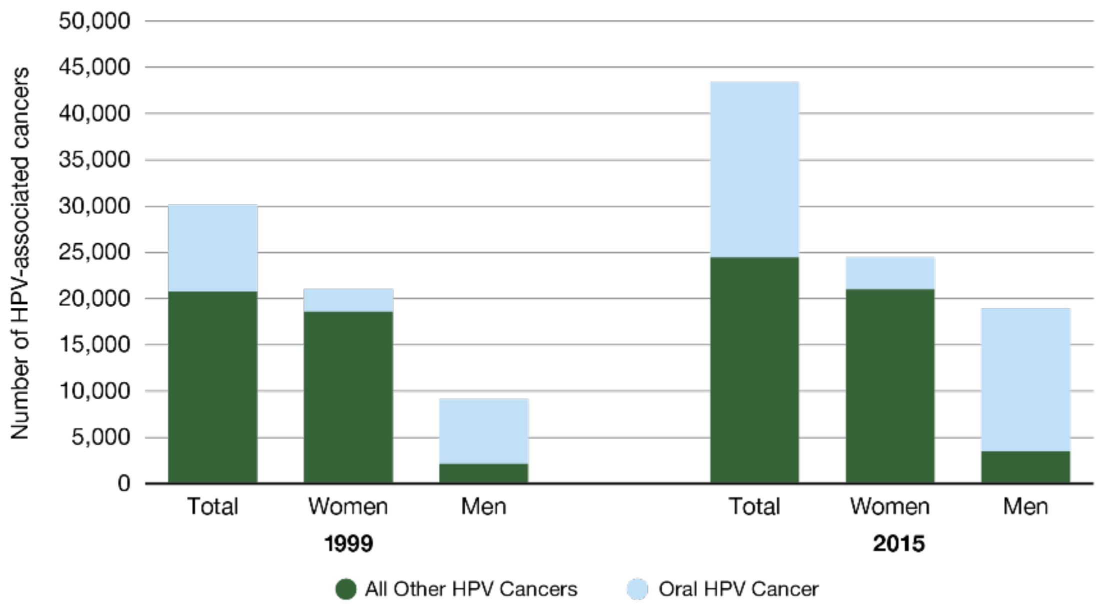
Note: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

current or former smokers, it is difficult to measure the singular impact of e-cigarettes on people who have used both combustible and e-cigarettes (Glasser et al. 2017).

Some recent studies have found that flavored e-cigarette aerosols are associated with a 27% decrease in the hardness of enamel in users (Kim et al. 2018). Oral mucosal lesions (Mokeem et al. 2019), nicotine stomatitis (inflammation), and oral hairy tongue (Bardellini et al. 2018) also have been reported among e-cigarette users. In a small study of men who had used e-cigarettes for an average of 2 years, researchers found no meaningful difference in periodontal disease (Javed et al. 2017). In contrast, cigarette smokers who quit smoking for 2 weeks and used e-cigarettes instead had more gingival inflammation and bleeding on probing during this period (Wadia et al. 2016).

Challenges in these studies, which would also apply to future studies, include the wide variability of e-cigarette products. More than 460 different brands of e-cigarettes are sold on the U.S. market, with more than 7,700 (Grana et al. 2014) combinations of flavors and constantly evolving product designs as well as inconsistent quality control (Trtchounian and Talbot 2011), differences in nicotine levels (Cobb et al. 2010; Pagano et al. 2015), and other factors create a challenge for researchers who are studying these products' effects on oral health and general health (Williams and Talbot 2011). The recent increase in the use of waterpipe tobacco smoking and newer electronic nicotine delivery systems among young and working-age adults also suggests the need to further delineate their prevalence and risks for oral cancer, OPC, and other oral diseases.

Figure 25. Change in the number of HPV-associated cancers (oropharyngeal vs. all others): United States, 1999 and 2015



Source: Van Dyne et al. (2018).

Although there is considerable research regarding the carcinogenic effects of chewing, dip, and spit tobaccos (Boffetta et al. 2008), not as much is known about snus, a powdered smokeless tobacco that is infrequently used in the United States, but that may have serious oral health consequences (Patil et al. 2019).

Cannabis Use

Since the turn of the century, there has been limited research to advance the evidence base on cannabis use and oral health and disease. For example, the role of cannabis use in the development of dental caries is unclear, although there are some studies that show more caries among users (Schulz-Katterbach et al. 2009). Unanswered questions remain including whether cannabis affects motivation in ways that could impact engagement in recommended oral hygiene behaviors or seeking oral health care, whether its use leads to dry mouth or an increased appetite for sweet and salty foods and beverages, and whether these things, in combination, create a cariogenic environment. It is currently unknown whether some forms of cannabis pose greater risks for oral health, whether frequency of use or route of ingestion matter, and whether the effects of cannabis are different when used in combination with smoked tobacco, alcohol, or other drugs.

New challenges have emerged as more states legalize recreational and medicinal cannabis. Measuring the impact upon oral health of cannabis use must start with more high quality, reproducible research on this drug. Topics to be covered include the types used (smoked, vaporized, edibles, and other forms), the psychological and motivational impact of tetrahydrocannabinol on oral self-care, the concentration of different cannabinoids, and FDA-approved medications. Without that knowledge, clinicians, patients, and policymakers will make decisions based on limited and possibly anecdotal information. The challenge remains to incorporate information on cannabis use and oral health into the curriculum of dental, dental hygiene, and dental assisting programs.

Alcohol

Our knowledge of the effects of alcohol on oral health has increased dramatically during the past 20 years. Epidemiological research now links alcohol use to a variety of oral diseases (Bagnardi et al. 2001; Tramacere et al. 2010). Not only has this newer research replicated previous findings, it also has identified mechanisms that firmly establish alcohol use as a significant modifiable risk factor for oral cancer, periodontal disease, and dental caries.

Improved study designs and meta-analyses have provided a better understanding of the effects of alcohol on oral disease, interactions with tobacco and other factors, and mechanisms of action. Prior research focused mainly on the oral health consequences of chronic alcohol dependence and assumed that the increased prevalence of tooth loss and periodontal disease were a function of poor health habits, rather than the direct effect of alcohol (Tezal et al. 2004). More recent studies have identified the health consequences of different levels of alcohol exposure, providing stronger evidence for plausible causal mechanisms. As previously discussed, plausible causal mechanisms include alcohol's effects on host defense, clotting mechanisms, bone metabolism, healing (e.g., protein deficiency), and direct toxic effects on periodontal tissues (Tezal et al. 2004). Additional information on tobacco, marijuana, and alcohol use and oral health is provided in Section 5.

Social Determinants of Health

Although the concept of social determinants of health (SDoH) is not new, it has gained much more attention since 2000. The landmark report of the World Health Organization (WHO) Commission on Social Determinants of Health (2008) and the Marmot Report for the United Kingdom (Marmot and Bell 2012) helped foster this attention, as did the 2011 WHO conference on SDoH (World Health Organization 2011). In the United States, the Healthy People 2020 initiative included SDoH, and this emphasis has been continued in Healthy People 2030, with further expansion of objectives addressing social, economic, and environmental factors that influence health and serve as milestones to measure progress in addressing health disparities and inequities (U.S. Department of Health and Human Services 2010a).

Oral health researchers have been trained to use traditional approaches to understand the direct effects of certain social factors on health outcomes (Newton and Bower 2005). Although associations have been made, questions remain about how and why they exist. This knowledge gap may explain why there is still an incomplete understanding of the mechanisms by which an adult's race/ethnicity, for example, might result in a higher level of oral diseases (Sisson 2007). Recent advances have often been a result of interdisciplinary collaborations with other fields, such as network science, social epidemiology, and computer modeling that emphasize community- rather than individual-level SDoH. Fostering this kind of collaboration, as well as attracting researchers trained in other disciplines to the field of oral health, will lead to a better understanding of the social determinants of oral health on communities and individuals and help to illuminate the origins of health disparities and their inequities.

Oral Health Disparities and Inequities

Following the 2000 Surgeon General's report on oral health's Call to Action to address oral health disparities (U.S. Department of Health and Human Services 2003), additional reports and recommendations were published by other entities with a similar message (Nelson 2002; Institute of Medicine 2011a; Hill et al. 2015; Fischer et al. 2017). New research funding and other initiatives to gather population-level data followed (Fischer et al. 2017). Some progress has been made to better understand the broad influences and general complexity underlying oral health disparities, enabling better progress in the future. There now exists some information on Asian American oral health status because the National Health and Nutrition Examination Survey (NHANES) oversampled this group when conducting the latest oral health survey. Oversampling is a technique used to increase the sample size of a population previously underrepresented in population surveillance efforts (Paulose-Ram et al. 2017). This oversampling facilitated the first reliable estimates of dental caries and tooth loss in Asian Americans (Dye et al. 2015; Eke et al. 2015), revealing that among working-age adults, compared with non-Hispanic Whites, Asian Americans have a caries experience more similar to that of Hispanics and non-Hispanic Blacks, although the prevalence of untreated caries is more similar to that of non-Hispanic Whites.

Progress also has been made among American Indian/Alaska Native adults, who have historically suffered disproportionately from oral disease; the gap between them and the general population has been gradually declining. In fact, this population's oral health status has slightly improved during the past 2 decades, such that "fewer have untreated decay, the prevalence of severe periodontal disease has decreased, and more adults are keeping their teeth into older age" (Phipps and Ricks 2016).

The challenge ahead is to move from research focused on identifying differences in health to improving our knowledge of factors that contribute to disparities and discovering interventions that will reduce them (Dye et al. 2019b). Although disparities in adult oral health are well documented, the relationships and interactions of the many factors that contribute to these disparities are not well understood. Several factors—including discrimination, food deserts, limited transportation, and limited access to medical/dental care—disproportionally affect minorities, low-income groups, and other underserved populations (Sheiham and Watt 2000; Gehlert et al. 2008). The impact of other population-level factors on oral health, such as housing quality and unemployment, need to be better understood across all populations, including adults (Watt 2007). These factors increase the risk for adverse health conditions, including poor oral health, and contribute to documented oral health disparities (Patrick et al. 2006). To effectively address oral health disparities across the lifespan, interventions need to target these population-level factors (Gehlert et al. 2008).

There has been some movement toward partnerships among health care systems and community-based organizations to address SDoH, but these types of interventions are complex, expensive to implement, and require new collaborations and funding mechanisms (Watt 2007). For example, the NCCare360 initiative in North Carolina, which works on state Medicaid transformation, connects health care and human services organizations with shared technology, resources, and coordinated care; however, it does not yet include oral health care (NCCare360 2021). Overcoming these obstacles is mandatory to create interventions that are population-specific, implementable at community and individual levels, and produce observable and lasting changes.

Women's Oral Health

The 2000 Surgeon General's report on oral health provided a general overview of the effects of gender differences on oral health and disease management. Since then, there have been several advances in oral health for women across the lifespan. Collaborative efforts have driven innovative practices concerning their oral and overall health. In 2013, the federal Health Resources and Services Administration commissioned a report that recommended improvements in education about women's health for six health professions programs, including dentistry. This report highlighted the need for additional evidence-based practices tailored to meet the unique oral health needs of women and girls (Health Resources and Services Administration 2013). In addition, the U.S. Department of Health and Human Services (HHS) Office on Women's Health has created educational material for women and girls about oral health (U.S. Department of Health & Human Services 2017). As a result of this report, ADA expanded their continuing education programs for dental professionals to include dental care for pregnant women and issues related to women's oral health.

Pregnancy and Oral Health

Even though having good oral health during pregnancy is important, challenges have persisted for encouraging pregnant women to seek dental care and encouraging oral health professionals to provide care (Huebner et al. 2009). Recently, a group of investigators (Stephens et al. 2020) has issued a call to action regarding efforts to increase use of dental services during pregnancy. Having found that fewer than 20% of Medicaid-eligible pregnant women in 2014–2016 received dental care in North Carolina during pregnancy, they call for a multidimensional approach focusing on patients, providers, and policymakers to take action. These recommendations include conducting educational campaigns to increase public awareness and knowledge of the importance of dental care during pregnancy, improving health professional education and training on the importance and safety of treating pregnant women, expanding the workforce, and extending dental benefits.

Oral health providers should recognize that dental treatment during pregnancy is safe, does not affect the fetus, and that there is no need to postpone or avoid oral health care (American College of Obstetricians and Gynecologists 2013; Hagai et al. 2015). The ADA has acknowledged that preventive, diagnostic, and restorative dental treatment to promote health and eliminate disease is safe throughout pregnancy and is effective in improving and maintaining the oral health of mothers and their children (American Dental Association 2019). Continuing challenges in oral health for pregnant women are the integration of oral health into prenatal classes for expectant mothers, the addition of aspects of oral health during pregnancy in obstetrics and gynecology and midwife education, and better education of the dental community in regard to the need for, and safety of, dental care during pregnancy.

Interrelated Effects of Oral Health and General Health

The 2000 Surgeon General's report on oral health brought awareness to the importance of oral health and its relationship to overall health. Today, a more complex relationship, in which oral health also influences general health, is better understood. For example, periodontal diseases have now been hypothesized to be associated with 57 systemic conditions, representing about 2% of all the diseases indexed within the Medical Subject Headings thesaurus, a controlled vocabulary system established by the National Library of Medicine (Figure 26) (National Library of Medicine 2021). Many of these systemic conditions can be classified as noncommunicable (chronic) diseases. When the Surgeon General's first report on oral health was released in 2000, WHO was beginning to promote efforts to collectively address multiple chronic health conditions by targeting common risk factors shared by a few of the more prevalent conditions. This became known as the CRFA. Shortly thereafter, oral health advocates called for an inclusion of the more common oral diseases, such as dental caries, periodontitis, and oropharyngeal cancer, into a CRFA strategy (Sheiham and Watt 2000). This approach aims to intervene on risk factors common to a number of noncommunicable diseases (Sheiham and Watt 2000; Watt 2005), including oral diseases, by taking a comprehensive, integrated approach that incorporates measures of SDoH. Additionally, the CRFA emphasizes upstream factors, such as socioeconomic status and discrimination, more than downstream factors, such as individual behavior and health status (Bharmal et al. 2015). There have been substantial advances in knowledge on linkages between some oral diseases and systemic disease, for example, periodontal disease and diabetes. At the same time, there are ongoing challenges with unmet oral health needs among an increasing population of adults aged 50 years and older with chronic diseases; consequently, progress in advancing the CRFA within oral health has been slow.

Effects of Cancer Treatment on Oral Health

Despite scientific and clinical advances, challenges remain regarding the impact of the oral complications of cancer therapy on people's lives. For example, the ability to maintain employment is compromised because of functional changes and aesthetic concerns that result from treatment. The time and cost of medically necessary oral care before, during, and after cancer treatment also increases the probability of financial difficulty (Mady et al. 2019). Other challenges include access to care, health inequities, education of dental practitioners, and facilitating research that develops relevant information to support evidence-based decision making that leads not only to better health outcomes, but improves quality of life.

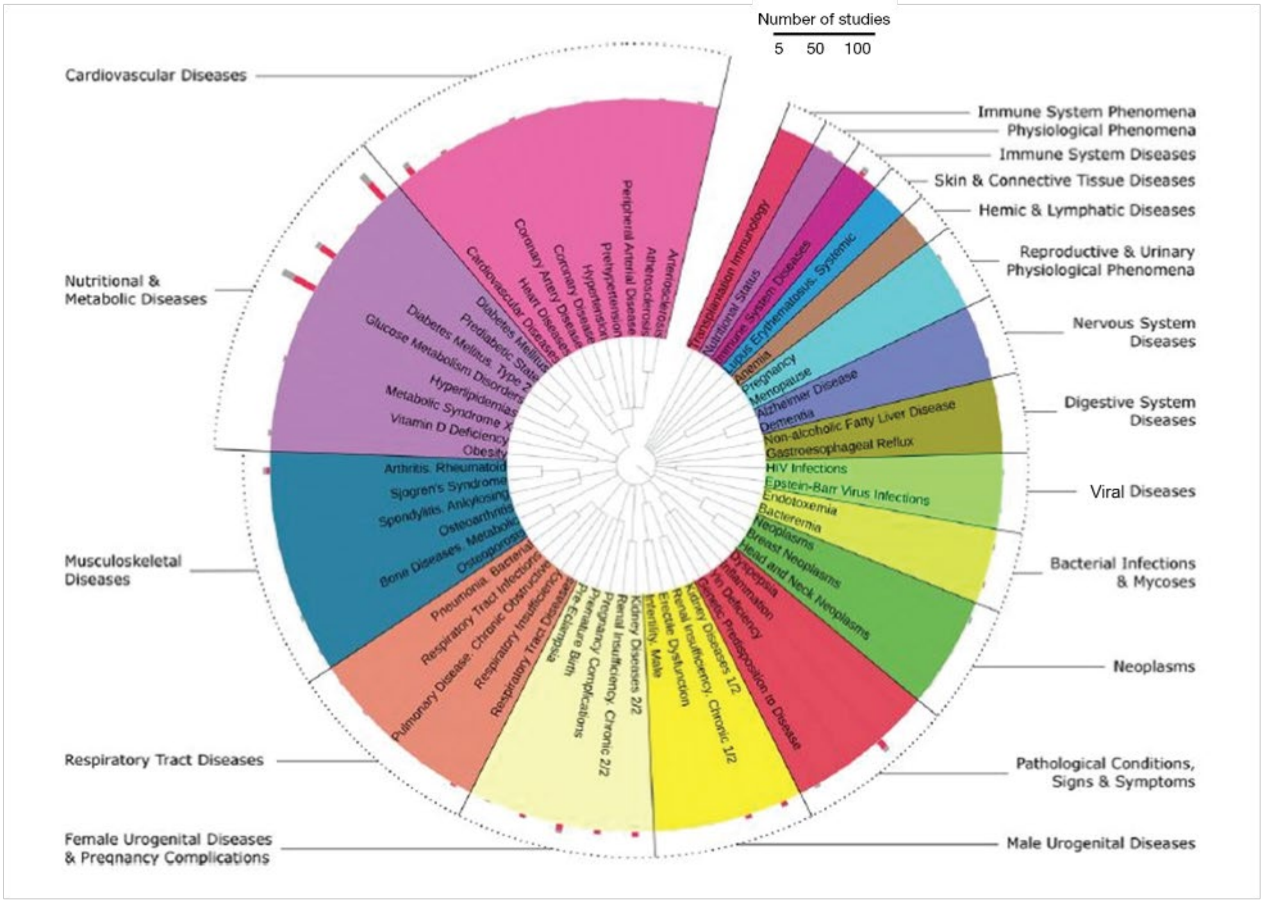
Chemotherapy and Targeted Cancer Therapies

Targeted cancer therapies have transformed the treatment of many types of cancer over the past decade (Hait and Hambley 2009; Sonis et al. 2010; Peterson et al. 2016). Even with precise targeting, oral and systemic adverse effects do occur (Boers-Doets et al. 2012; Lacouture et al. 2012). For example, oral mucosal injury caused by high-dose chemotherapy and head and neck radiation remains a problem. Researchers have made important advances in understanding this injury's biological basis (Peterson et al. 2012; Cinausero et al. 2017; Sonis et al. 2017; Bachour and Sonis 2018; Oosterom et al. 2018), including the inflammation biology cascade, as well as the genetic risk for, and governance of, the inflammatory response (Lecomte et al. 2004; Schwab et al. 2008; Hahn et al. 2010; Brzozowska et al. 2018). Novel molecular insights into the immunopathology of pain associated with oral mucositis also have been reported (Peterson et al. 2016). More recently, it has become evident that corticosteroids (topical, intralesional, and systemic) can be a safe and effective intervention for oral mucositis.

Head and Neck Radiation

The advent of intensity-modulated radiation therapy in the late 1990s defined a new era for treating solid tumors, including cancers involving the head and neck (Hong et al. 2005; American Cancer Society 2014). This technology

Figure 26. Relationship of periodontal disease and general health



Notes: Phylogenetic-like tree of systemic conditions that have been hypothesized to be related to periodontal diseases.
Source: Monsarrat et al. (2016). © John Wiley & Sons A/S. Reprinted with permission.

allows more precise delivery of radiation to the tumor, while enhancing the ability of the radiation oncology team to spare normal tissues. This therapy has improved the long-term quality of life of head and neck cancer patients by potentially protecting key oral tissues and other structures in the orofacial area from radiation damage.

Combination chemotherapy has been shown to be more effective than radiation therapy without chemotherapy for advanced head and neck cancer (Ghi et al. 2017). Increasingly, chemotherapy for this condition is given before or during radiation therapy.

Proton beam therapy has the potential to improve oral health outcomes and represents the newest technology used to treat a variety of solid tumors, including cancers involving the head and neck. This technology further enhances the precision of radiation delivery, with only minimal amounts involving nontumor tissue. Proton beam technology not only further spares normal tissues, but also targets high doses of radiation directly to the tumor. Recently, researchers found that patients with OPC treated with intensity-modulated proton therapy reduced the need for feeding tubes by more than 50%, compared to patients treated with intensity-modulated radiation therapy (Frank et al. 2018). This suggests that proton therapy may enhance oral health-related quality of life benefits for adults with tumors occurring at the back of the throat.

For health care professionals, there has been considerable progress since 2000 regarding oral management of cancer patients. Advances include updated interprofessional guidelines for oral mucositis management (Lalla et al. 2014; Peterson et al. 2015), updated systematic reviews by the Multinational Association of Supportive Care in Cancer/International Society for Oral Oncology (Elad et al. 2017; Hong et al. 2018), and inaugural oral oncology collaborations with the American Society of Clinical Oncology (Yarom et al. 2019). These advances have fostered increased interprofessional education and practice initiatives at the national and international levels. These advances also directly benefit patients suffering from oral cancer. The new therapies result in less loss of natural teeth and of salivary gland function and enable eating, chewing, and swallowing to improve posttreatment quality of life.

HIV

The 2000 Surgeon General's report on oral health recognized that the early identification of oral manifestations of HIV showed promise in helping to diagnose and manage HIV disease sooner. Public health programs initiated during the past 20 years have focused on early detection of HIV disease as a way to establish and facilitate care. New antiretroviral therapy has transformed HIV from a fatal illness to a chronic, manageable disease. Antiretroviral medications can sustain HIV viral suppression, reducing HIV transmission (Li et al. 2019) and the oral manifestations of HIV infection (Patton et al. 2000; Tami-Maury et al. 2011). In fact, incidence of the two most common oral manifestations of HIV, oral candidiasis and oral hairy leukoplakia, have decreased with rising immune competence (Chattopadhyay et al. 2005). Although the use of highly active antiretroviral therapy has resulted in significant reductions in HIV-related oral leukoplakias, some are still seen in patients with HIV infection. However, oral candidiasis remains the most common lesion seen with HIV infection (Patton et al. 2013).

Sickle Cell Disease

Improving oral health outcomes in people with sickle cell disease (SCD) remains a challenge. Patients with SCD should receive a thorough diagnosis and comprehensive options for dental treatment in consultation with their primary care provider or oncologist. Because there is insufficient evidence in the literature to guide oral health practitioners on the dental management of SCD patients and there are no guidelines on how to treat dental complications in patients with SCD, these patients may not receive appropriate treatment. However, the recent recommendations made by Kawar and colleagues (2018) (see also Appendix) provide a useful guide to dental care for individuals with SCD. These recommendations include:

- A healthy diet, routine dental checkups, and regular oral hygiene maintenance to prevent or at least minimize oral health-related complications. Patients should have oral health screenings provided by a dentist at least every 6 months.
- Minimize stress during dental treatment, because stress is a well-known factor that provokes a sickle cell crisis. Short morning visits are recommended for SCD patients, with anxiety assessment at the initial visit.
- Prevention and early management of any potential source of infection from gingival, periodontal, or endodontic origin. Dental infections should be treated aggressively with local and systemic measures.
- Encourage protective factors that promote teeth remineralization.
- Referral to an orthodontist for treatment of occlusal and skeletal discrepancies.

Laurence and colleagues (2013) observed a relationship between the presence of a dental infection and an increased likelihood of hospital admission among adult patients with SCD. The authors concluded that an increased focus on preventive oral health may reduce hospital admissions following visits to the emergency department. The challenge is to make more preventive and basic dental care accessible to patients with SCD and to help them take full advantage of available dental care.

Medications and Oral Health Complications

As mentioned in Chapter 1, among the most common oral side effects of some commonly prescribed medications is a decrease in salivary flow, leading to drug-induced xerostomia (dry mouth). It can be a challenge to recognize and manage the oral health side effects from these medications. Because the prevalence of some of the conditions related to these medications increases with age, the risk for caries may increase, as well. With an aging population in the United States and increasing prevalence of more chronic health conditions with increasing pharmacologic management, managing decreased salivary flow will become an increasing challenge. Doctors prescribing these medications and pharmacists who dispense them should be educated to inform their patients about the risk for dry mouth, including increased risk for dental and root caries, as well as other side effects that can potentially impact oral health. See Section 3B for more information on xerostomia and dry mouth.

Prevention and Management of Oral Diseases and Conditions

Management of Dental Caries

During the past 2 decades, there has been a change in our approach to prevent, diagnose, and manage this disease. An important aspect of this change has been a minimally invasive, nonsurgical approach to dental caries management that requires a documented assessment of risk, application of a remineralization treatment, and the ability to track changes in demineralization.

The use of fluorides continues to have an important role in preventing and controlling dental caries among working-age adults, but new information during the past decade is helping us to better understand how fluorides can be used effectively for this age group. Although some studies have suggested that community water fluoridation can be effective in preventing caries in adults (Griffin et al. 2007; Slade et al. 2013b), a large scale systematic study found insufficient evidence among adults, because the available studies did not meet the study criteria (Iheozor-Ejiofor et al. 2015). Nevertheless, other topical fluorides—in the form of rinses, gels, and varnishes—have been shown to be effective in adults who are at risk of developing caries (Weyant et al. 2013; Canadian Agency for Drugs and Technologies in Health 2016). However, a 2016 Canadian governmental review of the clinical and cost-effectiveness of fluoride varnishes concluded (with moderate certainty) that youth up to 18 years of age can benefit from the application of fluoride varnish biannually for the prevention of dental caries, while for adults, the strength of the evidence was lower and more directed to preventing dental caries occurring on exposed tooth roots. In general, the evidence summarized during the past decade has led to guidance for dental clinicians in the United States to prioritize the use of prescription fluoride (1.1% NaF) toothpaste or gel to reverse noncavitated lesions or to arrest smaller cavitated lesions on root surfaces of permanent teeth (Slayton et al. 2018). For more advanced cavitated lesions on permanent teeth, the guidance is to prioritize the use of silver diamine fluoride (SDF) biannually.

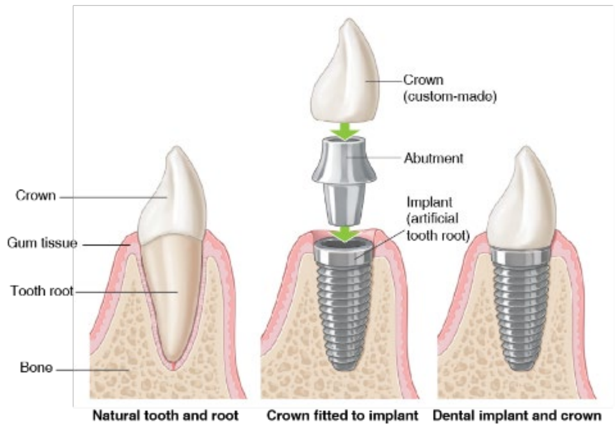
SDF is an inexpensive, noninvasive addition to the fluoride armamentarium and has re-emerged in the last decade as an important intervention to prevent and control dental caries on exposed tooth roots in adults. The use of fluoride varnish with 38% SDF, a silver fluoride salt, has been cleared by the FDA for hypersensitivity in adults, which makes its use to arrest dental caries in children and adults an off-label application (more information on SDF use in children is provided in Section 2A). As a noninvasive intervention, it has been reported that SDF can be beneficial to use in adults for whom patient cooperation is difficult because of complex medical or behavioral concerns, or when other unique circumstances must be considered, for example, in hospital settings or other places such as nursing homes (Horst et al. 2016). The application of this material does not replace the form or function of the tooth as does traditional restorative dental care. It is advisable to apply SDF to cavitated teeth with a plan for restorative care, so the cavitated lesions do not act as a reservoir for bacteria that promote tooth decay.

The longevity of restorations has not changed significantly in the past 2 to 3 decades, despite improvements in dental materials. Each time a restoration is replaced, it destroys more tooth structure. Results of clinical trials suggest that most restorations placed with current dental materials should last a relatively long time; however, early restoration failure is common, and replacement accounts for more than half of all restorations (Eltahlah et al. 2018). The challenge lies in helping dentists understand when to restore or replace a restoration and if remineralization is an option. If cavitation is not present, the cost of dental care can be reduced, and outcomes can be improved by choosing to remineralize a tooth.

Management of Tooth Loss and Replacement

The use of osseointegrated dental implants to replace missing teeth in working-age adults has increased considerably during the past 20 years. Implants are used to replace single missing teeth (Figure 27) and to support removable dentures. Each dental implant procedure may cost $3,000 or more, which includes the implant, the abutment, and the crown.

Figure 27. Dental implant



Source: Created by Jonathan Dimes for this NIH Report.

During the past 20 years, the percent of working-age adults obtaining at least one dental implant has tripled, from less than 1% to nearly 3% (Table 6). The greatest difference in the prevalence of dental implants among working-age adults is between those living in poverty and those who are more affluent; that difference has increased significantly in the last 2 decades. Adults with educational attainment beyond high school or with private dental insurance are twice as likely to have dental implants than those with lower education or no insurance (Elani et al. 2018). Throughout that time, improvements have been made in implant materials, coatings, threads, and shapes to improve the osseointegration process, as well as the health of the surrounding oral tissues (Buser et al. 2017). Additional improvements aimed to improve access to this costly treatment include reduction of the number of implants needed to retain prostheses (Bryant et al. 2015) and the use of narrow-diameter implants (de Souza et al. 2015). Current practice addresses issues important to patients, such as immediately placing implants following tooth extraction, early and immediate loading of implants so that patients do not need to live for weeks without a prosthesis, less invasive surgical techniques, and newer attachment designs so that patients can easily place and remove their prostheses (Buser et al. 2017).

New technologies, such as cone beam computed tomography imaging, and computer-assisted design and computer-assisted manufacturing (CAD/CAM) approaches, are used for more precise implant placement and prosthetic fabrication (Buser et al. 2017). The use of two implants to retain complete dentures in the mandible (lower jaw) has been shown to be more satisfactory for patients and provide greater oral health-related quality of life than new complete conventional dentures (Kodama et al. 2016).

Important challenges persist in educating patients when they are about to undergo extensive restorative dental treatment. When considering both tooth- and implant-borne, single- and multi-tooth restorations such as crowns, fixed partial dentures (bridges), and implant-supported prostheses, there is a critical need to educate patients on how to maintain complex restorations and improve the longevity of restorations (Bidra et al. 2016a; 2016b).

Unfortunately, most prosthodontic treatments, such as dentures, bridges, and implants, are available only to those who can afford them by using dental insurance benefits and/or paying out of pocket. As noted above, federal and state support for oral health care is limited to Medicaid (Title XIX of the Social Security Act), which provides some health benefits to people with limited income—mainly pregnant women, some adults with dependents, people with disabilities, and older adults. Of the states that do offer Medicaid benefits for adults, coverage varies considerably and often is restricted to emergency dental services. The lack of availability of dental bridges and implants may be further increasing oral health inequity. Although dental implants to replace single and multiple missing teeth are increasingly seen as the best treatment option in adults, they are financially out of reach for many working-age adults.

Managing Opioid Prescriptions to Prevent Misuse

Prescription opioids—such as Vicodin, OxyContin, and Percocet, among others—are typically provided by dentists and other health providers to manage orofacial pain. In response to the opioid addiction crisis, dental professionals have substantially changed their prescribing practices and have reduced the proportion of all prescriptions for immediate-release opioid analgesics to outpatients by more than half in the past 20 years (15% to

Table 6. Percentage of adults ages 20 and older with at least one dental implant present by select characteristics: United States, 1999–2004 and 2011–2016

Characteristic	1999–2004		2011–2016		Change
	Percent	Std Error	Percent	Std Error	(t-test)
Total	1.0	0.2	5.2	0.5	<.0001
Age/years					
20-64	0.7	0.1	2.6	0.3	<.0001
65 and older	1.4	0.3	7.8	0.8	<.0001
Gender					
Male	0.9	0.2	5.2	0.6	<.0001
Female	1.1	0.2	5.2	0.5	<.0001
Race/Ethnicity					
White, non-Hispanic	1.2	0.2	5.8	0.5	<.0001
Black, non-Hispanic	0.3	0.2	1.4	0.3	0.0019
Mexican American	0.2	0.1	1.5	0.5	<.0001
Poverty Status					
Poor	0.4	0.3	0.9	0.3	0.3195
Near poor	0.6	0.2	2.3	0.4	0.0004
Nonpoor	1.4	0.3	7.0	0.6	<.0001

Notes: Estimates are not age adjusted; Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988-1994,1999-2004, and 2011-2014.

6%) (Gupta et al. 2018). In contrast, primary care providers were the leading prescribers of all outpatient opioid analgesics, prescribing about half of those in 2012 (Denisco et al. 2011; Levy et al. 2015).

During the last decade, the trend to prescribe fewer opioids has accelerated. The estimated number of opioid prescriptions decreased from 69.3 million in 2010 to 63.4 million in 2018 for all drug classes combined. Opioid analgesics were the second most common drug class prescribed by dental providers, after antibiotics, with about 11.6 million prescriptions dispensed in 2018, a 43% decrease from 20.5 million prescriptions in 2010. Of note, the number of dispensed nonsteroidal anti-inflammatory drug (NSAID) prescriptions written by dental providers increased by 67%, from 4.5 million in 2010 to 7.5 million in 2018, despite the availability of over-the-counter NSAIDs (Symphony Health PHAST™ Prescription Monthly Database Data extracted May 2019).

The few studies that have evaluated the prescribing patterns of opioid analgesics by dentists reported that overprescribing was the result of a cautionary approach, generally associated with an overestimate of potential postprocedural pain (Wong et al. 2016; Thornhill et al. 2019). Nevertheless, in the last decade, policies implemented by professional organizations and a tightening of state prescribing authorities have resulted in declining dentists' opioid prescriptions. Opioid misuse is discussed further in Section 5.

Dental Fear and Anxiety

Management of dental fear and anxiety should begin with a thorough, individualized assessment of symptoms and potential causes (McNeil and Randall 2014). Pharmacologic approaches such as conscious sedation and general anesthesia, though commonly used, are not likely to yield long-term reductions in fear, anxiety, or avoidance (Boyle et al. 2009).

Since 2000, experts have recommended the use of behavioral approaches to the management of dental fear/anxiety in adults, reserving pharmacologic interventions for cases of high fear/anxiety and urgent need for dental treatment (Boyle et al. 2009; Newton et al. 2012). Evidence-based behavioral interventions include exposure therapy and skills training, as well as educating patients, building trust and rapport, enhancing sense of control, distraction, and offering positive reinforcement. In addition, cognitive-behavioral therapy may encompass relaxation training, cognitive restructuring, and systematic desensitization (Armfield et al. 2007). Many of these strategies are delivered by trained dental personnel in the dental setting, with referral to a clinical psychologist for severe cases. They may be used as part of an integrated behavioral-pharmacologic approach to management when clinically indicated (Boyle et al. 2009; McNeil and Randall 2014).

Digital Dentistry and CAD/CAM Technologies

Convergence of software development and hardware technology has increased the ability to plan oral care and has enhanced and improved care for many adults. Since the introduction of CAD/CAM systems in the 1970s and 1980s (Duret et al. 1988), their use continues to evolve. These digital technologies have driven improvements in diagnosis and treatment planning (Bhambhani et al. 2013; Cooper and Ludlow 2016), as well as the development of new and better materials for dentistry, including indirect restorations to replace teeth. Although ceramics, metals, and polymers have been used in dentistry for many years, the advent of CAD/CAM technology has improved the use of these materials, resulting in better outcomes for patients through improved precision.

CAD/CAM systems include the use of digital radiographic imaging, color matching and shade selection, photographic imaging, intraoral and extraoral scanning to capture anatomical features and inanimate objects, and computer-assisted pantographic recording of mandibular jaw movement. For capture of inanimate objects, extraoral scanners include optical, laser, and touch probe methods. The resulting images are then used in diagnosis and treatment planning.

CAD/CAM systems also make possible tooth preparation and restoration in one visit. Restorations can be fabricated chairside in reasonable time frames, reducing the number and length of appointments. At the same time, this new technology has opened access to new, better-performing materials for restorations and prostheses—to the point where restorations and prostheses fabricated by modern CAD/CAM systems are clinically equivalent to, and sometimes better than, those created with conventional methods (Ahmed 2018; Alshawaf et al. 2018; Kirschneck et al. 2018; Benic et al. 2019; Dickens et al. 2019; Wang et al. 2019).

Digital images can be created using optical or ionizing radiation energy sources (intraoral scanners or digital two-dimensional and three-dimensional radiographs, respectively). Both are easily shared electronically among health care providers. Intraoral scanning technologies have proliferated since the original CAD/CAM systems. Now, full arch, full color, high resolution images are captured in minutes. Captured data, displayed on a computer screen, are an important asset for patient consultation. Not surprisingly, patients much prefer images captured by a 1-inch diameter intraoral scanner than conventional impression methods that can be uncomfortable, or even painful (Burzynski et al. 2018; Sailer 2018).

Advances in Consumer Dental Products

There have been considerable advances in consumer dental products in the past 20 years. Most notably, many powered toothbrushes are available today, along with new toothpastes, antimicrobial rinses, and tooth-whitening strips. Powered toothbrushes are designed with different modes of action (oscillating-rotating, sonic, counter-oscillating, side-to-side, and back-and-forth). A Cochrane review found that, when compared to manual tooth brushes, oscillating-rotating power toothbrushes (relative to other modes of action) were more effective in reducing plaque and gingivitis in the short- and long-term (Yaacob et al. 2014). A recent systematic review (Rosema et al. 2016) evaluated the efficacy of powered toothbrushes on pre- and post-brushing plaque scores in a dataset of 6,713 participants. The review found that a weighted mean of 46% in plaque reduction was achieved following a brushing exercise. Similarly, another review (Yaacob et al. 2014) conducted a meta-analysis of 51 clinical trials involving 4,624 participants and found an 11% reduction in plaque in the short term (1–3 months) and a 21% reduction in plaque in the long-term (more than 3 months). Another meta-analysis conducted in the same review found 6% and 11% reductions in gingivitis in the short-term and long-term, respectively. Newer oscillating-rotating powered toothbrushes use Bluetooth technology to connect with a consumer's smartphone to provide an interactive brushing experience.

Oral Health Literacy

In the past 2 decades, there has been considerable progress in investigating the relationship between oral health literacy and oral health (Horowitz et al. 2020). The HHS national action plan to improve health literacy (U.S. Department of Health and Human Services 2010b) stated two guiding principles: (1) everyone has the right to health information that helps them to make informed decisions; and (2) health services must be delivered in ways that are understandable and beneficial to health, longevity, and quality of life. Practitioners, researchers, and policymakers have used this plan as a guide to address the oral health needs of adults.

An evidence-based toolkit that primary care practices can use to address health literacy was first published by the Agency for Healthcare Research and Quality in 2010 (DeWalt et al. 2010) and updated in 2015 (Brega et al. 2015). It states that all adult patients at some point may have difficulty understanding information and navigating the health care system. This approach shifts responsibility from the patient to the practice, with the result that health care organizations and practitioners now are expected to provide clear health communications to their patients.

During the past 20 years, professional dental organizations in the United States have recognized the importance of oral health literacy in the context of dental practice. In 2016, ADA resolved to support "the use of health literacy principles and plain language for all patients and providers to make it easier for them to navigate, understand, and use appropriate information and services to help patients be stewards of their oral health" (ADA Council on Access, Prevention, and Interprofessional Relations 2016). The ACA, or Patient Protection and Affordable Care Act of 2010 (HealthCare.gov 2010), provides guidance for all health promotion activities, including those related to oral health, as well as communication strategies that can be used in health literacy programs.

The role of oral health literacy in helping to inform oral health decision making for both individuals and care providers is increasingly being recognized (Horowitz et al. 2020). Despite the intuitive importance of oral health literacy in oral health status/outcomes, empirical studies are inconsistent. Systematic reviews have questioned the effectiveness of oral health literacy in influencing outcomes related to oral health disease status, perceptions and behaviors, and treatment outcomes (Firmino et al. 2017; Firmino et al. 2018). One of these reviews examined the tools used to measure oral health literacy and concluded that the majority were biased toward word recognition, numeracy, and reading skills, instead of health behavior and dental care utilization comprehension. However, more current studies are beginning to incorporate behavior and care navigation elements. Although these reviews are challenging the perceived potential effectiveness of oral health literacy, they also remind us that more robust research in this area with improved study designs will be needed.

Furthermore, adults increasingly rely on computers, smart devices, and internet resources to navigate a complex and difficult U.S. health care system. These technologies often are challenging for individuals with limited health literacy skills. The fact that many adults are making health decisions that encompass unfamiliar procedures, complicated forms, and confusing insurance coverage represents both a social and a policy challenge. Overcoming all of these health literacy-related challenges will be important for improving oral health at both the individual and population levels.

Special Needs Populations

Adults with Disabilities and Special Health Care Needs

Major changes during the past 2 decades have had a significant impact on the oral health of adults with disabilities and special health care needs (SHCNs). These changes include provisions within the ACA that have benefitted a broad population, especially young adults with special needs. These include expanded Medicaid eligibility to low-income adults without dependent children; dependent care coverage on parents' policies until 26 years of age; expanded health insurance; and, to a lesser extent, dental coverage for previously uninsured populations. These changes have resulted in improved access to needed oral health care for some adults with disabilities and SHCNs in selected states that have expanded their Medicaid coverage. However, inconsistent dental coverage across the country continues to limit the ability of many in this vulnerable group of people to achieve or maintain optimal oral health.

The availability of trained dental providers who feel comfortable providing prevention, treatment, and disease management for adults with SHCNs remains a challenge in achieving oral health for this population. According to Families USA, this is a serious problem (Families USA 2019). However, progress is underway in educating dental students and dental residents to care for adults with complex medical conditions and special needs. For example, the Commission on Dental Accreditation has recently approved a new standard for predoctoral education that requires all U.S. dental schools to educate students to be competent in assessing and managing patients with intellectual and developmental disabilities, among other special needs populations. By mid-2020, all schools must comply with this educational standard or risk jeopardizing their accreditation (Commission on Dental Accreditation 2019).

Incarcerated Populations

Incarcerated individuals face oral health challenges, even after their incarceration ends. Release from jail or prison frequently means interruptions in care, as well as the tasks of finding providers and obtaining insurance or other means to pay for care. Poor dental health and tooth loss may make it more difficult to find employment. In short, a history of incarceration remains a significant factor in the unmet medical and dental needs of former prisoners (Kulkarni et al. 2010). It is evident that incarcerated people should be designated as an underserved population based on their demographics, limited access to adequate oral health care, increased likelihood of facial trauma, and continuing health care challenges. Unfortunately, meeting the health needs of the large U.S. prison population, both during and after incarceration, remains a challenge.

The high incidence of oral diseases, the increased prevalence of disease risk factors, and limited access to dental services are significant challenges for this population. These challenges extend beyond release from incarceration and affect these individuals' families and communities. Developing and implementing recommendations to better support the oral health of those formerly incarcerated would improve population health outcomes.

Rural Communities

People living in rural communities often have limited access to dental care. Geographical distances, especially for Native Americans living in tribal communities, make dental care even more scarce and may require many miles of expensive and time-consuming travel.

Addressing the oral health inequities that still exist among rural and Native American populations is a significant impediment in reaching objectives for Healthy People 2030. Specifically, if the Indian Health Service and tribal programs are to meet the Healthy People objectives for untreated decay, considerable progress must be made in developing preventive programs and improving access to and utilization of the dental care system.

A recent review (Tiwari et al. 2018) of studies aimed at reducing health inequities among indigenous communities included communities from the United States, Canada, Brazil, Australia, and New Zealand. The interventions largely focused on early childhood caries but several also addressed outcomes among adults, including oral health literacy (Ju et al. 2017), the efficacy of an oral health literacy intervention among Indigenous Australian adults (Ju et al. 2018), and periodontal health among Indigenous Australians (Kapellas et al. 2013). Both oral health literacy and periodontal health improved in these studies. The authors identified common methodologies and challenges. The common methodologies included culturally-tailored interventions, community-based interventions, and community workers to deliver the interventions. The studies faced challenges because the communities were spread over vast areas and remote locations and required resource intensive interventions that would be difficult to scale up for broad implementation.

Lesbian, Gay, Bisexual, Transgender, and Queer (LGBTQ) Oral Health

Estimates of the percentage of lesbian, gay, bisexual, transgender, and queer (LGBTQ) people include about 6.8% of men and 4.5% of women over the age of 18 who self-identify as lesbian, gay, or bisexual, thus representing a fairly substantial proportion of the U.S. population

(Russell and More 2016). As recently as 20 years ago, oral health in the LGBTQ community received only a brief mention in the 2000 Surgeon General's report on oral health, which noted the lack of data and the need for more research for this population. A limited number of studies have since begun to address this gap in knowledge (Russell and More 2016).

Although LGBTQ people are a heterogeneous group, they share experiences of discrimination and social stigma in the broader society as well as in the health care system, resulting in health inequities. A study of sexual orientation and health based on data from the 2001–2008 Behavioral Risk Factor Surveillance System surveys (N=67,359) in Massachusetts found that, compared to individuals who identify as heterosexuals, gay/lesbian and bisexual individuals reported more disability, worse mental health, and more frequent health risk behavior, such as smoking and drug use (Conron et al. 2010). Bisexuals experienced greater cardiovascular disease risk and barriers to health care. Another study based on Behavioral Risk Factor Surveillance System surveys from 2005–2010 in seven states suggested that the health inequities experienced by LGBTQ people are derived from poor economic circumstances and social disadvantages, compared to heterosexuals (Gorman et al. 2015).

Data on the oral health of LGBTQ people are more limited than that on medical conditions. Schwartz and colleagues (2019) indicated that the analysis of oral health data for LGBTQ people did not even exist before their study of NHANES data from 2009 to 2014. The authors investigated health inequities among lesbian, gay, and bisexual adults aged 18 to 59 years, relative to heterosexual adults. They examined clinical indicators, including dental caries, tooth loss, chronic periodontitis, and oral HPV, as well as self-reported oral health status and use of dental services. They did not find any differences in clinical oral health status between lesbian, gay, and bisexual adults, compared to heterosexual adults, although lesbian, gay, and bisexual adults reported worse perceived oral health. This study is the first to shed light on the oral health of LGBTQ people. Clearly, more research is needed on the oral health inequities that LGBTQ people experience.

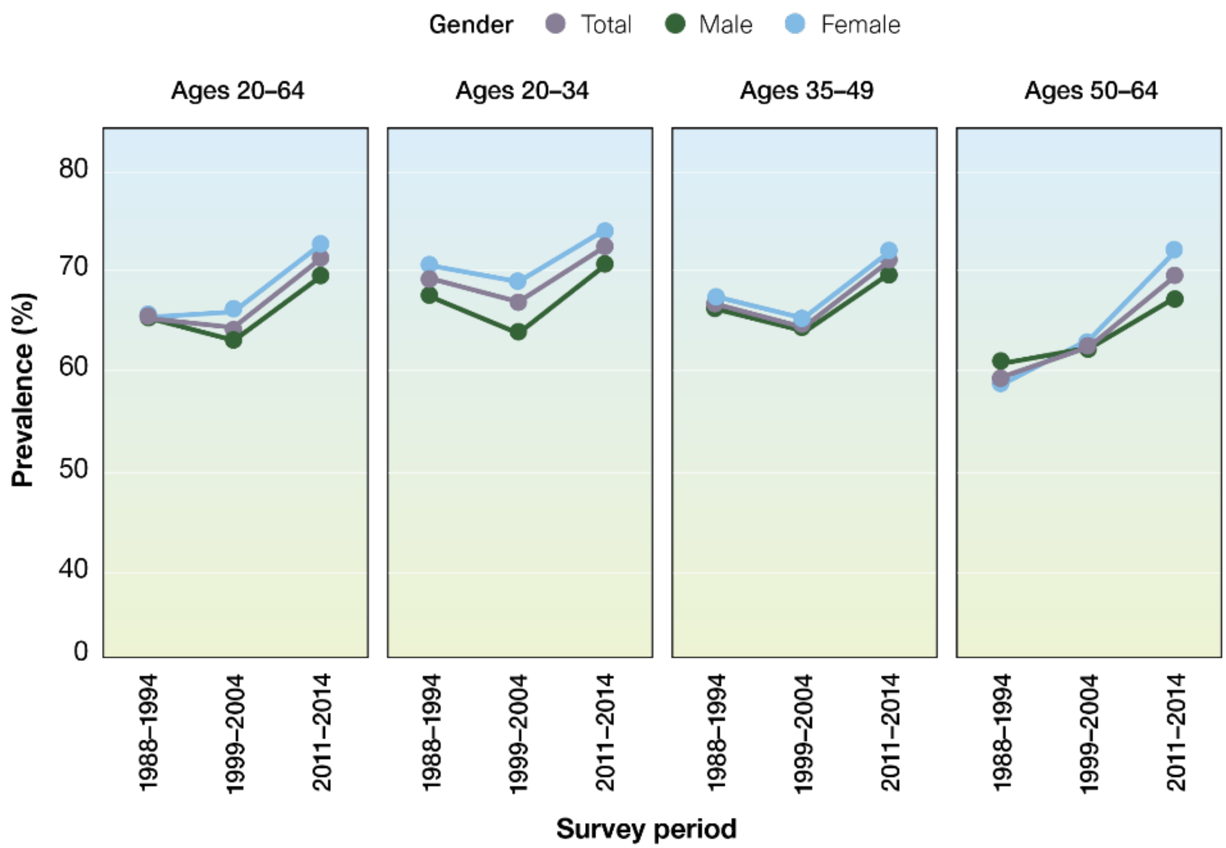
Oral Health and Quality of Life

Twenty years ago, the science of oral health-related quality of life (OHRQoL) was relatively new. OHRQoL involves peoples' perceptions of their overall well-being and happiness related to their oral conditions, and poor oral health (e.g., pain, tooth loss, esthetics) has been shown to negatively impact OHRQoL (Gerritsen et al. 2010; Seirawan et al. 2011; Tan et al. 2016; Larsson et al. 2020). At that time, it was noted that oral disease was related to an individual's well-being and quality of life and that it contributed to the burden of illness in the U.S. population. Today, OHRQoL is a common topic in oral health research for both acute and chronic conditions and is now incorporated into definitions and conceptual models of oral health. In fact, since that time, research publications on OHRQoL have substantially increased. In 2019, both "oral health" and "quality of life" were major subject headings in 1,286 PubMed indexed citations. Ninety-seven percent of these (1,250 citations) were published after 2000, 63% (813 citations) were studies of adults, and 38% (494 citations) were studies of older adults aged 65 years or more.

In the past 20 years, working-age adults' overall satisfaction with their mouth and teeth has improved from nearly 66% to 71% (Figure 28). Although all socioeconomic groups have reported higher levels of satisfaction with their oral health during this period, substantial disparities between groups continue. For example, 54% of Mexican Americans and 64% of non-Hispanic Blacks rate their oral health status as satisfactory, whereas 75% of non-Hispanic Whites are satisfied with their oral health status (Figure 29). These differences represent a small improvement during the past 20 years as the disparity between non-Hispanic Black and White working-age adults has decreased. Nevertheless, the largest disparity in perceived satisfaction of oral health exists between working-age adults living in poverty and those living at twice the FPG—51% versus 80%. The magnitude of this disparity has persisted for the past 20 years.

Although OHRQoL has assumed a prominent position in the oral health research field in the past 2 decades, long-term cohort studies are needed to understand life course influences on OHRQoL. To date, studies of this type have been conducted only in New Zealand (Shearer et al. 2011).

Figure 28. Percentage of adults ages 20–64 reporting overall satisfaction with their teeth and mouth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Overall satisfaction is a self-report of excellent, very good, or good.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

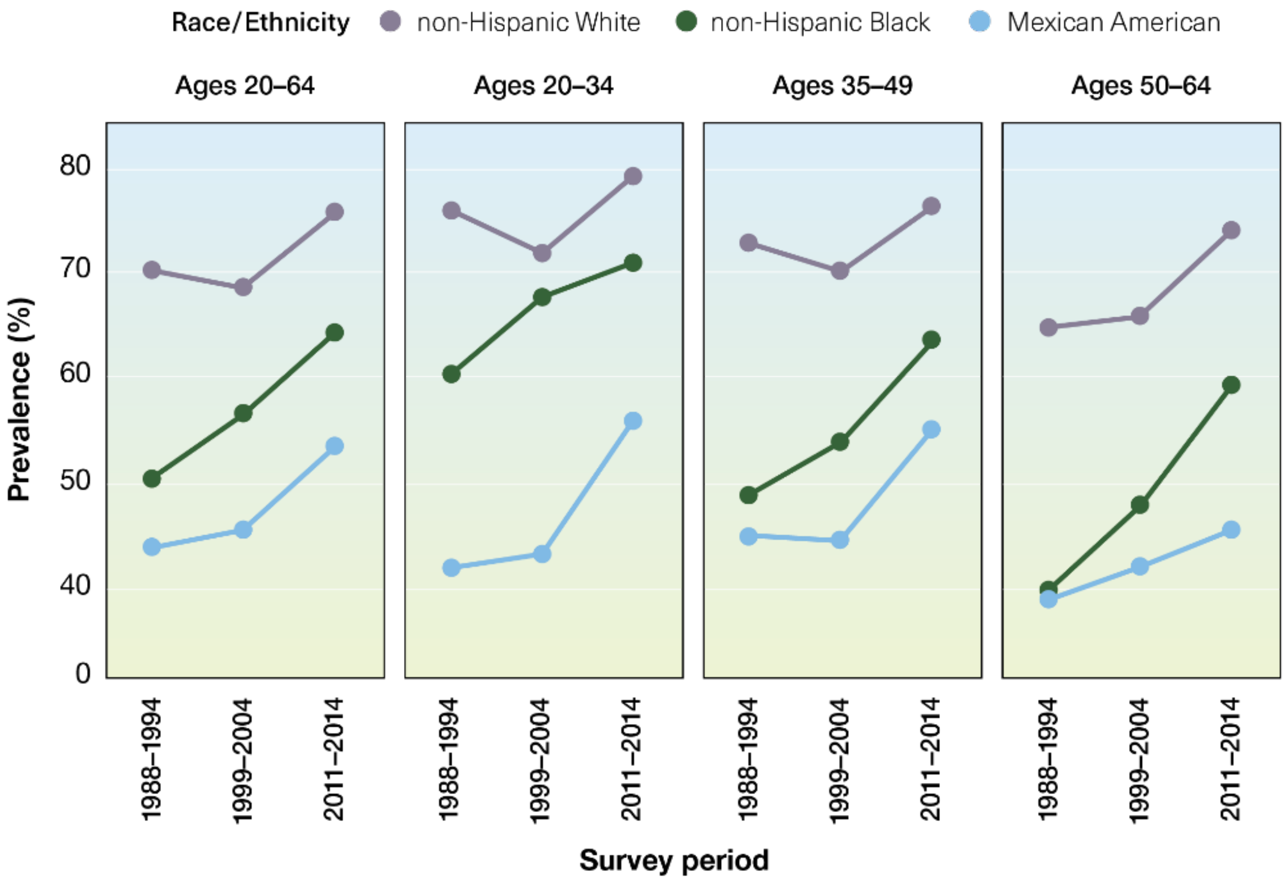
Clinical trials also are needed to evaluate OHRQoL outcomes following treatment for dental caries in adults, one of the most prevalent oral diseases. Although convincing evidence exists for the efficacy of implant-supported prosthesis for restoration of edentulous jaws, there is little evidence for the far more common and accessible forms of dental treatment that restore or replace single teeth.

In addition to strengthening the research evidence on OHRQoL, practical models of oral health care that incorporate the evidence are needed. In principle, OHRQoL is relevant when determining priorities for oral health care, targeting treatment and prevention to patients most likely to benefit, and evaluating outcomes of care. The provision of oral health care needs to emphasize improving OHRQoL in balance with biological and mechanical endpoints to facilitate well-being.

Dental Services Utilization

In 2015, about 40% of adults aged 21 to 64 years reported having a dental visit in the past year, and this has essentially remained unchanged since 1996 (Manksi and Rohde 2017). In general, among working-age adults, little has changed since 2000 regarding dental utilization (Nasseh and Vujicic 2016). About 1 in 5 people living in poverty have had a dental visit, whereas about 1 in 2 living at 400% of the FPG have had a dental visit. For working-age adults with private dental insurance, about half have had a dental visit within 12 months. For the uninsured, the percentage with a dental visit appears to be gradually decreasing, from about 23% to 15%.

Figure 29. Percentage of adults ages 20–64 reporting overall satisfaction with their teeth and mouth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Note: Overall satisfaction is a self-report of excellent, very good, or good.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

The average dental expenditure for working-age adults increased from about $360 to $661 per person per year between 1996 and 2015. When adjusted to the 2015 U.S. dollar, the net increase was $166 per person during the 2-decade period (Manksi and Rohde 2017). Mean out-of-pocket dental expenditures increased per person from $173 to $256 during the same period. With about 1 in 5 working-age adults not receiving needed dental care, a large proportion of working-age adults faced financial barriers to receiving dental care (Gupta and Vujicic 2019). Although health insurance has been expanded through the ACA, more U.S. adults do not receive needed dental care compared to all other health services, regardless of income or insurance level (Vujicic et al. 2016).

Dental insurance has been shown to improve access to dental care. The ACA included dental care as an essential health benefit for children, although not for adults (Vujicic 2014), and the dental safety net has remained limited for low-income adults. In 2018, only 23 states and Washington, D.C. offered extensive dental benefits to adults enrolled in Medicaid (National Academy for State Health Policy 2021). Furthermore, 27.6% of working-age adults had no dental insurance, compared to only 12.1% of children (Manksi and Rohde 2017). Lack of dental insurance is a major barrier to obtaining dental care. In a study by Vujicic and colleagues (2014), the expansion of the ACA to include young adults up to 26 years of age showed that this dependent coverage policy was associated with an increase in dental benefits coverage and a decrease in financial barriers to receipt of dental care among young adults 19 to 25 years of age (Vujicic et al. 2014). Since the turn of the century, working-age adults are the only age group that have not seen an expansion of dental insurance coverage (see Figure 36, Section 2A of this monograph).

To address the growing inequity in access to oral health services for adults with chronic illness, Donoff and colleagues (2014) called for reform based on two recommendations: (1) the federal government and states must offer dental care coverage in all health insurance policies, and (2) general medical and dental care must be integrated into practice settings and professional education. Suggestions for additional reforms include the integration of medical and dental electronic health records, integrated health homes for patients, medical screening by dental clinicians, and oral health screening by physicians. Several of these ideas are discussed further in Sections 4 and 6.

Provision of Adult Oral Health Care in Alternative Settings

Community and Family-Based Interventions

Progress during the past decade has included the development and implementation of intergenerational and family-based interventions for rural and immigrant communities. Many of these emphasize university-community partnerships, often using community-based participatory research (CBPR) and qualitative approaches and methods (Huebner et al. 2014; Kavathe et al. 2018). Such interventions recognize that intergenerational influences—including caregivers' attributes, attitudes, and knowledge—may be viewed as intermediary mechanisms through which societal and community influences affect the oral health of family members, particularly in disadvantaged communities (Milgrom et al. 2013; Northridge et al. 2017b). According to a review by Tiwari and colleagues (Tiwari et al. 2018), preferred intervention methodologies included community-based research approaches, culturally tailored strategies, and use of community workers to deliver the initiative. CBPR methods also have been used for examining attitudes, perceptions, and barriers toward oral health and oral health care seeking. The variety of populations and contexts for this work has included one involving Black men living in low-income, urban communities (Hoffman et al. 2017; Akintobi et al. 2018) and another that focused on migrant Mexican families involved in oral health educational interventions (Finlayson et al. 2017).

Chapter 3: Promising New Directions

Advances in science and technology that improve oral health through prevention, early diagnosis, and less costly treatment of disease are now available, but not to all Americans. Collaborations of dental and medical professionals, as well as others in health and social care, offer opportunities to expand access to oral health services and reduce inequities related to the development of oral diseases and conditions in specific populations. The stage is set for major improvements in adults' oral health.

Etiology and Prevalence of Oral Diseases and Conditions

Advances in Periodontal Disease Diagnostic Staging and Influence on Dental Implant Success

New genomic and statistical technologies have led to the redefinition and reclassification of periodontal disease (Caton et al. 2018a). This change in periodontal disease classification is expected to help improve diagnosis and treatment decision making, leading to better prognoses and outcomes for patients (Tonetti and Sanz 2019). In addition, recent information is improving our understanding of peri-implantitis (inflammation forming around dental implants), including risk factors and indicators that favor onset and disease progression (Berglundh et al. 2018a; Schwarz et al. 2018a; Berglundh et al. 2018b; Schwarz et al. 2018b). Given the increased use of dental implants among adults, this will help to guide decision making and reduce implant failure.

Orofacial Pain and Temporomandibular Disorders

The recent U.S. National Pain Strategy, an interagency initiative launched in 2017 by the U.S. Department of Health and Human Services (National Institutes of Health 2021a), addresses many aspects of pain relevant to temporomandibular disorders (TMD). This initiative is beginning to provide robust national data on the personal and societal impact of chronic pain (Dahlhamer et al. 2018) and is expected to help prioritize effective treatments to reduce the impact of pain. Furthermore, the proposed incorporation of TMD into the Institute for Health Metrics and Evaluation's Global Burden of Disease Study will provide data on the impact of TMD around the world. Finally, ongoing research on factors related to susceptibility to multiple pain conditions will likely yield new findings, allowing for early targeting of effective interventions for TMD patients at risk for high-impact chronic pain.

The opioid crisis, although focused primarily on decreasing the number of opioid prescriptions written by dentists, also is leading dental professionals to a new understanding about acute and chronic pain in their patients. This effort assists dental clinicians in the management and treatment of patients with TMD.

Oropharyngeal Cancer and Human Papillomavirus

Research has revealed the epidemiologic underpinnings and clinical implications of oropharyngeal cancer caused by the human papillomavirus-related oropharyngeal squamous cell cancer (HPV-OPC), yielding a clearer understanding of the disease process. At the same time, there is much to learn about the pathogenesis of oral HPV infection. Although the HPV vaccine offers great promise in preventing future cases of OPC, questions remain about the minimum serologic titer needed to be protective and how this might affect the vaccine's long-term impact upon HPV-OPC. With the increasing burden of HPV-OPC, it is important for researchers to develop an effective screening strategy by addressing questions related to whether there is an identifiable precursor lesion and who is at risk for persistent infections that lead to malignant transformation. This work will involve seeking potential biomarkers to identify individuals at increased risk for malignancy and factors that influence the cascade from infection to malignancy. It also will be important to develop diagnostic tools to aid in early identification of lesions and to determine whether early detection can result in less therapy, less morbidity, and improved survival. Finally, investigators should explore the potential of early patient education for reducing the incidence of OPC.

Prevention and Management of Oral Diseases and Conditions

Managing Effects of Cancer and Other Treatments on Oral Health

There are several strategic research directions to increase our knowledge of the unique oral health challenges faced by cancer patients being treated with pharmacologic agents and of strategies for improving their dental management. Research opportunities include: (1) mechanistic-based research addressing bone and oral mucosal biology and the genetic risks for developing medication-related osteonecrosis of the jaw; (2) continued population health studies regarding antibiotic prophylaxis for prevention of infective endocarditis and prosthetic joint infection; and (3) novel health professional curricula to encourage interprofessional education and practice.

In addition to cancer treatments, many medications affect oral tissues, notably those that cause xerostomia, salivary hypofunction (Wolff et al. 2017), and gingival hyperplasia (Aral et al. 2015). In addition, the dental management of patients can be influenced by anticoagulant/antiplatelet medications (Mingarro-de-Leon et al. 2014; American Dental Association 2018b), the use of prophylactic antibiotics for those with prosthetic joints of the hip or knee (Sollecito et al. 2015), and individuals who have cardiac risk factors for infective endocarditis (Wilson et al. 2008; Nishimura et al. 2017). Clinical guidelines developed jointly by physicians and dental clinicians can improve management of these medically complex patients.

Managing Opioid Prescriptions to Prevent Misuse

Partnerships among various stakeholders at national, state, and community levels have led to significant successes in mitigating prescription opioid misuse, abuse, and overdose deaths. Federal agencies are developing additional initiatives and strategies. For example, the National Institutes of Health, through the Helping to End Addiction Long-term Initiative, is advancing the development of new and innovative medications and biologics for the prevention and treatment of opioid misuse and addiction and to enhance nonaddictive pain management (National Institutes of Health 2020).

The U.S. Food and Drug Administration (FDA) also is committed to the development of safe, effective nonopioid analgesics and new medications to treat opioid use disorder. In May 2018, FDA launched an innovation challenge to develop medical devices to combat the opioid crisis. In April 2019, the agency approved the first generic naloxone hydrochloride nasal spray (Narcan), a life-saving medication that can stop or reverse the effects of an opioid overdose. The agency is supporting the development of over-the-counter naloxone to increase access to this critical drug for reducing opioid overdose deaths (U.S. Food and Drug Administration 2015; 2017; 2019).

On the state level, policies and laws that curb the prescribing of opioids by dentists have emerged. States are changing their dental practice acts to include mandatory continuing education on opioid use and abuse and requirements for dentists to register for and use state-based prescription drug monitoring programs before prescribing an opioid analgesic for chronic or acute pain.

Nonsurgical Treatment Innovations

Nonsurgical treatment approaches, such as therapies based on fluoride agents such as silver diamine fluoride (SDF), frequently are good alternatives to problems commonly addressed by dental surgical procedures and are beginning to represent new standards of care. Further progress is possible with better implementation of evidence-based treatments, such as fluoride varnish and SDF, and development of new therapies.

Regarding treatment, the American Dental Association Center for Evidence-Based Dentistry and other organizations have developed evidence-based guidelines for the prevention and management of dental caries. Yet, changes in clinical practice appear to be occurring at a relatively slow pace, in large part because the dental care reimbursement system continues to reward the restorative management of disease, rather than value-based care.

Similarly, nonsurgical approaches to the treatment of periodontal disease continue to be developed. These nonsurgical approaches are based on research findings that have shown how to decrease the bacteria that cause periodontal disease. New treatments for dental sensitivity also continue to be developed. Changes in treatment standards and practices are just one aspect of an evolving landscape for oral health care. Many patients now come to the oral health professional with a great deal of knowledge about their condition, often obtained from web searches (Seymour et al. 2016). They are actively engaged in monitoring and managing many other aspects of their health, e.g., using wearable devices that track and report activities, exercise, sleep, heart rate, glucose levels, and more. Similar technologies for oral health could be valuable additions to these options. Some electric toothbrushes already monitor the recommended brushing time of 2 minutes.

These nonsurgical approaches for both dental caries and periodontal disease, in addition to the more traditional surgical approaches to managing dental diseases, can help adults keep their teeth throughout their life. Point-of-care devices for monitoring daily oral home care will continue to be developed and assist working adults to maintain good oral health as they age.

New Technologies for Dentistry

Digital technologies are transforming clinical dental practice. These new technologies are making clinical dental care faster, easier, and more precise. Digital technologies have become the most promising platform for creating clear communication among dental professionals, patients, dental laboratories, and insurers. The quality of data enhances workflow, recordkeeping, and therapeutics. These technologies also have delivered diagnostic improvements, lowered radiology exposure rates, and simplified processes.

With digital technologies, it is now possible to integrate data from multiple sources, including digital optical and radiographic data; computer-assisted design/computer-assisted manufacturing (CAD/CAM) restoration design and fabrication commands; patients' medical, social, and dental status; progress notes; and treatment plans drawn from electronic health records (EHRs). Using some or all of these data facilitates referrals and conversations between dental and medical professionals about patient care and enhances the interoperability of EHRs.

A potential and promising new use of CAD/CAM systems is the opportunity to use them in underserved areas. For instance, a mobile van using these systems could deliver care to underserved areas, including nursing homes, prisons, and rural areas with no permanent onsite dental clinician. Use of CAD/CAM systems in such settings could result in restoration, rather than extraction, of teeth and lead to improved oral health for many working-age rural adults.

Teledentistry is another promising new direction that can expand the provision of oral health services to those who cannot easily access dental care, including patients who are homebound or live in rural areas (Cooper and Ludlow 2016; Estai et al. 2018; Kopycka-Kedzierawski et al. 2018). Teledentistry can be used for a variety of services. For example, intraoral scans, even those captured by cell phones, enable data collection for screening and diagnosis from afar (Giraudeau et al. 2017; Signori et al. 2018; Binaisse et al. 2019; Giacomini et al. 2019). In the future, workplace and school-based screenings could be done without the need for highly skilled examiners onsite (Tynan et al. 2018).

To more completely integrate new technologies into clinical practice will require incentives that encourage providers and patients to embrace digital dentistry. Reimbursements, especially for remote services and teledentistry activities, will be critical. Reimbursement for outcomes-driven and prevention-focused oral health care—regardless of the delivery mode—has become increasingly important (Shetty et al. 2018).

Artificial intelligence (AI) systems, which recognize trends and patterns in large datasets, then refine projections with exposure to more data, offer promising new opportunities to improve not just clinical treatments, but the training of clinicians. AI systems have been trained to review radiographs and diagnose tooth decay. Other uses in oral health are emerging. Virtual, augmented, and mixed reality are being used to create virtual patients that can be used for training or enhancing the treatment of existing patients (see Section 6 for more on AI).

Oral Health Literacy

One promising new direction in the area of improving oral health literacy is a recent initiative focused on Native Americans. In 2019, the Indian Health Service (IHS) created the IHS Oral Health Literacy Initiative to give dental professionals tools to improve oral health literacy among the American Indian/Alaska Native population. The theme for this initiative is SMILE—**S**haring oral health **M**essages to **I**mprove **L**iteracy for **E**veryone. This innovative oral health literacy initiative includes oral health materials and an oral health literacy presentation for dental professionals to offer patients (Indian Health Service 2021).

In addition, companies such as GoodHealthTV® provide oral health information to more than 200 IHS, tribal, and urban clinics through subscription-based health education networks broadcast in clinic waiting areas. According to GoodHealthTV®'s website, 99% of viewers indicated they watched and learned new information, and 92% said that the programming prompted them to seek more information (GoodHealthTV 2018). The use of digital and social media is another way to reach individuals in Indian country with targeted oral health messages. Additional research is warranted to demonstrate that improved oral health literacy results in improved oral health outcomes (Horowitz et al. 2020).

Provision of Adult Oral Health Care in Alternative Settings

Community-Based Interventions

Promising new directions to improve oral health equity for working adults include embedding clear, culturally appropriate messages on oral health within community-based health interventions, such as those for tobacco prevention and cessation, nutrition, injury prevention, HPV vaccination, and diabetes education (Benzian and Williams 2015). Moreover, the broad reach of mobile and other digital technologies provides opportunities for remote monitoring and self-care to reinforce preventive oral hygiene behaviors (Shetty et al. 2018) at the individual level. For researchers, community-based participatory research, qualitative approaches, and implementation science hold promise to address barriers to community-based oral health promotion (Simpson 2011).

Given cultural influences on health attitudes and behaviors and the potential for isolation of some new immigrants, community institutions and community health workers may serve as cultural bridges that can link immigrants to needed oral health information and resources (Marino et al. 2014; Kavathe et al. 2018). Community-based peer support programs aimed at diabetes prevention or tobacco cessation also may improve oral health among underserved adults (Thankappan et al. 2018).

Community Programs Targeting Special Needs Populations

Achieving optimal oral health among adults with disabilities and special health care needs is a complex undertaking. Although progress is being made and some programs are showing promise, achieving this goal will require broader and more sustained efforts affecting systems change. Promising new directions that demand further evaluation and expansion include the education of dental clinicians and specialists in preventing and treating dental diseases in this vulnerable population (Dao et al. 2005). Also promising are programs that provide a public or private dental insurance benefit for adults and older adults, regardless of employment, to improve access to needed oral health services (Wehby et al. 2019).

In addition, many working-age adults with complex health needs are military veterans who may have service-related conditions such as post-traumatic stress syndrome, risk for substance use disorders, homelessness, or any number of other health conditions and limitations. Many of these conditions can substantially affect access to dental care, leading to poor oral health. An example of a community service designed to improve the oral health of military veterans is the Heroes Clinic in Denver, Colorado. A partnership between the University of Colorado School of Dental Medicine and Delta Dental of Colorado, this clinic provides a range of free dental services to veterans and can even accommodate their service dogs (Box 1).

Interprofessional Care

There is some evidence that interprofessional practice improves patient outcomes (Reeves et al. 2017). Although interprofessional, integrated, personalized care is a promising approach to achieve health equity and eliminate oral health disparities, most work in interprofessional care has been done with children, rather than adults. Interprofessional collaborations have occurred for special needs adults with developmental disabilities to improve their oral health (Fenton et al. 2003). Although some interprofessional collaborations have been developed for adults, many of these are hospital-based and focus on adults with various severe medical diseases, and oral health has not been universally incorporated. There has been an attempt at integrating some oral health care for pregnant women in places where they most frequently seek care and counseling. One example is Grace Health in Michigan where dental hygienists are co-located in an obstetrics suite (Atchison et al. 2018), and another is prenatal care centers operated by CenteringPregnancy in San Francisco (Adams et al. 2017). For working-age adults, there are many opportunities to expand interprofessional practice. These opportunities should focus on locations frequented by working adults, such as worksites, grocery stores or pharmacies, or other settings where medical or oral health care is delivered.

Chapter 4: Summary

Using the 2000 Surgeon General's report on oral health as a comprehensive baseline for many oral conditions, the oral health of U.S. adults has not improved significantly. Untreated tooth decay and periodontal disease continue to affect working-age adults, and access to needed dental care has worsened, especially for low-income adults, some racial/ethnic minorities, and other underserved groups. Notably, more than 1 in 4 working-aged adults have untreated tooth decay, with significant disparities by race/ethnicity and income. The most current estimates for periodontitis show that at least 2 in 5 adults in the United States have some form of the disease, and 8% have severe periodontitis.

On the other hand, there have been some improvements since 2000. For example, adults today lose fewer teeth than previous generations and new technologies promise more effective treatments and less suffering for many patients. Complete tooth loss (edentulism) is rare among working-age adults in the United States today. Just 2.2% of persons aged 20 to 64 years were edentulous based on data from 2011–2016; edentulism was higher among adults who were poor (6%), had less than a high school education (5%), and were current smokers (6%).

A key development is the recognition of the interplay between general health and oral health across the lifespan—an important theme of the 2000 Surgeon General's report on oral health. The recognition of several associations between oral health and general health illustrates the importance of addressing the common risk factors of both. Chronic diseases that start in adulthood also can have a greater impact on oral diseases as individuals age.

The many oral health needs of adults are well documented and present challenges for oral health care professionals. Since publication of the 2000 Surgeon General's report on oral health, three important themes have emerged that affect oral health in working-age adults in the United

States (Box 2). These themes address the interrelationships between oral health and general health and their common risk factors, the persistent inequities in good oral health for vulnerable population groups, and the transition from restorative to preventive approaches for managing oral diseases. Although a paradigm shift in dental treatment from a restorative approach to a preventive approach is improving the management of oral diseases in many working-age adults, obtaining access to needed care often is difficult and this difficulty exacerbates oral health inequities. Strong associations between oral health and general health continue to illustrate the importance of addressing the common risk factors of both, including advocating for improved models of comprehensive care. Policies are needed to improve regular access to professional dental care for working-age adults, ensuring access to both preventive and early treatment services.

Improving oral health is an ongoing challenge for groups that experience inequities in oral health and access to adequate dental care. Racial/ethnic minorities and low-income adults suffer from significantly greater levels of oral disease than the rest of the U.S. population as a result of environmental, economic, social, and behavioral inequities. Military veterans, homeless individuals, immigrants, incarcerated individuals, and adults with disabilities and special health care needs also face unique challenges that must be better addressed.

Health literacy provides a framework for addressing a variety of challenges in general health and oral health. As populations of non-English speakers or people who speak English as a second language increase, using clear communication and plain language will help Americans better understand complicated health delivery systems, health insurance benefits, and preventive care and treatment regimens.

Lack of dental insurance and other means to pay for dental care is a primary reason adults do not seek needed care. An important realization since the last report on oral health is the fact that working-age adults are the only age group that hasn't benefited from any increase in dental insurance coverage. Restructured public and private dental insurance programs are needed to help increase access to oral health services. In addition, because oral diseases are so common in U.S. adults, there is a need for both individual-based dental preventive programs and services and public health approaches. Both could be aided by improved models of integrated medical and dental care, as well as better interprofessional education and innovative approaches to improve oral health literacy.

The time has come to conquer dental fear. Nearly one-fifth of U.S. adults experience moderate to high dental fear and anxiety. This has a significant impact on the utilization of dental care and is associated with more decayed and missing teeth. Pharmacologic approaches during treatment, such as conscious sedation and general anesthesia, have not led to long-term reductions in fear and anxiety. Newer approaches that use cognitive-behavioral techniques hold greater promise for long-lasting alleviation of dental fear.

Providing support for pregnant women to take care of their oral health and ensuring that they have easy access to care is important. Research increasingly shows that poor oral health during pregnancy is linked to adverse health outcomes for both mother and baby. Programs that increase the awareness of oral health during pregnancy, along with policies that make it easier for pregnant women to pay for and access dental care, would go a long way to reverse this.

Newly developed and rapidly advancing digital technologies in dentistry, including integrated electronic health records, computer-assisted design/computer-assisted manufacturing technology, teledentistry, and artificial intelligence-driven diagnostic and treatment modalities, offer clinicians opportunities to make treatments faster, easier, more accurate, and ultimately, more successful.

Oral health can be maintained throughout a lifetime and is even more important as individuals age and manage increasing numbers of chronic diseases and conditions. Although system-level change is never easy, the benefits—better oral health for millions of people throughout their lifespan—will be worth the effort.

Box 2. Key summary messages for Oral Health Across the Lifespan: Working-age Adults

- Although adults now retain most of their natural teeth, many working-age adults continue to experience the same levels of tooth decay, gum disease, and oral cancers that were observed 20 years ago.
- Many working-age adults—especially low-income and minority adults—don't have dental insurance.
- Nearly 1 in 5 adults experience moderate to high dental fear or anxiety, preventing some from seeking needed oral health care.
- Poor oral health during pregnancy has been linked to some adverse health outcomes for both mother and baby.
- As adults retain more of their natural teeth, and relationships between oral infection or oral inflammation continue to be identified with diseases such as cardiovascular disease, diabetes, and cognitive impairment, the need to prevent and control periodontitis becomes more important.
- Although there has been some improvement in 5-year survival for oropharyngeal cancers, HPV-associated oral cancers have doubled, with men having more than three times oropharyngeal cancer than women.
- Health promotion and health literacy programs can improve people's understanding of oral health and, in turn, help reduce the burden of disease and improve quality of life.

Call to Action:

- Policies are needed to improve regular access to professional dental care for working-age adults, assuring access to both preventive and early treatment services, leading to better oral health.

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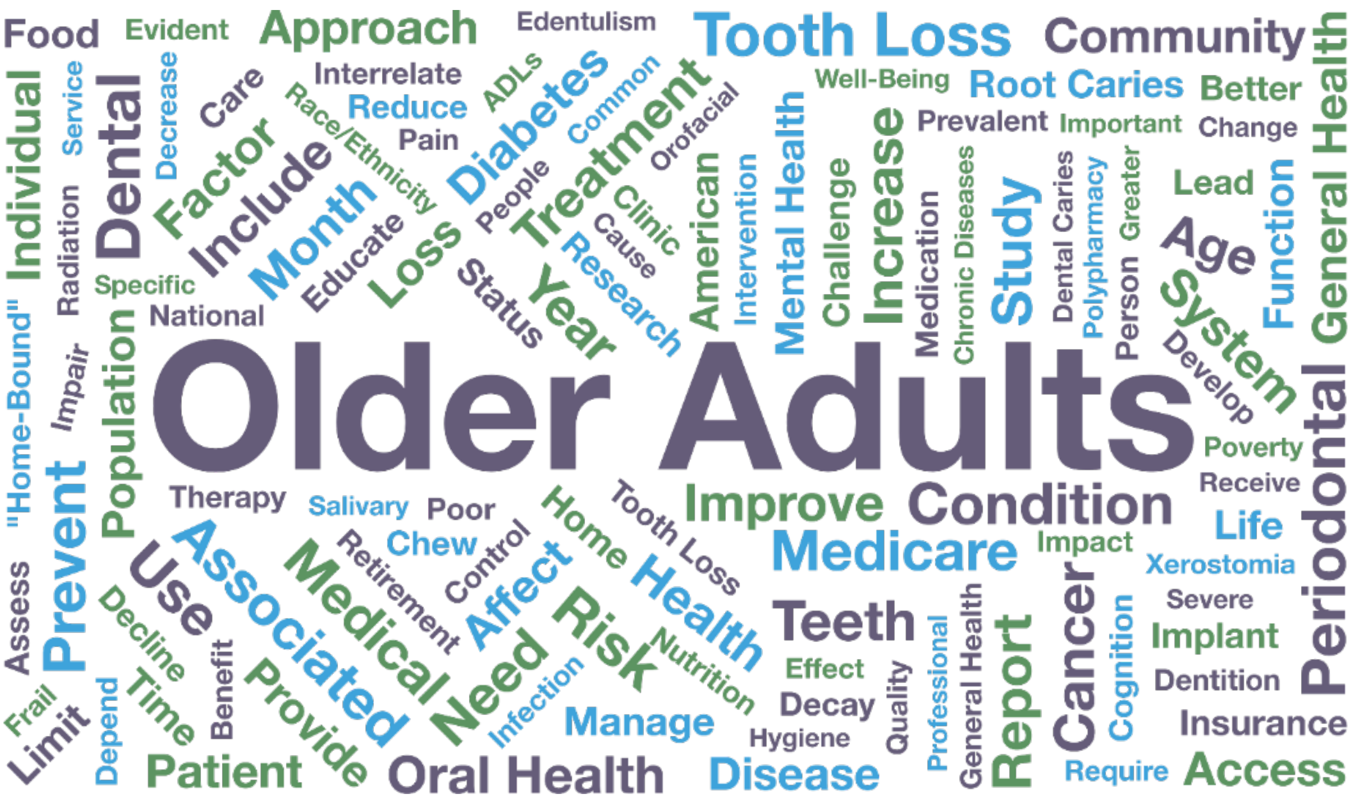
Older Adults
Food
Evident
Approach
Edentulism
Tooth Loss
Community
Individual
Service
Dental
Decrease
Care
Interrelate
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Reduce
ADLs
Diabetes
Common
Treatment
Orofacial
Well-Being
Root Caries
Better
General Health
Factor
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Decline
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Limit
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Need
Infection
Nutrition
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General Health
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Oral Health in America: Advances and Challenges

Section 3B: Oral Health Across the Lifespan: Older Adults

Chapter 1: Status of Knowledge, Practice, and Perspectives

Although many older adults (people 65 years and older) experience the benefits of improved oral health—more are retaining their natural teeth and are enjoying a better quality of life as a result—substantial challenges remain for some. Older Americans often face significant obstacles to adequate oral health, including persistent inequities in oral health and difficulties in accessing oral care. The cumulative effects of risk factors associated with poor health, and the potential loss of employer-provided dental insurance benefits for some older adults transitioning into retirement, can adversely affect oral health.

The U.S. population 65 years and older is growing rapidly. Today, 1 in 6 Americans, or 54.1 million, is more than 65 years old (U.S. Census Bureau 2019). By 2030, 1 in 5 Americans—about 70 million people—will be older than 65, increasing to 98.2 million by 2060 (Colby and Ortman 2015). The older adult population in the United States will be one of the most diverse ever in terms of race/ethnicity, socioeconomic status, health, and functional status (Mather et al. 2015). With a graying population and increasing expectations for good oral health–related quality of life, older Americans are seeking dental care in higher numbers than before. Although "progress in prevention and treatment of caries and periodontal diseases has been translated to better oral health and improved tooth retention in the adult population" (Tonetti et al. 2017, p. S135), older adults remain at risk for many oral diseases, including tooth decay, dental root decay, gum disease, and oral cancer. Xerostomia and dry mouth affect a greater percentage of older adults than younger adults and are often side effects of many medications.

About 80% of older Americans live with at least one chronic disease, and nearly 70% have at least two chronic diseases (National Council on Aging 2021). As these diseases progress, physical and neurobiological changes become more common and can lead to disability. The Centers for Disease Control and Prevention reports that 40% of people older than 65 report a physical or cognitive disability (Centers for Disease Control and Prevention 2018a). These disabilities affect the capacity to maintain good oral self-care and negatively impact accessibility and affordability of oral health care (Okoro et al. 2018).

Many baby boomers (individuals born between 1946 and 1964) will keep their teeth longer than any generation before, yet they continue to experience a preventable decline in oral health. As with younger age groups in the United States, older adults experience socioeconomic inequities in tooth loss, untreated decay, periodontal disease, oral cancer, and other oral diseases and conditions. Better access to oral health care improves health outcomes by detecting oral conditions sooner and identifying preventable risk factors, yet there are obstacles to achieving that access.

Barriers to care are not only economic but also include social disparities experienced by all age groups, as well as ageist discrimination, such as the belief that older adults have few or no teeth and do not require routine dental care. Despite higher expectations than ever before for maintaining one's own natural teeth, society continues to accept declines in oral health related to aging and to make oral health care an elective, rather than a mandatory, part of overall health care. Medicare, the primary form of health insurance for millions of older Americans, excludes dental benefits except in certain narrow circumstances. In addition, the state-to-state variability of adult dental benefits provided through Medicaid perpetuates discrepant perceptions and expectations for oral health care. Most dental insurance is provided through employers' optional benefit plans, so those who leave full-time work find it hard to afford dental insurance. These discrepancies between medical and dental coverage contribute to the erroneous perception that oral health care is not essential for older adults. This mistaken belief has made oral health care an elective part of our health care system and places the oral health and general well-being of every older American at risk.

Etiology and Prevalence of Oral Diseases and Conditions

The Global Burden of Disease study recognized severe tooth loss—having fewer than nine teeth—and untreated tooth decay as the dental conditions that most diminish health and quality of life (Marcenes et al. 2013). People with chronic conditions, such as diabetes, heart disease, and rheumatoid arthritis, who tend to be older adults, are at higher risk for these oral conditions (Griffin et al. 2009). Common risk factors such as smoking, poor diet, a reduced capacity to care for one's teeth and obtain professional dental care, and direct or indirect biological mechanisms—such as low salivary flow caused by medications—may contribute to tooth decay and tooth loss (Griffin et al. 2009). Most national surveillance data on these conditions come from health examination surveys that rarely survey homebound persons or long-term care residents, yet it is known that these vulnerable adults have poorer oral health than their peers who are living more independently (Griffin et al. 2012).

Dental Caries

Tooth decay occurs when tooth enamel or exposed tooth roots are demineralized by acidic bacterial by-products of food and drink. If left untreated, the destructive process of dental caries can cause pain, tooth loss, and infection (see Section 2A, Figure 8) that may spread and lead to serious systemic consequences (Pitts et al. 2017). For more information on what causes caries, see Section 2 of this monograph, which focuses on oral health in children and adolescents.

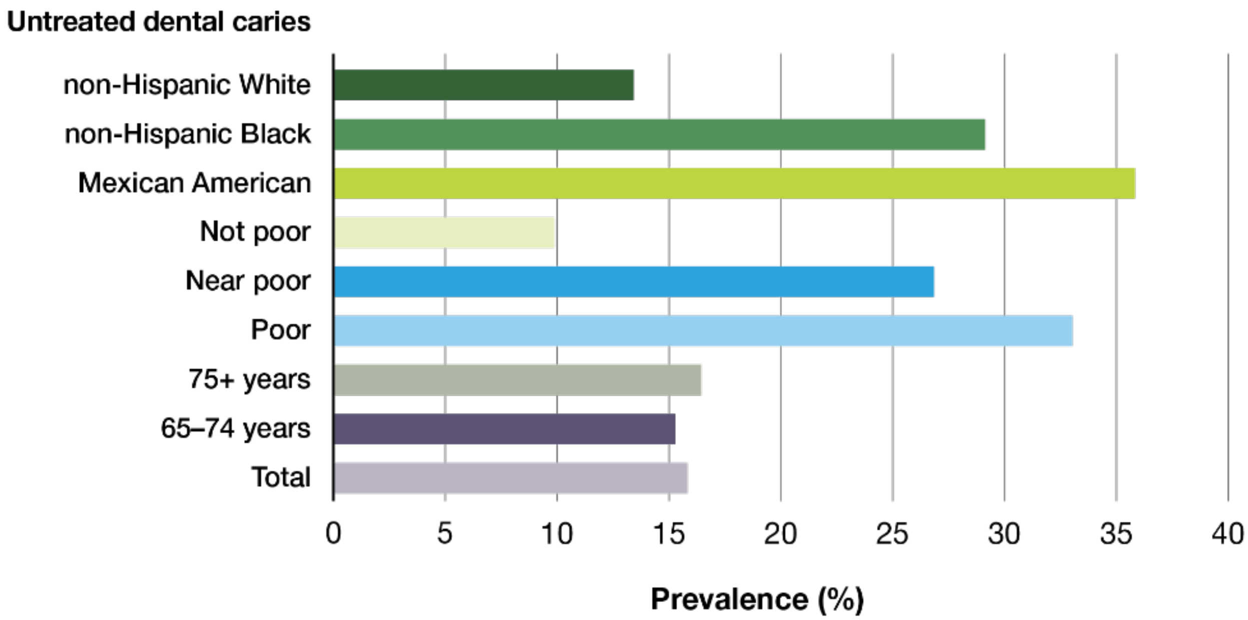
Today, 96% of all non-edentulous older adults (those with some natural teeth) have experienced tooth decay in their lifetime, with untreated tooth decay present in 1 of 6 (Centers for Disease Control and Prevention 2019). Prevalence of untreated caries varies considerably by race/ethnicity and poverty status (Figure 1). Non-Hispanic Black (29%) and Mexican American (36%) adults aged 65 and older were more than twice as likely to have untreated decay than non-Hispanic White (14%) adults. Older adults living in poverty were at least three times more likely to have untreated tooth decay than their higher-income counterparts (33% vs. 10%). A review of surveys conducted among vulnerable, older adults in nine states found that the percentage of non-edentulous adults with untreated decay ranged from 25–53%, with a median value of 40% (Griffin et al. 2019). In 2015–2016, 29% of adults 75 years and older had dental root surface caries (Griffin et al. 2019).

About 1 in 6 older Americans experiences root caries (Badr and Sabbah 2020), which is dental caries that affects the area on a tooth surface at or below the demarcation between the coronal and root portions of a tooth (cemento-enamel junction). Older age is associated with a greater prevalence of root caries. However, tobacco use, poor plaque control, xerostomia, lower socioeconomic status, and the inability to afford dental care also are important risk factors (Hayes et al. 2016; Badr and Sabbah 2020; Zhang et al. 2020a).

Periodontal Disease

Periodontitis is a prevalent oral disease in older adults and is typically marked by inflammation of the gums and supporting structures of the teeth, resulting in sore and bleeding gums as well as painful chewing problems. Loss of the supporting structures of the teeth (periodontal ligament and supporting alveolar bone) results from an imbalance in which bacteria residing in the space between the teeth and the gums elicit an inflammatory response, leading to progressive periodontal disease (Hajishengallis 2015). As teeth lose support, mobility and tooth drifting are observed, and periodontal abscesses may occur (see Figure 2, Section 3A), ultimately resulting in tooth loss. As the disease intensifies, bone loss around affected teeth can advance with a worsening infection that can have systemic consequences (Scannapieco and Cantos 2016).

Figure 1. Percentage of adults ages 65 and older with untreated dental caries in permanent teeth by age group, poverty status, and race/ethnicity: United States, 2011–2016



Notes: Dental caries experience (DT > 0); **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: Centers for Disease Control and Prevention (2019).

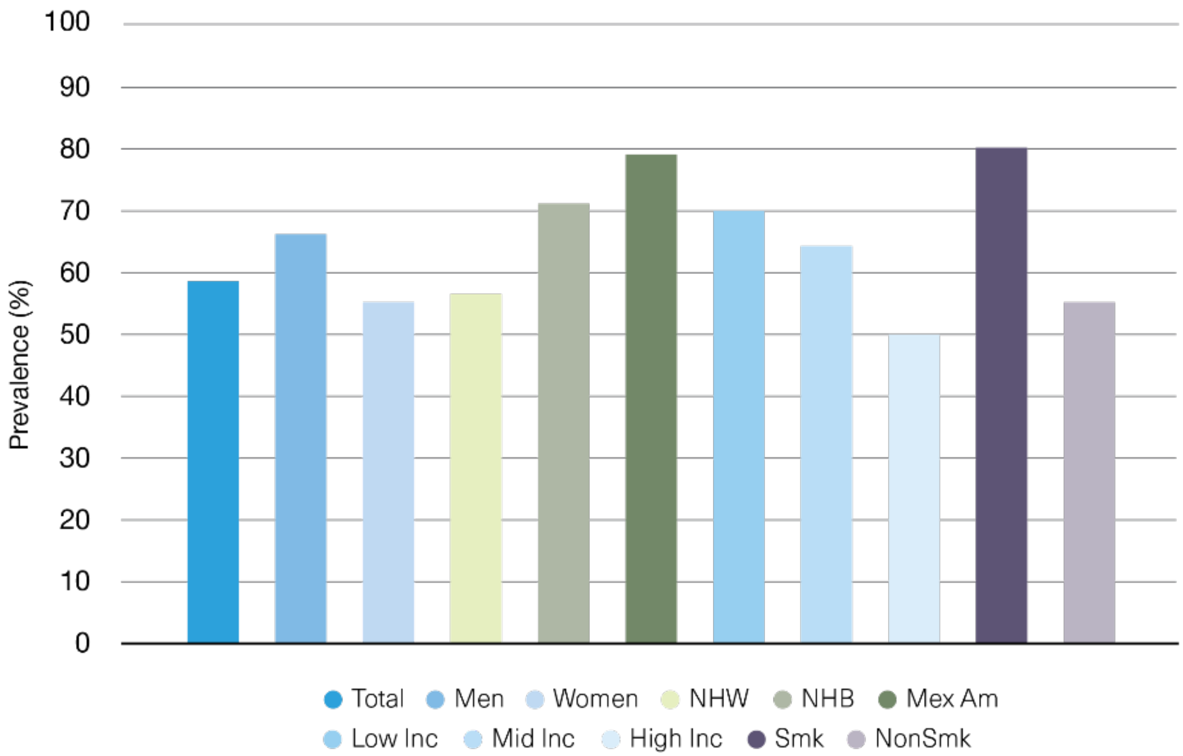
Periodontal disease is associated with chronic diseases such as cardiovascular disease, diabetes mellitus, respiratory disease, and cognitive impairment (Bansal et al. 2013; Teixeira et al. 2017; Cardoso et al. 2018; Liccardo et al. 2019).

The prevalence of any periodontitis (mild, moderate, or severe forms) among older adults is high (Eke et al. 2018). Three in five older adults are affected, with prevalence higher in men, non-Hispanic Blacks and Mexican Americans, and persons with low incomes (Figure 2). Four in five older adults who smoke cigarettes have some form of periodontitis. Among older adults, 9% have severe periodontitis, with prevalence higher among men, non-Hispanic Blacks and Mexican Americans, and persons with low incomes (Figure 3). One in four older adults who are current smokers has severe periodontitis. Periodontitis also varies among states, with prevalence generally higher in the southern half of the United States (Figure 4) (Eke et al. 2016a). This can be attributed to several factors, including the demographics of certain states that have a higher proportion of older adults or racial/ethnic minorities, and that smoking remains more prevalent in some states compared to others (Centers for Disease Control and Prevention 2020a). For more information on periodontitis, see Section 3A of this monograph.

Tooth Loss

The loss of all natural teeth, called edentulism, reduces quality of life because it interferes with the ability to eat, speak, and feel comfortable among other people. Tooth loss affects a person's ability to consume nutritious food and also can impact how a person eats and socializes with others while consuming food. Edentulism has continued to decline among older adults aged 65 to 74, from about 50% in the 1960s to 13% today (Figure 5) (Dye et al. 2019). Overall, 17% of adults 65 and older are edentulous (Centers for Disease Control and Prevention 2019). Among older adults, persons living in poverty are three times more likely to be edentulous (34%) than those living at 200% or more of the federal poverty guidelines (11%), and non-Hispanic Black older adults are twice as likely (31%) to be edentulous as non-Hispanic White (15%) or Mexican American (17%) older adults.

Figure 2. Percentage of adults ages 65 and older with any periodontitis by gender, poverty status, race/ethnicity, and smoking status: United States, 2009–2014



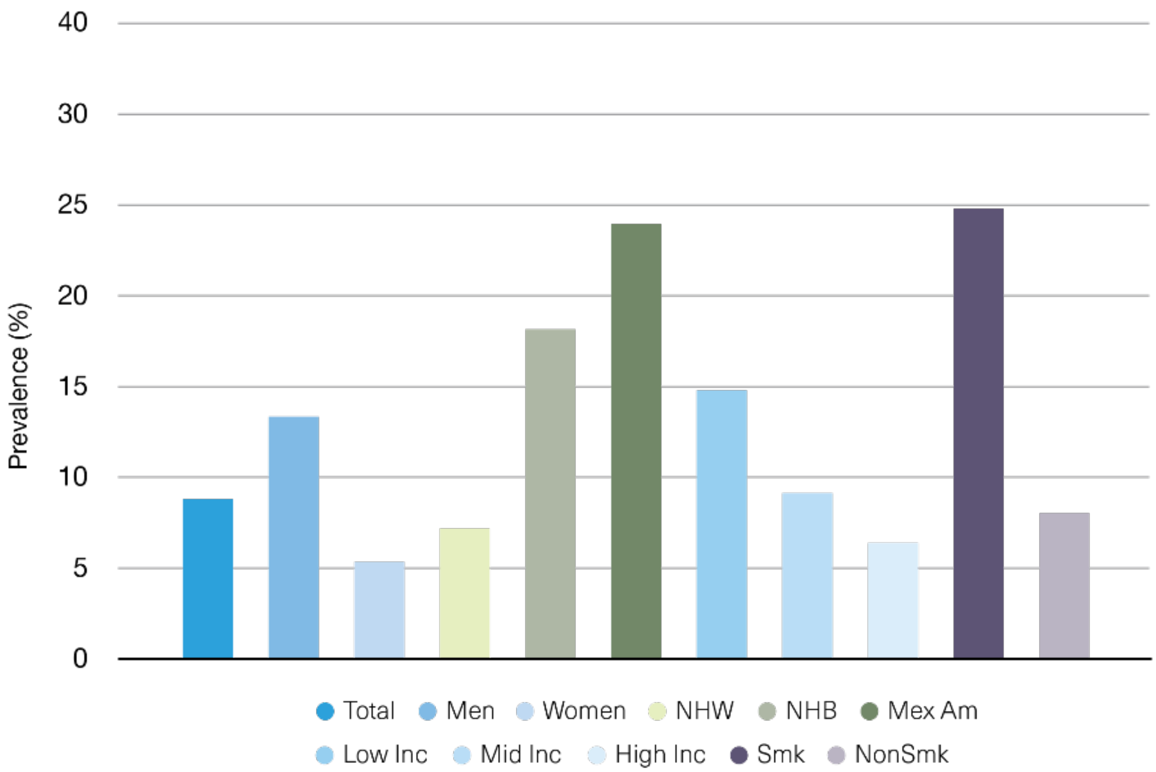
Notes: Any periodontitis includes CDC/AAP mild, moderate, and severe forms. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American, High Inc (High income is >350% FPG), Mid Inc (Middle income is (131-350% FPG), Low Inc (Low income is (≤130% FPG), Smk = current smoker, NonSmk = nonsmoker. FPG = Federal Poverty Guidelines

Source: Eke et al. (2018).

A recent study from eight states indicated that approximately 32% of vulnerable older adults were edentulous (Griffin et al. 2019). The likelihood that a person has lost all of their teeth also varies by where they live in the United States. Edentulism rates (2018) differ greatly by state for older adults, ranging from approximately 6% (Hawaii) to 26% (West Virginia) (Figure 6) (Centers for Disease Control and Prevention 2018b). In general, edentulism was more common among adults aged 65 and older in specific south-central, midwestern, and northeastern states. Although edentulism rates have substantially improved for older adults, many still experience some tooth loss and are partially edentulous. Overall, older adults have on average 20.7 teeth, and the disparity in tooth retention is substantial between people living in or near poverty and those with family incomes at least twice as high as the federal poverty guidelines (17.6 vs. 22.2 mean teeth) (Centers for Disease Control and Prevention 2019).

However, being partially edentulous does not always negatively impact quality of life. Having a functional dentition, that is, having at least 21 natural teeth (Sheiham and Steele 2001; Brennan et al. 2008) or a minimum of 20 teeth, with 9 or 10 pairs of contacting units (Gotfredsen and Walls 2007), is considered necessary for efficient chewing. Three in five adults aged 65 to 74 years have a functional dentition, with substantial disparities observed by poverty status. Only 31% of older adults 65 to 74 living in poverty have a functional dentition, compared to 74% of nonpoor older adults. Differences also exist by race/ethnicity, with prevalence higher in non-Hispanic Whites (78%) and Mexican Americans (70%), and lower in non-Hispanic Blacks (56%).

Figure 3. Percentage of adults ages 65 and older with severe periodontitis by gender, poverty status, race/ethnicity, and smoking status: United States, 2009–2014



Notes: Any periodontitis includes CDC/AAP mild, moderate, and severe forms. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American, High Inc (High income is >350% FPG), Mid Inc (Middle income is (131-350% FPG), Low Inc (Low income is (≤ 130% FPG), Smk = current smoker, NonSmk = nonsmoker. FPG = Federal Poverty Guidelines

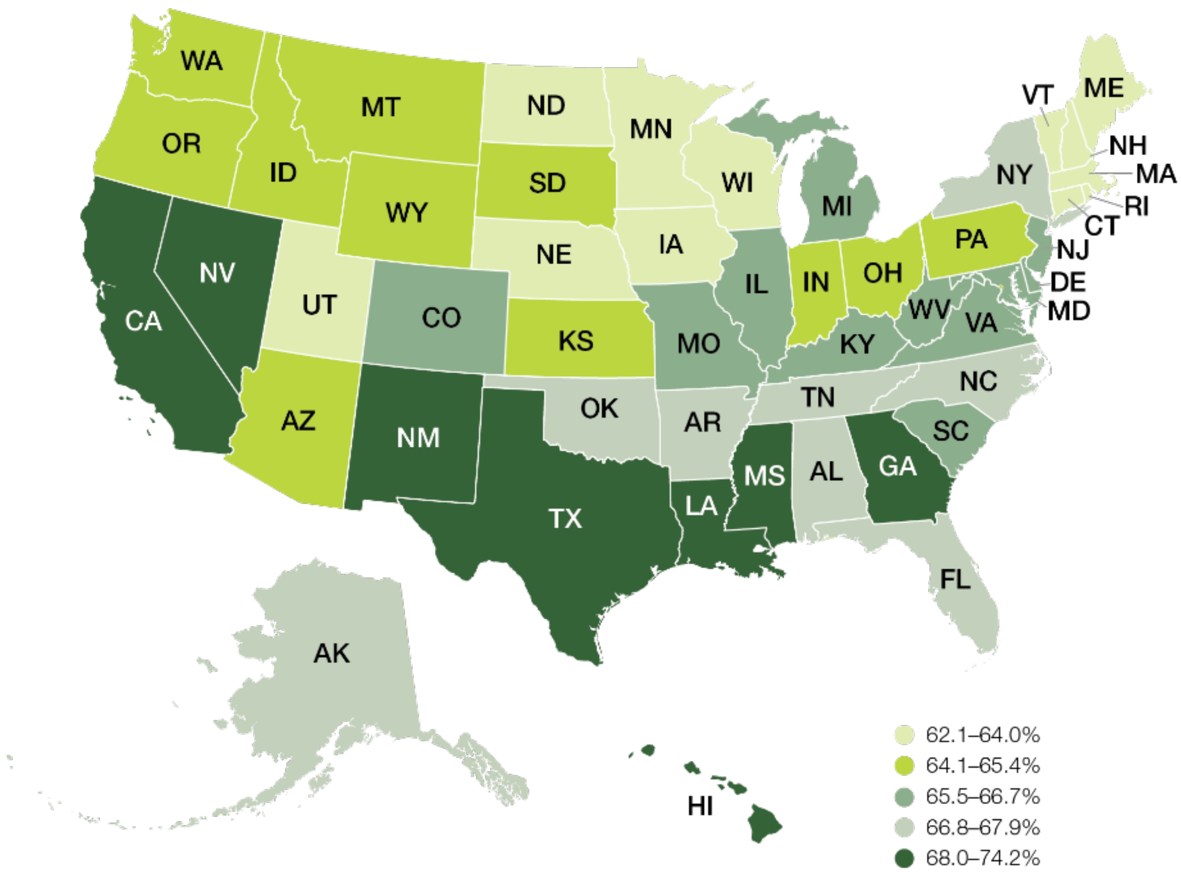
Source: Eke et al. (2018).

Among older adults 75 years and older, 46% have a functional dentition, but large differences also exist by poverty status and race/ethnicity. One in five adults 75 years and older living in poverty has a functional dentition, whereas about 1 in 6 non-Hispanic Black or Mexican American adults 75 years and older has a functional dentition (Dye et al. 2019).

The likelihood of an older adult losing some of their natural teeth also varies by where they live in the United States. For adults aged 65 and older who have reported the loss of six or more teeth due to tooth decay or periodontal disease, prevalence varies substantially, from about 22% (Hawaii) to 55% (West Virginia) (Figure 7) (Centers for Disease Control and Prevention 2018b). Similar to edentulism, but with a few exceptions, tooth loss was also more common in many states in the southern regions of the United States.

Having fewer than nine teeth is considered severe tooth loss and can cause major difficulties in eating fruits, vegetables, and meat (Marcenes et al. 2013). Limiting food choices in response to compromised chewing efficiency can result in either weight loss or obesity (Griffin et al. 2012). Extensive tooth loss also detracts from physical appearance and impedes speech, which in turn can restrict social contact and job prospects, inhibit intimacy, lower self-esteem, and impact overall quality of life (U.S. Department of Health and Human Services 2000).

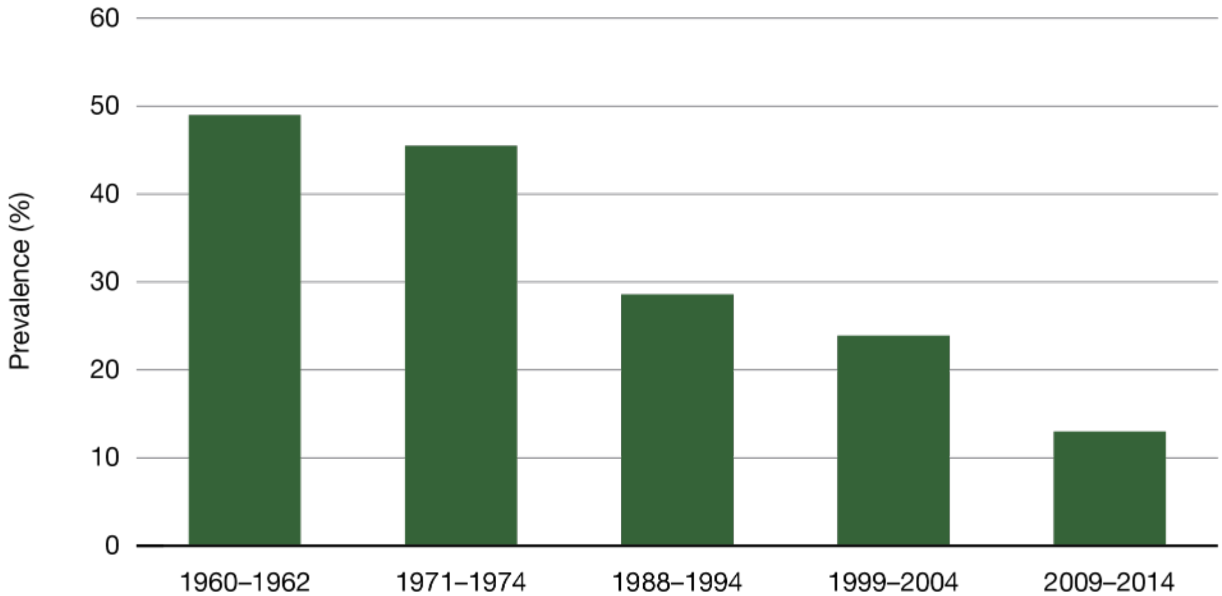
Figure 4. Prevalence of any periodontitis among adults ages 65 and older by state: United States, 2009–2012



Source: Eke et al. (2016a). © John Wiley & Sons A/S. Reprinted with permission.

The Global Burden of Disease estimates that U.S. productivity losses attributable to severe tooth loss equaled $32.7 billion in 2015 (Righolt et al. 2018). Nearly one-quarter of adults 65 and older suffered severe tooth loss (Griffin et al. 2019). Prevalence of severe tooth loss was significantly higher among racial/ethnic minorities—46% for non-Hispanic Black and 28% for Mexican American older adults—than among non-Hispanic White adults (22%). Likewise, severe tooth loss was notably higher among lower-income (42%) than higher-income (16%) older adults (Griffin et al. 2019). Recent studies suggest that missing teeth also may be a marker for lifelong, accumulated inflammatory burden of oral disease and may be a risk factor and occur concomitantly with cardiovascular disease (Liljestrand et al. 2015; Lee et al. 2019). Longitudinal studies also have reported associations between the number of missing teeth and cardiovascular disease. Tooth loss is associated with incident mortality resulting from a myocardial infarction (Oluwagbemigun et al. 2015) and is associated with a sevenfold increased risk for mortality from coronary heart disease in persons with fewer than 10 teeth compared to those with more than 25 teeth (Holmlund et al. 2010). National studies have found that adults with diabetes have a higher risk of tooth loss and edentulism than those without diabetes (Patel et al. 2013; Luo et al. 2015). In general, evidence is growing that clearly supports a relationship between increasing tooth loss and adverse health effects in older life.

Figure 5. Trend in edentulism among adults ages 65–74: United States, 1960–1962 to 2009–2014



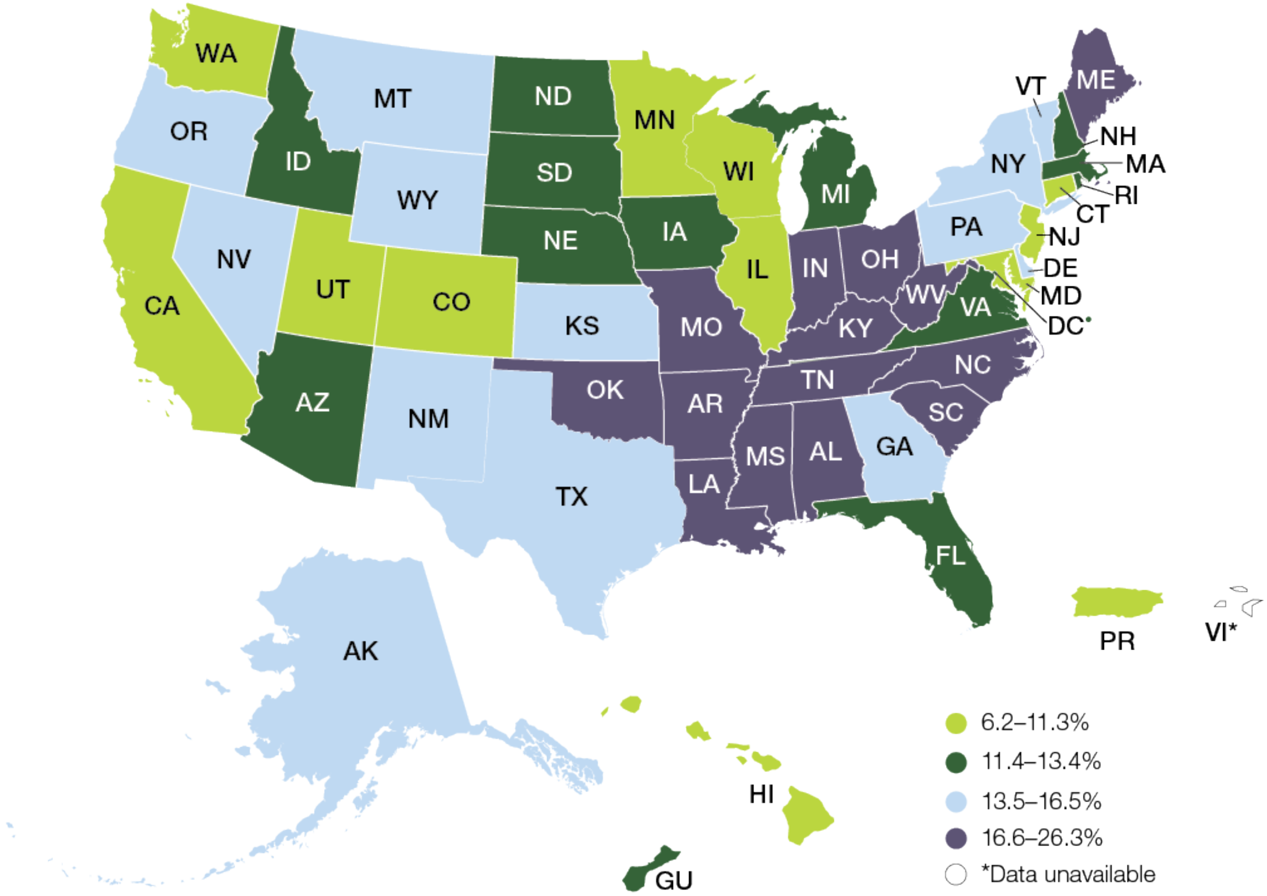
Note: Edentulism is complete loss of all natural permanent teeth.
Source: Adapted from Dye et al. (2019).

Oropharyngeal Cancer

Although the increasing prevalence of human papillomavirus (HPV) infection has led to a substantial increase in oropharyngeal cancers among adults aged 40 to 59 years, these cancers remain more prevalent in older adults with a median age at diagnosis of 63 years (National Cancer Institute 2020). Because oropharyngeal cancers are seen more often in older persons than in younger adults (Chi et al. 2015; Tota et al. 2019), these cancers continue to be a public health concern for older adults. The mortality rates for these cancers are higher for older adults (median age of death is 68 years) than for working-age adults (Figure 8) (National Cancer Institute 2020a). Oral cancers can occur anywhere in the oral cavity, while oropharyngeal cancers primarily affect the pharynx, back third of the tongue, soft palate, side and back walls of the throat, and tonsils (see Figure 1 in Section 3A of this monograph). The most common sign is a sore throat or enlarged lymph node (lump or mass in the neck). Table 1 lists the full range of signs and symptoms of oropharyngeal cancers (American Society of Clinical Oncology 2021). See Section 3A for more information on oral cancer and HPV.

Heavy tobacco and alcohol use (defined as two or more packs per day and four or more drinks per day) and the interaction of the two are considered the traditional risk factors for oral cavity and pharyngeal cancers (Blot et al. 1988), particularly squamous cell carcinomas (SSCs). More recently, some subtypes of the human papillomavirus (HPV) also have emerged as a major etiologic factor for this group of cancers. Some studies show that quitting smoking can decrease the risk of these cancers 10 years after cessation, and vaccination against HPV for prevention of cervical cancer also shows great potential for preventing oral and pharyngeal squamous cell carcinomas (Chi et al. 2015). Nearly 9 in 10 oral cancers is SSC, and it is the 11th most common cancer globally (D'Souza and Addepalli 2018). Males are more likely than females to develop oral cancer because of their greater consumption of alcohol and tobacco products (National Institute of Dental and Craniofacial Research 2021). Other implicated risk factors include excess exposure to ultraviolet radiation and cancer of the lip (Samarasinghe et al. 2011). Lip SCC rates declined substantially from 1975 to 2005, but have since remained flat at a rate of 0.6 per 100,000 men and women per year in the U.S.

Figure 6. Prevalence of edentulism among adults ages 65 and older by state and territories: United States, 2018



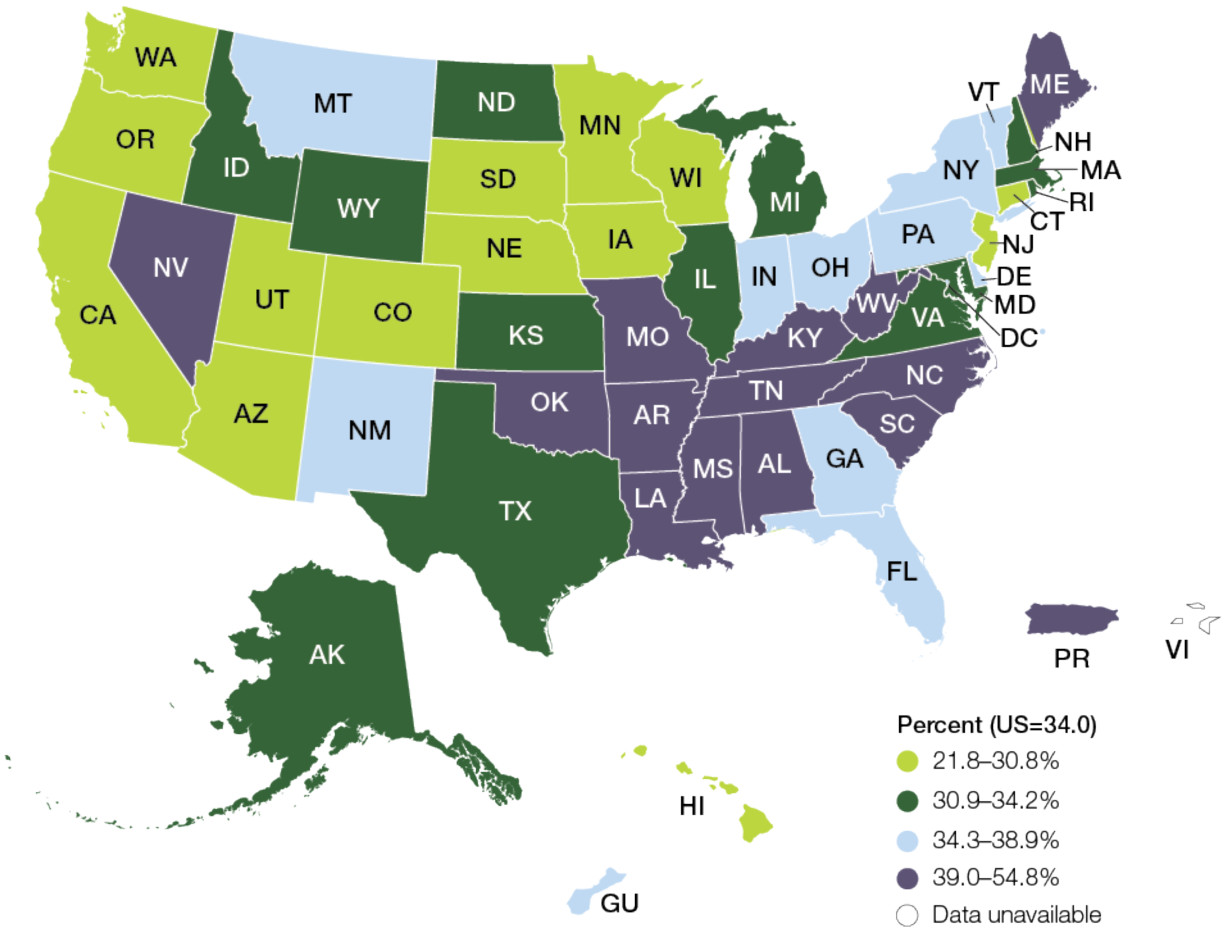
Note: Edentulism is complete loss of all natural permanent teeth.
Source: Centers for Disease Control and Prevention. Oral Health Data, Behavioral Risk Factor Surveillance System, 2018.

The median age at diagnosis is 69, and the 5-year relative survival rate is 90.9% (National Cancer Institute 2020b). Globally, rates for cancer of the lip and mouth vary substantially, with rates highest in parts of south-central Asia and Oceania (Miranda-Filho et al. 2019).

Infection with HPV is a major risk factor for oropharyngeal cancers (Chi et al. 2015). The prognosis for older adults with oropharyngeal cancer is mostly dependent on the specific location and extent of the tumor, as well as the presence of regional or distant metastasis (Goldenberg et al. 2014). Five-year relative survival rates for all oral and oropharyngeal cancers range from 73% for localized tumors of the lip to only 12% for metastatic tumors of the oropharynx (Sanabria et al. 2007). In addition, there is some evidence to suggest that being older than 65 years is independently associated with poor prognoses among adults with oropharyngeal cancer (Camilon et al. 2014). The impact of cancer therapy on quality of life among survivors depends on stage at discovery, tumor site, degree of side effects, symptom and treatment management strategies, and the specific organs involved (Valdez and Brennan 2018).

Oral structures in proximity to surgical sites and radiation fields may be affected and compromise the ability to eat, chew, and swallow. They may undergo significant alteration from surgery and radiation therapy, even when not directly affected by cancer (Kent et al. 2015; Choi et al. 2016; Epstein et al. 2018).

Figure 7. Prevalence of adults ages 65 and older who have lost six or more teeth due to dental diseases by state and territories: United States, 2018



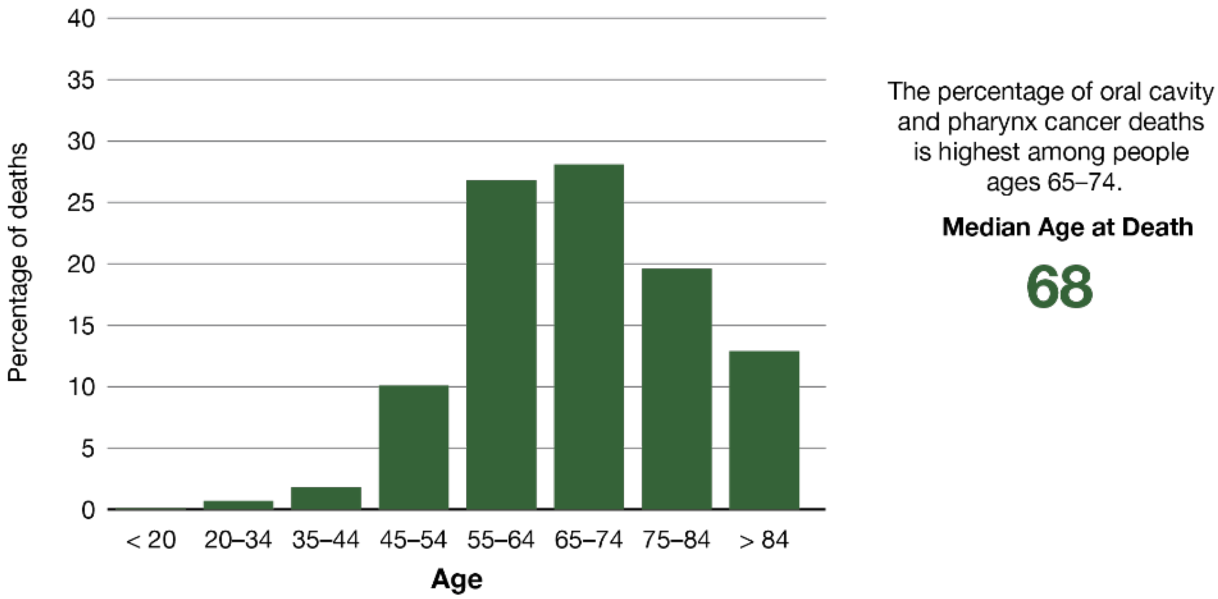
Source: Centers for Disease Control and Prevention. Oral Health Data, Behavioral Risk Factor Surveillance System, 2018.

The effects on the oral cavity of multiple, potentially aggressive procedures—surgery, radiation, and chemotherapy—may place patients at elevated risk for dental disease. Moreover, oral health may be overlooked during cancer treatment because of lack of insurance or limited medical-dental integration in oncology centers.

Cancer survivorship can mean several different things to many people, but survivorship often means living with cancer beyond treatment. In 2019, there were an estimated 374,000 oral cavity and pharyngeal cancer survivors in the United States. By 2030, that number is expected to grow to nearly 475,000 (American Cancer Society 2019). This projected increase is partly due to the emergence and rapid rise in HPV-related oropharyngeal carcinomas. Disparities in survival exist based on race and ethnicity, with minorities diagnosed at later stages partially due to insurance status (Ragin et al. 2011). Older adults with low education or low income also have worse survival rates (Choi et al. 2016).

Although the American Cancer Society provides clear guidelines on the care needed to minimize risk of some adverse outcomes (Cohen et al. 2016), practitioners and patients face continued challenges, including a lack of predictable protocols to navigate posttreatment issues.

Figure 8. Percentage of deaths by age groups for those diagnosed with oropharyngeal cancer: United States, 2014–2018



Source: National Cancer Institute (2020).

Specific challenges include accessing care for dental disease prevention and speech pathology, which often are not covered by health insurance. Other challenges are the management of the side effects of chemotherapy drugs, intravenous bisphosphonates, and radiation therapy.

Orofacial Pain and Temporomandibular Disorders

Orofacial pain can significantly affect quality of life in older adults. Although it is not known how many older adults experience orofacial pain, some studies suggest that orofacial pain frequently affects older adults with mild cognitive impairment and dementia (Delwel et al. 2017; Delwel et al. 2019). Orofacial pain in older adults can originate inside the mouth from tooth-related or gum infections; or it may originate outside the mouth, such as pain in the jaw joint area, or face and cheeks. Orofacial pain often results from ill-fitting dentures or a microbial infection causing an inflammatory reaction known as denture stomatitis.

Temporomandibular joint and muscle disorders (TMDs) are conditions characterized by pain affecting the temporomandibular jaw joint and the muscles used for chewing in the temporomandibular region (see Figure 6 in Section 3A). TMD can cause functional problems, such as limiting how widely the jaw can open, deviant jaw patterns, and joint sounds (The Advisory Committee of the Temporomandibular Conference 1983). The prevalence of TMD in adults aged 65 years and older is estimated to be 3–5% in the U.S. population (Yadav et al. 2018). Although diagnoses of TMD decline for all people 65 years and older, the highest prevalence for non-Hispanic White women is at 55 years of age, with subsequent decline. Non-Hispanic Black females and males have a lower prevalence of TMD than Whites in younger years. Individuals of lower socioeconomic status have more orofacial pain and pain-related behavioral impacts than individuals of higher socioeconomic status (Riley et al. 2003). Many older adults experience painful conditions such as osteoarthritis and postherpetic neuralgia, which can affect temporomandibular joints (Lautenbacher et al. 2005; Riley et al. 2014). The personal and societal impact of TMD is primarily due to its status as a chronic/recurrent pain condition, and pain is the main reason that patients seek treatment for TMD (Dworkin et al. 1990). Additional information on orofacial pain and TMD disorders is provided in Section 3A.

Table 1. Cancer of the oral cavity and pharynx: Symptoms and signs
Oral Cavity
● Sore in the mouth or on the lip that does not heal; most common symptom
● Red or white patch on the gums, tongue, tonsil, or lining of mouth
● Lump on lip, mouth, neck, or throat or a feeling of thickening in the cheek
● Persistent sore throat or feeling that something is caught in the throat
● Hoarseness or change in voice
● Numbness of the mouth or tongue
● Pain or bleeding in the mouth
● Difficulty chewing, swallowing, or moving the jaws or tongue
● Ear and/or jaw pain
● Chronic bad breath
● Changes in speech
● Loosening of teeth or toothache
● Dentures that no longer fit
Systemic
● Unexplained weight loss
● Fatigue
● Loss of appetite, especially when prolonged; this may happen during the later stages of the disease

Source: Adapted from American Society of Clinical Oncology (2021).

Salivary Gland Dysfunction and Xerostomia

The term "dry mouth" refers to salivary gland hypofunction (SGH) and xerostomia. SGH means low salivary flow, while xerostomia is the subjective sensation of dry mouth. The exact degree of concordance between these two aspects of dry mouth remains unclear (Villa et al. 2016). Dry mouth is surprisingly common—an estimated 35 million U.S. adults may have xerostomia (Benn et al. 2015). Common causes of xerostomia and SGH include medications, autoimmune disease, systemic diseases, head and neck irradiation, and surgery. A recent systematic review reported the overall prevalence of SGH to be 20% and xerostomia 23%, with prevalence of both conditions highest among older people (Agostini et al. 2018).

Epidemiologic studies in which both salivary gland hyposalivation and xerostomia have been measured are scarce, most likely because of the logistical difficulties of measuring SGH in larger samples. The South Australian Dental Longitudinal Study observed that about 1 in 5 older adults had either xerostomia or SGH, and that the two conditions coincided in only one-sixth of those with either condition—about 6% of the overall sample (Thomson et al. 1999). This was the first empirical evidence to suggest strongly that xerostomia and SGH do not necessarily occur at the same time.

While conditions such as chronic dehydration or anxiety play a part, drugs are by far the most common risk factors for chronic dry mouth. Nearly 9 in 10 (89%) adults aged 65 and older take prescription medicine. More than half (54%) report taking four or more prescription drugs (Kirzinger et al. 2019). However, disentangling the effects of medications on salivary flow and subjective dry mouth is challenging. A particular drug may exert its effect at more than one step in the salivary secretion pathway; and the strength of the effect is determined by dose, duration, metabolism, and the effects of other drugs being taken (Villa et al. 2016).

The drugs most consistently implicated in dry mouth are antidepressants, diuretics, anti-anginals, bronchodilators, and antihistamines. Polypharmacy (the use of multiple drugs) remains a challenge, especially in older adults, and only a few studies have assessed its impact on dry mouth (Johnson et al. 1984; Thomson et al. 2000; Thomson et al. 2006a; Singh and Papas 2014). Chew and colleagues (2008) introduced the concept of anticholinergic burden, in which the greater the number and dosage of these types of common drugs being taken, the greater the likelihood and severity of side effects, such as dry mouth. In addition, many older adults treated with radiation for head and neck cancer experience very severe dry mouth or xerostomia, with many complications, such as rampant cervical and root caries.

The impact of dry mouth is considerable, as shown consistently by epidemiologic studies (Locker 2003; Gerdin et al. 2005; Thomson et al. 2006b; Ikebe et al. 2007; Enoki et al. 2014; Benn et al. 2015). Ikebe and colleagues (2007), for example, observed a strong association between dry mouth and quality of life among older Japanese adults who had xerostomia or SGH, suggesting that both aspects of dry mouth can affect quality of life. Individuals with xerostomia and SGH may have problems with eating, speaking, swallowing, or wearing dentures, and often need to sip liquids while eating. The crucial role of saliva in tasting foods means that there also may be taste alterations, with persons unable to enjoy their food as much as before (Turner and Ship 2007).

Halitosis, burning mouth/tongue, and intolerance of acidic or spicy foods can lead to changes in diet that also can have an adverse effect on nutritional status and quality of life (Atkinson and Wu 1994). Dietary changes also can be induced as a result of difficulty in using dental prostheses, with a lack of saliva in the denture-mucosa interface producing denture sores. Although speech and eating difficulties are perhaps most severe in those who have undergone radiation treatment for head and neck cancer (Turner and Ship 2007), they also are apparent among less severely affected dry mouth sufferers. Amifostine is a medication sometimes provided to relieve dry mouth during head and neck cancer treatment. However, there is insufficient evidence to suggest that amifostine prevents the feeling of dry mouth while receiving radiotherapy to the head and neck (with or without chemotherapy) in the short or medium term following radiation treatment (Riley et al. 2017). There is limited evidence for nonpharmacological interventions, including acupuncture and electrostimulation, for the treatment and relief of dry mouth (Furness et al. 2013).

High-Risk Behaviors Affecting Oral Health in Older Adults

High-risk behaviors are generally less common among older adults than in younger age groups. About 9% of those 65 years and older reported that they were current smokers, and 8% reported excessive alcohol consumption, defined as having five or more drinks in one day at least once in the past year (Han and Palamar 2020). Cannabis use also is on the rise among seniors, increasing from less than 1% in 2006/2007 to 3% in 2015/2016, and more than 4% in 2018. See Section 5 for more information on substance use.

Social Determinants of Health

Social determinants of health (SDoH) are key social and economic factors that influence individual and population health. SDoH concepts described in *Healthy People 2030* include the domains of economic stability, health care access and quality, neighborhood and built environment, social/community context, and education access and quality (U.S. Department of Health and Human Services 2020). All of these concepts relate to oral conditions among older adults. For example, access to care, education, and income are strongly related to tooth loss, periodontal diseases, and dental caries. A broader discussion on SDoH is provided in Section 1 of this monograph.

In immigrant communities, oral health risks for older people also are compounded by difficulties in accessing health care and by multiple linguistic, cultural, economic, and social barriers. Acculturation plays a role in oral health status and promotion and can either support or negatively impact oral health. Cultural beliefs can influence both health care choices and service use. For instance, in Asian cultures, friends, neighbors, and family often are consulted before turning to formal services (Esperat et al. 2004). An analysis of studies on the influence of culture on oral health–related beliefs and behaviors of older Chinese immigrants found a common belief that dental caries and tooth loss are inherited conditions and inevitable in old age (Smith et al. 2013). In a study of Dominican, Puerto Rican, and African American older adults, the authors concluded that being sensitive to culture-bound knowledge, beliefs, and behaviors may help to improve health equity for underserved populations (Shedlin et al. 2018). Additional information on acculturation and oral health is discussed in Section 1.

Interrelated Effects of Oral Health with General Health

Older adults' health status can vary widely, ranging from good health to ill health as the result of comorbid chronic conditions. Some older adults also may have cognitive or functional impairments that require skilled assistance to help with daily activities. Most older adults have at least one chronic health condition, and many have multiple conditions. The more frequently occurring conditions among older adults are hypertension (67% of men 75 years and older and 79% of women 75 years and older), arthritis (54% in 2018 among people 75 years and older), heart disease (28%), any cancer (19% in 2016–2017), and diabetes (28% in 2013–2016) (Administration on Aging 2020).

Oral bacteria and their toxins can spread into the bloodstream through ulcerated or inflamed tissues during chewing, routine oral hygiene, and dental procedures. Plaque and gingival inflammation transiently increase the prevalence of bacteria in the bloodstream following toothbrushing (Lockhart et al. 2009; Matthews 2012). In addition, the presence of oral bacteria or their toxins may induce inflammatory responses, which can prompt insulin resistance (Johnson et al. 2017). Oral bacteria can reach tissues in the lung, heart, gut, placenta, joints, and even the brain. They have been associated with infective endocarditis, and chronic inflammation may contribute to systemic conditions such as cardiovascular disease and diabetes (Aviles-Reyes et al. 2017; Sudhakara et al. 2018; Konkel et al. 2019). Although a large body of literature supporting the interrelationship between oral health (particularly periodontitis) and general health exists, the evidence is insufficient to support or invalidate the notion that treating periodontitis can prevent cardiovascular disease (Berlin-Broner et al. 2017; Sanz et al. 2020).

Common Risk Factor Approach

The Common Risk Factor Approach (CRFA) aims to identify and reduce risk factors common to a number of noncommunicable diseases (World Health Organization 1980; Grabauskas 1987; FDI World Dental Federation 2012), including oral diseases, by taking a comprehensive, integrated public health approach. This approach has the potential to decrease disease severity at a lower cost with greater efficiency and effectiveness than disease-specific approaches. The CRFA addresses upstream factors, such as socioeconomic status and discrimination, and should be used in tandem with downstream factors, such as individual behavior and health status (Bharmal et al. 2015).

Focusing on risk factors shared between chronic systemic and oral diseases/conditions has the potential for broad impact (Watt 2005) when there are population-based interventions. One example is a multi-decade and multi-sector public health approach to tobacco prevention and control that included media campaigns, increased taxation, and policies that established smoke-free environments, resulting in a 67% decline in smoking since 1965 (Janakiram and Dye 2020). A population-level intervention that uses an oral health message to promote overall geriatric health is the long-running public awareness campaign focusing on encouraging people to keep at least 20 teeth by age 80—the 8020 Campaign in Japan (Shinsho 2001; 8020 Promotion Foundation 2021). The general idea is that good oral health and nutrition are linked, and together they facilitate health in older adults. Addressing shared risk factors between oral diseases and noncommunicable diseases provides opportunities to incorporate oral health as an integral part of the messaging and care to positively affect oral and systemic health outcomes (Janakiram and Dye 2020).

Dementia and Cognition

Alzheimer's disease and related dementias (ADRDs) affect approximately 8.2% of the U.S. older adult population (Dwibedi et al. 2018) and increase in old age; for persons older than 85 years, prevalence reaches more than 40% (Beydoun et al. 2014). Poor oral health in persons with ADRD is well documented, with higher rates of acute and untreated oral diseases and conditions than in older persons without dementia. These oral diseases and conditions include untreated decay and retained tooth roots (Delwel et al. 2017), periodontal inflammation (Leira et al. 2017a; Delwel et al. 2018), ulcerations and infections (Ribeiro et al. 2012; Aragon et al. 2018), and diminished salivary flow, all of which have been linked to both medication use and ADRD (Ship et al. 1990). One report has suggested an association between the periodontal pathogen *Porphyromonas gingivalis* and the development of ADRD (Dominy et al. 2019).

Memory impairment may increase the risk of these oral diseases and conditions. Older adults with dementia may forget to perform daily oral care and, in the later stages of dementia, forget how to perform oral care. In addition, many caregivers are not comfortable with this task, and oral care may not be prioritized because of the many tasks involved with daily care (Marchini et al. 2019a). It follows that ADRD is a primary risk factor for rapid oral health deterioration (Marchini et al. 2017).

Some studies suggest that the relationship between poor oral health and dementia is bidirectional. A 10-year cohort study found that patients with severe or untreated periodontal disease were more likely to receive a diagnosis of dementia at a later date, and periodontal disease has been hypothesized as a modifiable risk factor for dementia (Noble et al. 2013; Lee et al. 2017a; Lee et al. 2017b). A feedback loop relationship has been hypothesized between poor periodontal status and cognitive status (Yaffe et al. 2004; Petersen and Yamamoto 2005). Patients with mild cognitive impairment are more susceptible to periodontal diseases and edentulism (Petersen and Yamamoto 2005). Related basic science studies looking at the interaction of inflammatory mediators and brain cells suggest that chronic periodontitis can contribute as a peripheral source of pro-inflammatory cytokines entering the nervous system through the blood-brain barrier or through peripheral nerve stimulation (Kamer et al. 2008; Tonsekar et al. 2017), and pro-inflammatory cytokines can stimulate glial cells to produce pathologic protein molecules, which then may cause neuronal damage (McGeer and McGeer 2001; Tonsekar et al. 2017). It is noted that current data on the role of periodontal disease in cognitive functions are inconsistent and warrant future studies that use comprehensive and comparable uniform periodontal measurement methods (Yaffe et al. 2004; Cerutti-Kopplin et al. 2016).

Tooth loss also has been associated with dementia in epidemiologic studies and neurologic testing in animal models (Avivi-Arber et al. 2010; Avivi-Arber et al. 2015; Avivi-Arber et al. 2016). Several studies suggest associations between tooth loss and cognitive function. A systematic review and meta-analysis reported a 22–26% higher risk of cognitive impairment and dementia among people with fewer than 20 teeth (Cerutti-Kopplin et al. 2016). Another meta-analysis of 11 studies showed that tooth loss was associated with a 1.4 times greater rate of developing dementia (Shen et al. 2016). Other studies showed that having more teeth was associated with an almost 50% lower rate of dementia (Oh et al. 2018), and that tooth loss was associated with a 1.34 times greater rate of developing dementia (Chen et al. 2018).

Recent prospective studies have shown similar associations between tooth loss and deficient cognition (Tsakos et al. 2015; Sato et al. 2016; Li et al. 2017; Saito et al. 2018). A longitudinal cohort study in Sweden reported a positive association between tooth loss, periodontal bone loss, and cognitive function (Nilsson et al. 2018). Another study among English older adults showed an association of early-stage cognitive impairment with poor oral health and greater risk of tooth loss (Kang et al. 2019).

Aging can affect oral sensorimotor functions and their control (e.g., swallowing or speaking) (Bakke et al. 1990; Karlsson and Carlsson 1990; Kossioni and Karkazis 1998; Lewis et al. 2013; Lin et al. 2017; Peyron et al. 2017; Avivi-Arber and Sessle 2018). About 1 in 5 older adults is orally disabled because of tooth loss associated with reductions in efficiency of chewing, bite force, altered patterns of mastication and speech, and reduced quality of life (Jacobs 1998; Feine and Carlsson 2003; Trulsson et al. 2012; Cerutti-Kopplin et al. 2016; Avivi-Arber and Sessle 2018). Older adults with such impaired oral sensorimotor functions are more likely to have neurological disorders than those with intact sensorimotor function (Daniels 2006; Onder et al. 2007; Martin 2009; Schimmel et al. 2017).

While oral rehabilitation, such as dental implants, can replace lost teeth and restore oral function, they also produce new changes to compensate for the missing periodontal tissues (Avivi-Arber et al. 2015; Avivi-Arber et al. 2016), and neuroplastic changes occur in the sensorimotor cortex of humans with tooth loss. Oral rehabilitation has been shown to reverse these neuroplastic changes and improve an individual's ability to eat and chew food (Luraschi et al. 2013; Avivi-Arber and Sessle 2018; Kumar et al. 2018).

Cardiovascular Disease

Coronary heart disease (CHD), a form of cardiovascular disease, is the leading cause of death and morbidity in the United States and around the world (GBD 2013; Causes of Death Collaborators 2015). It has become well accepted that chronic inflammation is a risk factor for CHD. Several studies have also suggested that severe periodontitis promotes elevated levels of systemic mediators of inflammation that are risk factors for cardiovascular disease (Schenkein et al. 2020).

It has been suggested that periodontal disease is an independent risk factor for CHD, increasing risk by 24–35% (Humphrey et al. 2008). Studies also have shown an association between atherosclerosis and periodontitis (Almeida et al. 2018). The number of teeth remaining is significantly associated with fatal and nonfatal myocardial infarction (MI), commonly known as a heart attack. The hypothesized link is that MI is closely associated with low-grade chronic inflammation (Holmlund et al. 2017). Research has yet to confirm, however, that treatment of periodontal disease improves cardiovascular outcomes (Humphrey et al. 2008; Li et al. 2014; Liu et al. 2019). A recent review found that, for patients preparing for cardiovascular surgery, there is consensus on the need for screening and treatment of oral-related infections, but a uniform pre-surgical screening approach has not been established (Cotti et al. 2017). Consequently, the authors concluded that guidance on dental care before cardiovascular surgery is needed. Furthermore, individuals with cardiovascular disease should be made aware of the importance of oral health, undergo an oral health risk assessment, and establish a dental home with regular, routine care. Patients often are willing to learn about oral health after an acute cardiac event, after discharge from the hospital, or during rehabilitation following a cardiac event. Further, patients are receptive to nurses educating, assessing, and referring patients for oral care (Sanchez et al. 2017).

Stroke and Cerebrovascular Disease

Stroke is the third-leading cause of death in the United States; nearly three-fourths of all strokes occur in people older than 65 years (Kelly-Hayes 2010). Stroke also is the leading cause of serious long-term disability in the United States, and can have a devastating impact on oral health. A stroke can be ischemic—the result of blockage of a blood vessel supplying the brain—or hemorrhagic, the result of bleeding into or around the brain.

Recent systematic reviews suggest that periodontal disease is associated with stroke (Leira et al. 2017b; Fagundes et al. 2019). Studies evaluating the oral health of patients following a stroke found that these patients have higher levels of plaque and calculus, more gingival bleeding, more periodontal disease, more decayed teeth, and more missing teeth than controls. The more severe the functional disabilities following a stroke, the worse the oral health (Karolyhazy et al. 2018), and poor oral health following a stroke might be associated with rehabilitation outcomes in hospitalized patients (Gerreth et al. 2021). Nevertheless, the evidence is unclear if improving oral care following a stroke reduces the risk of pneumonia or mortality (Lyons et al. 2018).

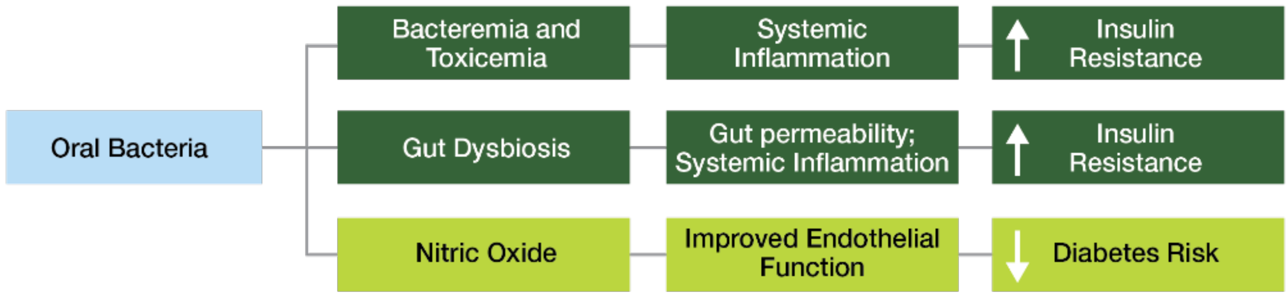
Studies suggest that poor oral health care and resulting systemic inflammatory markers are associated with an increased risk of recurrent stroke (Sen et al. 2013). Functional deficits, including hemiplegia, apraxia, hypoalgesia, and hyperesthesia following a stroke, may result in fewer dental visits (Sanossian et al. 2011). Difficulty swallowing following a stroke may affect nutritional status and overall health and cause aspiration of food and oral debris. For patients with poor oral health, the bacterial load in oral debris can lead to aspiration pneumonia (Loeb et al. 1999), which is why oral health care among older adults with comorbidities, including those needing long-term care assistance, is important (Oda et al. 2021).

Diabetes and Glycemic Control

Diabetes, in which the body does not make insulin or does not use it the right way, causes dysfunction of the immune system. Studies show a link between chronic inflammation and the development of type 2 diabetes (Simpson et al. 2015). Several pathways by which oral bacteria could potentially influence the metabolic disturbances associated with diabetes have been proposed (Figure 9).

Periodontal disease, an inflammatory condition, has a two-way link with type 2 diabetes. People with diabetes are three times more likely to develop periodontal disease than their healthy counterparts. Diabetes can worsen periodontal disease because it alters the immune response and leads to decreased elimination of associated bacteria.

Figure 9. Potential linkage of the oral microbiome to diabetes



Notes: Oral microbiome effects on diabetes: **dark green** = negative effects, **light green** = positive effects.
Source: Graves et al. (2019).

Conversely, periodontal disease hampers the control of diabetes. Some research suggests that periodontal treatment can decrease systemic inflammation, allowing for better glycemic control (Kudiyirickal and Pappachan 2015), while a clinical trial suggests that periodontal disease treatment in individuals with type 2 diabetes did not improve glycemic control (Engebretson et al. 2013; Geisinger et al. 2016).

Diabetes also is associated with gingivitis, xerostomia, dental caries, oral candidiasis, delayed wound healing, and increased incidence of infection after surgery. In elderly individuals, diabetes is associated with a higher prevalence of root caries, burning mouth syndrome, and candidiasis on the corners of the mouth. In addition, some people with diabetes may be taking medications that cause dry mouth (Kudiyirickal and Pappachan 2015). Older adults with type 2 diabetes and poor metabolic control have poorer health-related quality of life and diminished cognitive functioning (Wandell 2005), compared to those without diabetes. These individuals also are more likely to report poor oral health, dry mouth, and use a dental prosthesis (Azogui-Levy et al. 2018).

Taste impairment and tooth loss, which are more prevalent in older adults, may have a negative impact on diet, thereby affecting an older person's risk for diabetes or progression of existing diabetes (Muller et al. 2017; Asgary et al. 2018; Guess 2018; Rice Bradley 2018; Burton-Freeman et al. 2019). The impact of these losses on dietary choices and intake are further compounded by coexisting systemic diseases or conditions that impact oral sensory and motor function, such as stroke or Alzheimer's disease.

Other oral health conditions, such as oral pain, periodontal disease, dental caries, and soft-tissue lesions, also influence nutritional status (Ritchie et al. 2002) and increase the risk for diabetes or compromise diabetes control (Sami et al. 2017). Periodontitis is linked with increased systemic inflammation, dyslipidemia (abnormal lipid levels), and low levels of adiponectin (a protein that regulates glucose and lipids) and can lead to an increased risk of prediabetes and diabetes. Many significant associations between periodontitis and diabetes have been reported in observational studies, suggesting that an important relationship exists between these two diseases. More information on diabetes and oral health in adults is found in Section 3A.

A recent systematic review found significant associations between salivary dysfunction and appetite loss, imbalanced diet, and malnutrition in elderly adults (Munoz-Gonzalez et al. 2018). Xerostomia may lead to inadequate lubrication of the mouth, making it difficult to chew food and swallow. Nutrition therapy is an efficient and cost-effective component of diabetes management (Evert et al. 2019) and is associated with significant improvements in fasting blood sugar, HbA1c, weight, body-mass index, waist circumference, cholesterol, and systolic blood pressure (Razaz et al. 2019).

Diet and Nutrition

Because the mouth is the entryway to the gastrointestinal tract for foods and fluids, any changes in oral soft or hard tissues, including tooth loss, can influence food choices and impact nutrient consumption and nutritional status.

The number and patterns of teeth that best ensure a functional dentition have been defined in a variety of ways, ranging from the number of remaining teeth (Hobdell et al. 2003; Dye et al. 2019) to numbers of occluding (contacting) pairs of tooth surfaces (Sahyoun et al. 2003). The number of natural and prosthetic teeth can affect nutrient intake (carotenes, vitamin C, and folates) of older adults (Ervin and Dye 2012).

Studies show that the risk of malnutrition is greater in adults aged 60 years and older with tooth loss than in those with a complete dentition (Kikutani et al. 2013; McKenna et al. 2014; Toniazzo et al. 2018; Zelig et al. 2018). Kikutani and colleagues (2013) found that community-dwelling, older Japanese adults with inadequate occlusions were at 3.2 times greater risk of malnutrition than those with natural teeth and a functional dentition. People with dentures in the maxilla, mandible, or both were at a 1.7-fold greater risk of malnutrition than those with a functional natural dentition. Older people who were at risk for or had malnutrition had significantly fewer teeth than older adults with no risk of malnutrition (Toniazzo et al. 2018).

Tooth loss—with and without replacement—affects eating behaviors and the overall eating experiences of adults. People with dentures are more likely to engage in certain behaviors such as avoiding raw fruits and vegetables, avoiding eating in public, and eating smaller amounts of foods that require minimal or no biting or chewing (Hyland et al. 2009; Al-Sultani et al. 2019; Zelig et al. 2019). Fear of the dentures making noises, falling out, or causing pain may result in self-imposed limitations on food choices and limit social engagement with others. In contrast, when eating in private, some report positive behaviors, such as peeling and cutting fruits and vegetables, as well as using sauces and broths to moisten tough meats and poultry.

Older men and women who wear dentures consumed fewer servings of fruits and vegetables, especially those rich in carotenes and vitamin C, than did those with teeth (Ervin and Dye 2009). However, it is possible that among the very old, those with well-fitting dentures are able to have more varied nutrient intakes and good dietary quality, compared to those with poorer-fitting dentures or none at all (Marshall et al. 2002). Emerging information is suggesting that tailored dietary advice by dentists offered immediately following delivery of a new set of dentures can improve long-term effects on nutrient intake in edentulous older adults (Kanazawa et al. 2019). Oral health professionals can consider referring patients to a registered dietitian nutritionist for additional information/support.

Osteopenia and Osteoporosis

Research shows that chronic periodontitis is more prevalent and severe in postmenopausal women with osteoporosis than in those with normal bone density. Further, normal levels of vitamin D and use of anti-osteoporosis medication may improve periodontal status in women with osteoporosis (Penoni et al. 2016). Penoni and colleagues (2017), in a systematic review and meta-analysis, verified evidence for the association of periodontal attachment loss with low bone mineral density in postmenopausal women. They found that women with low bone mineral density, compared with those with normal bone mineral density, had greater mean clinical attachment loss (CAL). This indicator reflected a higher mean percentage of sites with CAL equal to or greater than 4 mm, and sites greater than or equal to 6 mm.

Advances in antiresorptive agents (bisphosphonates and denosumab) used to manage osteoporosis have given rise to a concerning oral complication known as medication-related osteonecrosis of the jaws (MRONJ). A systematic review showed that the mean age at onset of MRONJ was 69.7 years, plus or minus 5.2 years; occurrence was more common in females and in the mandible; and alendronate was the most commonly used associated agent. Duration of intake was 50.4, plus or minus 19 months, and 86.7% used the oral route of administration (Aljohani et al. 2017). Longer duration of use seemed to increase the risk of development of MRONJ.

Parkinson’s Disease

Parkinson’s disease is the second most common neurodegenerative disorder, after Alzheimer’s disease, in older people. The gradual degeneration of the brain causes motor, cognitive, and psychiatric symptoms in addition to tremor, rigidity, extreme slowness of movement, impaired balance, and swallowing and speaking difficulties (National Institute on Aging 2017a). Research shows that the body’s inflammatory response affects the progression of Parkinson’s disease, suggesting that chronic inflammation—like that found in periodontal disease—may contribute to the etiology and progression of Parkinson's disease.

Parkinson's disease can affect the progression of periodontal disease. Individuals with movement impairment often have trouble performing adequate oral hygiene, leading to poor oral health. In addition, Parkinson's disease is sometimes associated with cognitive impairment, which can further impair oral hygiene. Research shows that individuals with Parkinson's disease have more untreated decay, more teeth broken at the gum line, and more bacteria and food debris intraorally than healthy counterparts (van Stiphout et al. 2018). As Parkinson's disease progresses, individuals may have chewing difficulties (van Stiphout et al. 2018) and worsening periodontal probing depth and clinical attachment loss (Pradeep et al. 2015). The movement difficulties of Parkinson's disease also make it hard for individuals to travel to a dental office, resulting in fewer dental appointments (Wu et al. 2007).

Osteoarthritis and Rheumatoid Arthritis

Arthritis is a disease of the articular joints and has two main types. Osteoarthritis, the more common form, occurs when cartilage—the tissue that cushions the ends of the bones within joints—breaks down and wears away, causing joint stiffness and pain (National Institute on Aging 2017b). Less common but more destructive, rheumatoid arthritis (RA) is an autoimmune disease that also affects the articular joints. High amounts of bacterial antigens found in the periodontium and gastrointestinal tract may contribute to the etiology of the latter form (Nikitakis et al. 2017). Some studies suggest the periodontal pathogen *Porphyromonas gingivalis* as a possible trigger for autoimmune disease in some individuals with RA (Kharlamova et al. 2016). Studies also have shown an association between RA and complete tooth loss, as well as periodontal disease (Felton 2016; Bender et al. 2017). Individuals with more severe arthritis note difficulty performing daily oral care and have poorer oral health.

The temporomandibular joint also can be affected and can cause condylar flattening, discomfort, pain, and limited range of motion in severe cases. In addition, individuals may be on high-dose nonsteroidal anti-inflammatory drugs for osteoarthritis, which could increase risk for bleeding following procedures, such as root planing or extractions. Individuals with RA may take corticosteroids or immunosuppressants to manage the disease, increasing the risk of infections, poor healing, and prolonged bleeding, which should be considered in treatment planning and surgical management. In addition, limitations in mobility with advanced disease can make access to care difficult and may limit an individual's ability to receive treatment owing to discomfort while in the dental chair or the inability to transfer from a wheelchair (Kelsey and Lamster 2008; Chavez et al. 2018).

Sjögren's Syndrome

Sjögren's syndrome, the second most common chronic autoimmune disease after rheumatoid arthritis, causes inflammation and fibrosis of the glands that secrete tears and saliva. Although it primarily affects the lacrimal and salivary glands, many other organs and systems within the body, including the respiratory and gastrointestinal systems, also can be affected. Sjögren's syndrome affects more women than men, generally between 40 and 60 years old. The prevalence for people older than 65 years is much higher than for the general population, varying from five to eight times the prevalence in the younger adult population (0.1–2.7%, depending on criteria used and population studied) (Patel and Shahane 2014). The destruction of the salivary glands by this disease can cause moderate to very severe dry mouth, with reductions in both resting and stimulated salivary flow. Decreased salivary flow, in turn, leads to oral discomfort, difficulty articulating and swallowing, enhanced sensitivity in the oral cavity, and increased fungal and bacterial infections, including tooth decay resulting from loss of the protective components of saliva. The related oral symptoms and disease processes often are compounded in older patients who have other systemic diseases with oral symptoms, or require medications that cause dry mouth (Donaldson et al. 2014).

Medications and Polypharmacy

Specific medications and polypharmacy (the simultaneous use of multiple prescription drugs) affect both salivary flow and the feeling of xerostomia, or dry mouth (Sreebny 1989; Janssens et al. 2017). Janket and colleagues found that taking at least one xerostomic medication was associated with a higher risk of mucosal lesions (Janket et al. 2003; Janket et al. 2007), but a specific association between such medications and other oral diseases, including caries and periodontal disease, has been difficult to establish (Janket et al. 2003; Rindal et al. 2005; Maupome et al. 2006; Syrjala et al. 2011). The issue of polypharmacy in general has been associated with higher caries restoration rates in several studies (Rindal et al. 2005; Maupome et al. 2006; Jurasic et al. 2019). For older adults, polypharmacy should be considered in the assessment of their oral health and risk for oral disease. For more information on multiple medication use and dry mouth, see the section on Salivary Gland Dysfunction and Xerostomia in this chapter.

Ventilator-Associated Pneumonia

Older adults are at increased risk for developing and possibly dying from pneumonia. Ventilator-associated pneumonia (VAP) is an infection occurring in patients receiving mechanical ventilation and is the most common hospital infection associated with intensive care (Hunter 2012). VAP is associated with increased morbidity, mortality, length of stay, antibiotic use, and cost (Rello et al. 2002; Bouadma et al. 2012; Zilberberg et al. 2020), but several preventive approaches exist (Bouadma et al. 2012). Some of these preventive approaches are related to oral hygiene and the reduction of pathogenic oral bacteria. The most recent review on oral hygiene care including the use of prescription antibacterial mouth rinse (chlorhexidine), and the prevention of VAP has indicated some reduction in the development of VAP in critically ill patients (Hua et al. 2016). However, there is no evidence of a difference in the outcomes of duration of mechanical ventilation, length of intensive care, or mortality.

Late-Life Depression

Late-life depression is characterized by feeling sad, an inability to enjoy life, loss of self-esteem, guilt over past minor failings, or thoughts of suicide. This type of depression, reported by 10% of the male and 15% of the female population aged 65 years and older, can easily be masked as a side effect of other health conditions (Federal Interagency Forum on Aging-Related Statistics 2016) and can have a large impact on the oral health of older adults. For example, rampant tooth decay—including decay of the tooth roots—can occur if people lose interest in self-care, increase intake of high-carbohydrate foods, or are treated with medications that cause dry mouth. People with depression report more frequent tooth pain, painful chewing, and bleeding gums—all indicators of poor oral health (Park et al. 2014). They also are prone to periodontitis, which can lead to tooth loss and chewing impairment, affecting a person's overall quality of life. The number of teeth extracted also is associated with late-life depression. The severity of depression has been associated with the number of missing and decayed teeth, as well as with oral dryness (Skoskiewicz-Malinowska et al. 2018).

Frailty and Morbidity

Frailty is common in older adults and is characterized by an increased risk for poor health outcomes, such as falls, disability, hospitalization, and mortality (Xue 2011). Frail persons require assistance with mobility, suggesting the need for varied assistance with daily activities of life. Of note, frailty is more common among smokers (Kojima et al. 2015).

Global research shows a link between a variety of oral health problems and increased frailty in older age (Ramsay et al. 2018). Specifically, the need for a dental prosthesis was significantly associated with frailty (de Andrade et al. 2013). Tooth loss in healthy seniors has also been associated with mobility, gait instability (Brand et al. 2015), and a future decline in higher-level functional capacity. Treatment for tooth loss has attenuated this functional decline (Sato et al. 2016). A recent systematic review suggests a longitudinal association between oral health and frailty. However, whether oral health is a risk marker or risk factor for frailty remains unclear (Hakeem et al. 2019).

Frail people are at risk for new and recurrent oral diseases, such as root caries, periodontal disease, and fungal infections, stemming from other diseases, medications, and dependency on others for their oral health care. Frail individuals often require assistance with mobility and such activities as personal hygiene and eating. Avlund et al. (2003) reported that, for people 75 to 80 years who have few or no teeth, chewing limitations and mobility problems are interrelated. Thus, mobility problems must be addressed, because fatigued older adults who are dependent on others may not routinely access dental care (Avlund et al. 2003). Furthermore, because they rely on others for help, frail older adults also may have difficulty maintaining good oral hygiene and accessing oral health care, which then increases the risk for declining oral health. The cost of oral health care may be prohibitive in light of their extensive medical needs, and treatment options may be limited for those who are the most frail, especially those with extensive oral disease.

The associations between frailty and oral conditions underscore the importance of the approach developed by the Seattle Care Pathway (Pretty et al. 2014). Specifically, this approach emphasizes intensifying risk-based prevention and improved communication with caregivers to bring older adults to improve and maintain their oral health as frailty develops and dependency increases.

End of Life

Older adults with functional dependence may encounter challenges accessing and receiving appropriate oral health care (van der Putten et al. 2014). The Seattle Care Pathway is an approach that guides practitioners to protect, maintain, and optimize oral health throughout life (Pretty et al. 2014). This clinical pathway requires health professionals to identify a patient's level of dependency (from no dependency to high dependency) in order to guide assessment, prevention, treatment, and communication protocols (Pretty et al. 2014). This approach is used to develop appropriate treatment plans for independent, healthy older adults, as well as vulnerable adults toward the end of life, with a focus on preparing older adults for increasing dependency and frailty.

At the end of life, terminally ill patients rarely receive oral care because they cannot access dental offices. To address this issue requires an interdisciplinary approach to integrate dentistry into palliative and hospice care. Oral health care providers must use a whole-health approach to understand what type of care is needed and would be the most comfortable for people in their last days. Some have advocated addressing the stages in the death experience—decline, pre-actively dying, actively dying—and the dental care that might be appropriate at each stage, with the goal of promoting comfort, oral function, and quality of life (Chen and Kistler 2015).

Studies identified xerostomia as the most common oral health issue in terminally ill patients; they also face bacterial or fungal infections, oral pain, and prostheses that no longer function (Gordon et al. 1985; Chen et al. 2013a; Chen et al. 2013b; Kvalheim et al. 2016). Many of these issues can and should be treated with comfort-focused bedside care from a dental professional. Although this seems reasonable and empathic, dental students and other oral health professionals need learning opportunities to become comfortable with dying patients and how to manage care in the settings where they reside (Macdonald et al. 2020). This is also discussed in Section 4: Oral Health Workforce, Education, Practice, and Integration.

Mortality

Recent studies suggest an association between the number of missing teeth and mortality—specifically, the higher the number of missing teeth, the greater the risk of mortality (Caplan et al. 2017; Vogtmann et al. 2017; Jansson et al. 2018; Koka and Gupta 2018; Tanaka et al. 2018). A study using U.S. data showed that significant tooth loss (0–15 teeth), root caries, and periodontal disease were associated with higher mortality, and smoking was found to explain the link between mortality and root caries and periodontal disease (Kim et al. 2013). Such relationships are not necessarily causal. Tooth loss and oral disease are more common among those with unhealthy diets and limited access to health care, as well as those who use tobacco products. Those factors, which also place people at higher risk for chronic diseases, are associated with less education and lower incomes (Koka and Gupta, 2018).

Prevention and Management of Oral Diseases and Conditions

Separating the management of oral diseases and conditions in older adults from the management of general health is impossible. Oral and systemic diseases interact in ways that are not always clear. In some cases, systemic diseases influence oral outcomes. In other cases, oral diseases and conditions affect the symptoms and course of other health conditions, such as diabetes, or important daily functions, such as eating. As researchers advance knowledge about these complex relationships, oral health professionals will need to take a more person-centered, holistic approach to providing dental care to people aged 65 years and older.

It has become increasingly clear that general health—especially certain chronic conditions in older adults—influences oral diseases and conditions. Oral manifestations of systemic diseases are common and often are overlooked by medical providers, although there are significant conditions that can have a negative impact on quality of life. Table 2 shows some of these consequences. A medical provider's inspection of the mouth between the lips and uvula (back of the soft palate) can provide insights into general health. Medications and other treatment of chronic diseases can alter oral health, which may require special interventions to minimize adverse effects. It will be critical for dental and medical providers to work together to identify and minimize the systemic risks to oral health and to appropriately manage oral disease in light of the fact that many older adults develop multiple chronic diseases as they age. The ability of all health care professionals to identify risks for, and signs of, poor oral health is critical for ensuring timely referral for appropriate prevention and management of oral diseases and conditions.

Preventive health care typically considers three levels of prevention (primary, secondary, and tertiary). As in the case of working-age adults, the main preventive efforts directed at orofacial diseases in older adults are focused on dental caries, periodontitis, and oral cancer. Primary prevention interventions for dental caries aim to prevent tooth decay from occurring and often include health promotion activities that focus on changing poor dietary habits and encouraging better oral hygiene, including brushing and flossing (National Institute on Aging 2020). The use of fluoride, including varnish or fluoride-containing toothpaste, either purchased over the counter or provided by a dentist as a prescription, also are important primary prevention activities for dental caries. Other important primary prevention efforts include tobacco cessation interventions and substance misuse counseling to prevent periodontitis and other harms to the mouth.

Secondary prevention efforts are intended to detect early signs of disease, generally through receiving regular care, and to reduce the impact of early disease onset. Silver diamine fluoride is an effective chemotherapeutic intervention for managing the impact of dental caries (either coronal or root caries) when the caries process has been limited to a small cavity. A different chemotherapeutic approach to helping to control the progression of gingival inflammation and periodontitis is the use of anti-inflammatory, antibacterial mouth rinses such as chlorhexidine, which is by prescription only. A secondary prevention activity that is generally considered important for oral health is screening for oral and pharyngeal cancers.

The focus of tertiary prevention is controlling the disease after diagnosis to prevent progression to tooth loss or to provide rehabilitation to restore some function that facilitates quality of life. For controlling caries progression in adults, a variety of restorative options are available. In controlling periodontitis, the objective is to prevent bone loss by using a variety of nonsurgical therapies and periodontal surgery, if necessary. For oral and pharyngeal cancer, the objective is to intervene early with surgery, radiation, and/or chemotherapy to reduce mortality and impact on quality of life.

Prevention and Management of Dental Caries

Management of caries in healthy older adults follows the same principles of risk assessment, prevention, and minimally invasive care for working-age adults, as noted in Section 3A (Hayes et al. 2020). However, for older dependent adults, management of caries may be affected by physical and cognitive impairments, as well as intraoral and extraoral risk factors that are unique to older adults (Boehm and Scannapieco 2007). One important aspect of caries prevention for older adults with comorbidities lies in making them aware of the particular risk factors that result from their diseases and the medications used to manage them. A wide range of medications cause dry mouth, increasing the risk for caries, but individuals may be unaware of the risk. They may even be unaware that there has been a change in their salivary flow, and consequently unaware that their preventive routine may need to change.

Root exposure as an age-prevalent condition in older adults leaves them vulnerable to root caries in particular, although caries commonly occurs on other surfaces as well. Root caries also is distinct from coronal caries, with several important differences from the caries process to appropriate therapies (Damé-Teixeira et al. 2017). Because root caries is more prevalent in older adults, early detection is important to long-term control and management of the disease. However, the use of diagnostic tests, beyond the standard use of a dental explorer to detect caries, is unable to provide any additional benefit for the detection and diagnosis of root caries (Fee et al. 2020). Topical fluoride applications can be effective in preventing root caries (Zhang et al. 2020b).

Table 2. Medical conditions with oral health consequences

Medical condition	Oral health consequence
Alzheimer's disease and other progressive dementias	Poor oral hygiene, periodontal disease, dry mouth, dental caries risk (Delwel et al. 2018)
Anemias	Pale mucosa, atrophic glossitis, angular stomatitis, oral candidiasis, aphthous-like ulcers (Adeyemo et al. 2011; McCord and Johnson 2017)
Chronic kidney disease	Periodontitis (Deschamps-Lenhardt et al. 2019)
Diabetes	Periodontitis (Kocher et al. 2018)
Interpersonal violence, elder abuse	Oral and dental trauma (mandible fracture, facial contusion and laceration, dental concussion) (Ferreira et al. 2014)
Medications that impact the mouth (including antidepressants, antihistamines/decongestants, antihypertensives, herbal products)	Salivary gland dysfunction, gingival overgrowth, angioedema, oral pigmentation, lichenoid lesions, dysgeusia/taste changes, bleeding/petechaie, alveolar bone loss, mucositis/stomatitis, neuropathy, chemo-osteonecrosis (Ciancio 2004)
Neoplastic hematologic disease, including leukemia, multiple myeloma, lymphoma, and cancer chemotherapy	Mucositis, leukemic gingival infiltrates and inflammation, opportunistic infections, oral petechiae-ecchymosis, ulcers, tumor growth, periodontitis (McCord and Johnson 2017)
Osteoarthritis	Poor oral hygiene, temporomandibular joint pain (Kelsey and Lamster 2008)
Osteoporosis	Periodontitis, tooth loss (Kelsey and Lamster 2008)
Radiation therapy for head and neck cancers	Oral mucositis, rampant caries, osteoradionecrosis, trismus of muscles of mastication, taste change (Sciubba and Goldenberg 2006)
Sjögren's syndrome (and other autoimmune diseases)	Dry mouth/mucosa, salivary gland enlargement, oral candidiasis, rampant caries, oral ulcerations, taste changes/dysgeusia (Cartee et al. 2015)
Sleep disorders	Gingival inflammation, lower masticatory function (Carra et al. 2017)
Stroke and acquired brain injury	Poor oral hygiene-neglect, dental caries, dysphagia, xerostomia, tooth loss, gingivitis/periodontitis (Pillai et al. 2018)
Systemic sclerosis	Microstomia, caries, dry mouth, periodontal disease, gingival recession, mandibular bone resorption (Veale et al. 2016)
Thrombocytopenia and hemophilia	Petechiae and hemorrhagic bullae of mucosa, bleeding gingiva, spontaneous gingival bleeding (Adeyemo et al. 2011; McCord and Johnson 2017)

A caries risk assessment is a helpful precursor in determining risk-based treatment options, which may include such products as prescription-strength fluoride rinses and gels, salivary substitutes, and stimulants for home use. These may be combined with oral hygiene aids, such as electric toothbrushes and floss holders for the individual or a caregiver. For older adults with dental caries, the use of conventional restorative treatments (fillings, etc.) versus strategies that may include incomplete caries removal and atraumatic restorative techniques (ARTs), such as silver diamine fluoride (SDF) and conventional glass ionomer cement, is dependent on the extent of tooth decay and a person's ability to tolerate traditional restorative techniques.

For adults with a medical condition that impacts their ability to receive or access care, caries management may include glass ionomer restorations, interim therapeutic restorations, or ARTs. However, while the evidence to support the use of these minimally invasive treatment procedures for children is substantial, evidence for use in adults is limited (Dorri et al. 2017). Another minimally invasive procedure that has recently emerged to arrest or slow the advance of caries until the patient is able to receive definitive treatment is the application of SDF (Hendre et al. 2017; Oliveira et al. 2018). For some people at the end of life, any of these measures can also be provided as an element of palliative care to prevent the need for more extensive restorations or reduce the risk of an acute event that could result from untreated and advancing caries, such as tooth pain, infection, or tooth fracture (Boehm and Scannapieco 2007; Hayes et al. 2020).

Prevention and Management of Periodontal Disease

Periodontal disease often is associated with other comorbidities in older adults. For those who are healthy or for those with well-controlled systemic disease(s), treatment options and outcomes of treatment could be anticipated to be the same as for younger adults (Boehm and Scannapieco 2007; Renvert and Persson 2016). For those with multiple or poorly controlled systemic disease, treatment options may be limited, and outcomes of treatment may be compromised. People with a variety of medical conditions also use multiple medications, many of which can impact periodontal health, from diminished salivary flow (Wolff et al. 2017) to gingival hyperplasia (Aral et al. 2015). Further, the risk factors for many noncommunicable diseases and poor oral health, including periodontal disease, often are shared, such as poor nutrition, smoking, substance abuse, and limited health literacy or access to care. Such risks may be compounded by physical or cognitive impairments, resulting in refractory or advancing disease (van der Putten et al. 2013; Renvert and Persson 2016).

These risks must be identified and discussed with the patient or caregiver in order to develop a treatment plan and achieve the best outcomes in care. In some cases where a patient cannot or will not comply with recommendations to address modifiable risk factors, options for management may be limited to nonsurgical approaches, and success of treatment may be limited (Boehm and Scannapieco 2007).

For persons who are moderately to highly dependent on others for the tasks of daily living, a palliative approach focused on preventing progression of disease and maintaining dentition may be indicated (Boehm and Scannapieco 2007). Maintaining periodontally involved dentition may be of particular importance if this dependency also limits options for tooth replacement. Further, because periodontitis has been identified as a risk factor for many noncommunicable diseases, maintenance of the periodontium is critical. Periodontal treatment that reduces bacterial load is of particular importance for frail older adults. Because poor oral hygiene has been shown to be associated with aspiration pneumonia in this population (Loeb et al. 1999), addressing this is important. Establishing an individualized plan for daily oral hygiene, prevention, and maintenance to mitigate risks from systemic diseases and medications that can directly or indirectly affect oral health is critical for older adults with systemic disease and some level of dependency, and especially for persons who are most vulnerable because of frailty and high dependence (Boehm and Scannapieco 2007).

Management of Tooth Loss

Healthy older adults who have lost teeth can benefit from the full array of replacement options as described in Section 3A. Options will vary with changes in health status or level of dependency. For persons with no or low dependency issues, a full range of options is viable, with appropriate risk/benefit awareness from the patient, based on their specific conditions. For example, a patient with diabetes should be informed of the potential for oral infections if their diabetes is not well controlled. Once a disease and disability has begun to impact access to care and even the oral cavity directly—from dry mouth to diminished oral hygiene—options for replacement may become more limited. As dependency increases, maintaining function is critical, but less invasive procedures and easily cleansable fixed or removable prostheses or a shortened dental arch may need to be considered (McKenna et al. 2020). For individuals at the highest levels of dependency, tooth replacement may no longer be an option, and the primary goal will shift to general comfort of the oral cavity and maintenance of any existing dentition with adequate daily oral hygiene measures and regular preventive care (Boehm and Scannapieco 2007).

Oral Health Literacy

Health literacy is defined as “the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions” (Ratzan and Parker 2000). Adults with higher health literacy make better choices about their care, disease-prevention activities, health behaviors, and interactions with the health care system.

Health literacy is a resource. Like other resources, health literacy skills are not evenly distributed across the population. The National Assessment of Adult Literacy estimates that only 12% of the population is "proficient" in prose, document, and quantitative abilities (Kutner et al. 2006), meaning that the vast majority of Americans do not have the skills necessary to effectively respond to the complex requirements needed to understand the U.S. health care system. Older adults typically have lower average health literacy compared to younger adult age groups, and only 1 in 20 older adults had the skills to fully understand and communicate health-related information (Kutner et al. 2006). Oral health literacy among older adults was a concern communicated by the Surgeon General during a 2004 Senate Committee hearing on Aging and Health Care (2003). One study using community-based geriatric rotations involving dental students and community-dwelling older adults observed some improvements in oral health literacy as a result of the interactions between older adults and dental students (Hjertstedt et al. 2014). It is clear, however, that more work is needed to improve the oral health care system and oral health literacy to better meet the needs of older adults. More information on oral health literacy is presented in Sections 1 and 3A.

Special-Needs Populations

Older Adults with Disabilities and Special Health Care Needs

The majority of older adults in the United States use traditional settings for oral health care, such as private practices, community health clinics, and government-funded health centers. For adults of all ages, financial barriers such as low income, lack of insurance, and lack of transportation can limit access to oral health care. However, as medical, cognitive, functional, and behavioral challenges arise and dependence increases, additional constraints develop. In addition, individuals with developmental disabilities are aging at unprecedented rates and have unique health and service needs (Factor et al. 2012). Of the 49.2 million U.S. adults aged 65 years and older in 2016, 8.3 million (16.9%) required long-term care, including adult day care (0.6%), residential care (1.6%), hospice care (2.9%), nursing home residence (2.7%), and home health care (9.1%) (Harris-Kojetin et al. 2016). These individuals require some assistance with the activities of daily living, including daily oral care and accessing regular dental care. Chronic medical conditions, along with a reduced capacity for self-care, increases their risk for caries, periodontal disease, and oral pathology.

Often people with special needs, the medically compromised, and those who are older are considered "extreme caries risk," which by definition is a high-risk person who also has diminished salivary flow. This is an age-prevalent condition for older adults who may take several medications that result in diminished salivary flow, leading to multiple advanced caries lesions (rampant decay)—especially on root surfaces in older adults with recession—or to periodontal attachment loss.

Additional specific risk factors exist for this population. Some people may have poor oral hygiene as a result of some physical (e.g., severe arthritis, cerebral palsy, or Parkinson's disease) or cognitive impairment (e.g., Alzheimer's disease or vascular dementia). Some individuals may require special diets—such as soft, pureed, or thickened liquids—because of a gastrointestinal or swallowing disorder, or even due to poor oral health. These situations, in turn, place them at risk for caries because of the difficulty of removing such foods from the tooth surfaces and, for some, a reliance on others to perform oral hygiene (Chavez et al. 2018).

For people with a limited ability to cooperate for care, it also is important to note that behavioral techniques can be used to provide preventive and restorative care. A wide array of sedation options also are available, from oral to intravenous sedation and general anesthesia for persons with advanced dental needs and limited to no ability to cooperate because of physical or cognitive limitations. An interdisciplinary approach to treatment planning in these complex cases is critical to determine the patient's ability to tolerate and benefit from the proposed treatment and method of delivery (Chavez et al. 2018). Due to the many coexisting risk factors within vulnerable populations, some may be at risk for rapid deterioration of their oral health because of a combinations of factors related to their general health. These factors can include sensory loss or change, polypharmacy, the presence of disease (e.g., Parkinson's disease or diabetes), or physical or cognitive impairment following a stroke. Other factors can include social support needs (reliance on caregivers, living situation, palliative care status, or finances) as well as their oral condition (past dental history, current oral hygiene status, and oral mucosal conditions). A Rapid Oral Health

Deterioration Assessment of these three domains has been developed by Marchini and colleagues (2019b) to aid in appropriate treatment planning and intervention for these at-risk individuals. Four risk categories are defined in this assessment, and it is important to note that caries prevention is included in all four levels because caries is a leading cause of such rapid deterioration.

Issues of Abuse and Neglect

Ten percent of vulnerable older and disabled adults are estimated to be at risk for abuse and neglect, although this number is believed to be underreported. Abuse and neglect can be intentional (active) or nonintentional (passive) and can include neglect of oral health and trauma to the head and neck (Petti 2018). Individuals dealing with depression or dementia also can be at high risk for self-neglect. There may be a reluctance to report suspected abuse. Evidence may be attributed to, or confused by, findings that might otherwise be associated with aging or disability, such as bruising related to medication use or trauma; or from falls or other accidents as a result of vision, gait, or balance impairments. Identification of abuse and neglect also may be a challenge for persons with cognitive impairments who cannot clearly relay information or for persons who may be dependent on the abuser and fearful of making a complaint (Evans et al. 2017; Chavez et al. 2018; Centers for Disease Control and Prevention 2020b).

Homebound and Frail Older Adults

Homebound adults face high risks to their oral health (Crete et al. 2018), as well as greater rates of disease, frailty, and physical limitations that lead to dependence (Ornstein et al. 2015; Norman et al. 2018). In 2011, about 2 million community-dwelling older adults were homebound and in need of home-based care because of declines in physical and/or cognitive health (Ornstein et al. 2015). These adults live in the community with varying degrees of dependence, based on their physical, psychiatric, and/or social ability to leave home (Crete et al. 2018). In dentistry, the functional ability of an older adult is based on his or her ability to travel to a dental office, seek services independently, and perform oral health care (Table 3).

High-dependency individuals—people who cannot be transported or moved—must receive dental services in their home or a long-term care facility (Pretty et al. 2014). Recent studies categorize homebound adults using three main measures: *homebound* (in the last month, never left home or went out once a week or less); *mostly homebound* (went out once a week or less); *semi-homebound* (could leave home, but with the risk of becoming homebound due to a disease, symptom burden, or impairment creating a challenge; or if they need personal aid to leave home); and *non-homebound* (Cohen-Mansfield et al. 2012; Ornstein et al. 2015) (Figure 10). Although a great number of homebound individuals are older, some younger individuals are homebound as a result of developmental and other disabilities (Special Care Dentistry 2002).

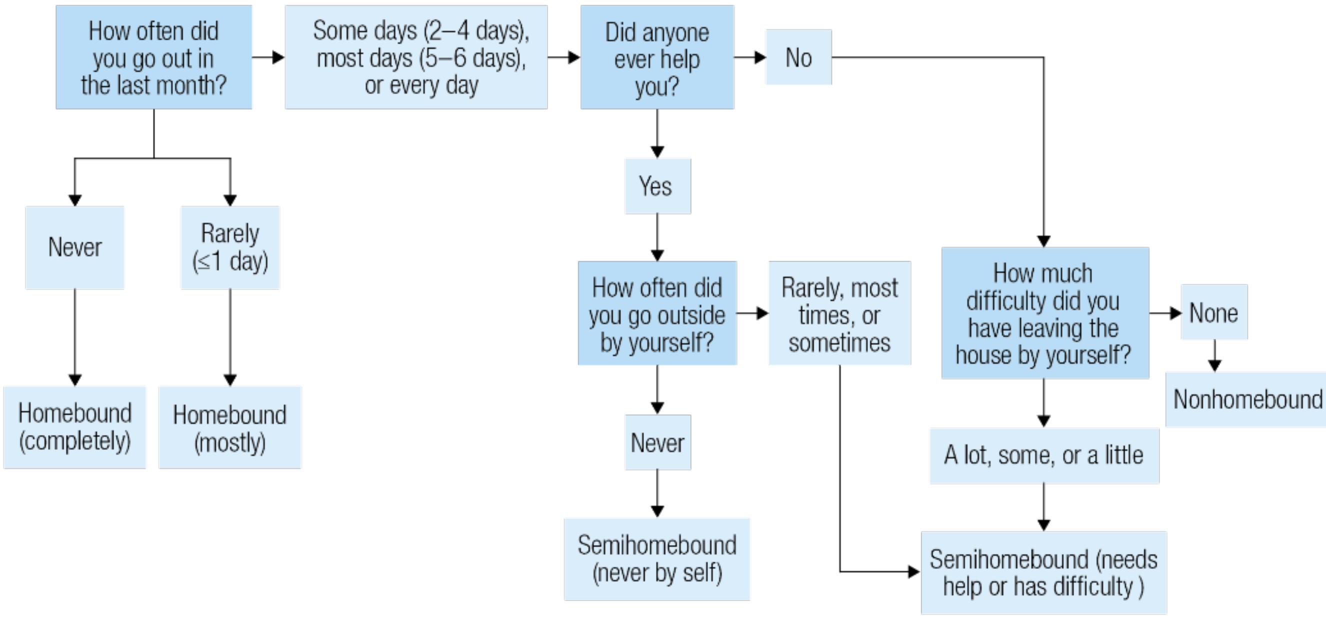
Compliance with regular dental visits is more difficult for homebound adults because of their social and physical challenges. A large proportion of homebound and semi-homebound adults have not seen a dentist in two or more years (Crete et al. 2018). Deterioration of oral health can be rapid and severe in the absence of routine care (Gluzman et al. 2013; Norman et al. 2018). Dental caries, periodontal disease, tooth loss, and the use of prostheses are basic indicators of poor oral health among older adults (Dye et al. 2015; Muller et al. 2017). The presence of untreated oral diseases can have a negative impact on quality of life, general health, well-being, and nutritional status.

Table 3. Functional ability for aging older adults applied to oral health care

a) No dependency	Fit individuals who exercise and are active for their age.
b) Pre-dependency	Individuals with chronic systemic conditions that could affect their oral health, but symptoms are well controlled.
c) Low dependency	Individuals with identified chronic conditions that have had an impact on their oral health. These individuals can access dental services on their own.
d) Medium dependency	Individuals with identified chronic conditions that impact their oral health at the moment. These individuals do not require assistance to access dental services and to maintain routine oral health practices.
e) High dependency	Individuals with complex medical conditions that preclude them from receiving dental care services at dental clinics.

Source: Pretty et al. (2014).

Figure 10. Determining homebound status using the National Health and Aging Trends Study



Note: Respondents were asked a series of questions as part of a Mobility Questionnaire found in the National Health and Aging Trends Study.
Source: Ornstein et al. (2015). © The American Medical Association. Reprinted with permission.

For these reasons, routine dental visits for homebound adults are required to maintain good oral health and detect oral and systemic conditions and diseases early (Chamut et al. 2021).

A 2011 Institute of Medicine report recommended that general health care professionals take a more active role in the dental care of adults living in long-term care facilities (Institute of Medicine and National Research Council 2011). The report suggested that such professionals assess risk and screen for common oral conditions, educate patients about how to prevent oral diseases (e.g., daily brushing with fluoride toothpaste), and deliver preventive services (e.g., fluoride varnish, silver diamine fluoride).

Oral Health and Quality of Life

Good oral health is an important aspect of quality of life (Jones et al. 2006). Van de Rijt and coworkers (2020) conducted a systematic review to identify oral health factors associated with oral health–related quality of life (OHQoL) in people 65 years and older.

They found that a functional dentition, oral pain, and functional complaints are all positively associated with OHQoL. Jones et al. (2002) showed that the single-item self-report of oral health (How would you rate the health of your teeth and gums?) using a Likert scale 5-item response (excellent, very good, good, fair, or poor) could accurately identify persons in need of dental care.

Dental Service Utilization

Older adults living in poverty are less likely to utilize the oral health care system, which contributes to the persistent oral health disparities observed in the United States. In 2017, 2 in 3 older adults had a dental visit in the past 12 months. Older adults who were either poor or close to poverty (43%) were less likely to have had a dental visit, compared with nonpoor (74%) older adults (Kramarow 2019). Non-Hispanic White older adults were more likely to have had a dental visit in the past year (69.1%), compared with Hispanic (54.7%), non-Hispanic Black (52.6%), and non-Hispanic Asian (52.8%) older adults. A recent survey of American Indian/Alaska Native/Native Hawaiian elders representing all regions of the United States and 262 tribes reported that nearly 57% of the older adult population had a dental visit in the past year (Schroeder et al. 2019).

Older adults with some natural teeth are more than twice as likely to have had a dental visit in the past 12 months (73.6%), compared to those with complete tooth loss (30.3%). About 8% of adults 65 years and older needed dental care in the past 12 months but did not get it because of cost. Older adults (65 years and older) who were poor or close to poverty were more likely to have an unmet need for dental care because of cost (14%), compared with nonpoor older adults (5%) (Kramarow 2019).

Among the elderly, dental utilization strongly correlates with dental insurance coverage. Two-thirds of older adults with private dental insurance have had a dental visit in the past 12 months, whereas only one-third who are uninsured had a dental visit. For those older adults with some public insurance, fewer than 15% had a dental visit in the past 12 months (Nasseh and Vujicic 2016). Among the four major age groups representing the lifespan, older adults are most likely not to have dental insurance (57%); they also spent the most out-of-pocket for dental care (see Section 1 Figures 13–14 in this monograph for more information).

Provision of Older Adult Oral Health Care in Alternative Settings

Alternative Models

Alternative models of care are required for older adults with severe impairments who are no longer able to come to a dental clinic. Examples include mobile practices and virtual dental homes using teledentistry. The latter allows care to reach people in long-term care facilities, senior centers, and other places where seniors normally congregate, as well as at home. A mobile practice can range from a mobile van equipped as a dental clinic to portable equipment brought to the patient's bedside (Langelier et al. 2017). Given the costs of transporting staff and equipment, the mobile model is a more costly alternative to an office visit. Virtual dental examinations have been shown to be an acceptable alternative to in-person examinations (Namakian et al. 2012). The virtual dental home is "based on the principles of bringing care to places where underserved populations live, work, or receive social, educational, or general health services, integrating oral health with general health, social and educational delivery systems, and using telehealth technologies to connect a geographically distributed, collaborative dental team, with the dentist at the head of team making decisions about treatment and location of services" (Glassman 2012a). See Section 4 for a discussion of telehealth technologies in dentistry.

Chapter 2: Advances and Challenges

The oral health of Americans 65 or older has improved significantly during the past 2 decades. Older Americans now have fewer teeth extracted, and the proportion with complete tooth loss (edentulism) is at an all-time low. Much of this improvement in tooth retention can be attributed to a greater focus on prevention and advances in treating and preserving teeth affected by dental caries and periodontal disease. Changes in attitudes, such as decreased social acceptance of tooth loss and decreased smoking rates, as well as improved awareness of the benefits of oral health, also have contributed to more older adults keeping more teeth than in any previous generation. Challenges to improve oral health in older adults remain, and barriers to achieving oral health care continue. The single most important barrier is the affordability of dental insurance and dental care, as many U.S. adults lose their employee benefits when they retire. Increases in tooth retention and the acquisition of dental implants by more older adults make ongoing preventive care very important for this age group.

Etiology and Prevalence of Oral Diseases and Conditions

Dental Caries

Overall, the prevalence of untreated decay in adults aged 65 and older has declined 6 percentage points since 2000, from approximately 28% to 22% (Figure 11). Men have experienced a significant decrease in untreated dental caries (32% to 25%), but prevalence still remains higher for men than for women (25% vs. 20%). There have been decreases in the prevalence of untreated caries for non-Hispanic Blacks and Mexican Americans aged 65 and older, but the decrease among older non-Hispanic Black adults has been the highest, especially for those 75 and older. Nevertheless, disparities remain (Figure 12). Unfortunately, untreated caries did not significantly decrease for older adults age 65 and older living in poverty (48% to 43%) or for more affluent older adults (21% to

14%), with the disparity being greatest among those 75 and older (Figure 13).

Although the prevalence of dental caries has changed little among older adults since the 2000 report (96% to 97%), another measure of dental caries experience has significantly changed. During the last 2 decades, the mean number of decayed, missing, and filled teeth (DMFT) has decreased from about 19 teeth affected by dental caries to 17 teeth affected by dental caries (Figure 14). This decrease has been driven by a substantial reduction in the mean number of missing teeth, declining from about 10 missing teeth to fewer than 7 missing teeth. Interestingly, this substantial increase in the mean number of teeth not extracted also parallels a significant increase in the mean number of teeth restored. Since the turn of the century, the mean number of teeth with dental fillings and crowns increased for older adults from about 9 to 10 teeth. Paradoxically, the mean DMFT for older adults living at 200% of the federal poverty guideline or higher has declined from 19 to 17 teeth affected by dental caries; but for those older adults living in poverty, the mean number of teeth affected has remained unchanged (about 18).

For older adults living in poverty, the mean number of teeth lost due to dental caries decreased from about 12 to 11 teeth during the past 2 decades, and the mean number of teeth with dental fillings and crowns increased from nearly 4 to 5. However, for those living at 200% of the federal poverty guideline or higher, the mean number of missing teeth decreased from about 8 to 6 teeth, with the mean number of teeth restored increasing from about 10 to 11 teeth.

Changes in DMFT by race/ethnicity indicate that disparities remain, although some indicators show improvement. For example, among non-Hispanic Blacks, the mean number of missing teeth decreased from about 14 to nearly 11 on average, whereas for non-Hispanic Whites, the decrease was from about 9 to 6 missing teeth (Figure 15). For Mexican Americans, the decrease was from about 10 to 9 mean missing teeth. Although non-Hispanic Black and White older adults have seen a reduction in the number of teeth affected by dental caries over the past 2 decades, Mexican American older adults have not.

Overall, these changes show that there has been some improvement in dental caries experience (DMFT) for some older adult groups, but substantial disparities remain. Clearly, older Americans living in poverty have not experienced the same kind of reduction in the prevalence of dental caries compared to more affluent older Americans.

Periodontal Disease

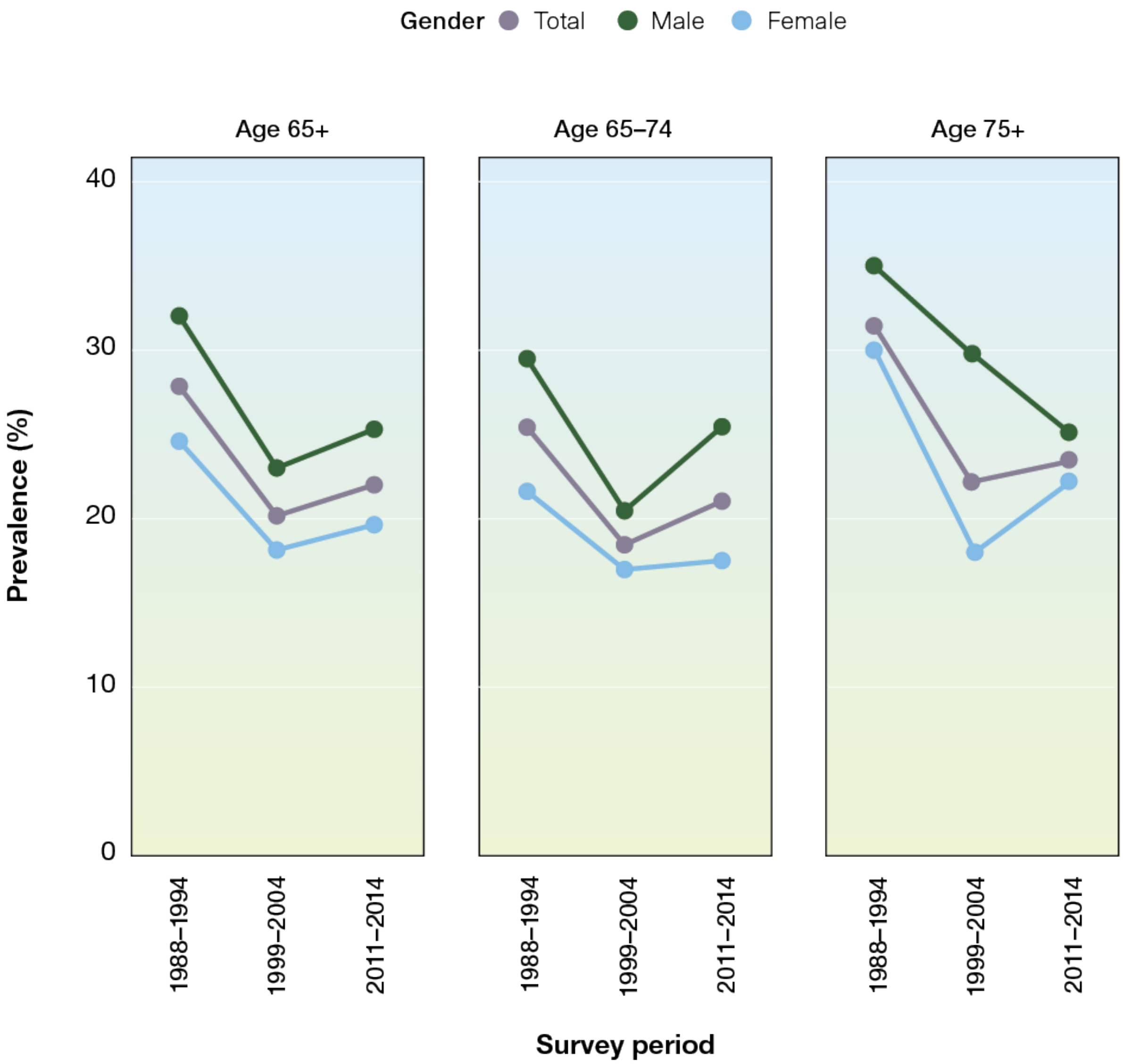
With nearly 1 in 10 Americans aged 65 years and older experiencing severe periodontitis (Eke et al. 2018), periodontal disease in this age group is an important public health problem that needs to be addressed. People who are poor, with fewer years of education, and who are Hispanic or African American, are at increased risk for severe periodontitis (Borrell and Crawford 2008; Eke et al. 2016b). These individuals have reduced access to oral health care services, and approaches to close this gap must be developed (Seo et al. 2019). Moreover, measures that are used to assess the prevalence and severity of periodontitis, such as clinical loss of attachment or gingival recession, increase with age, which clearly demonstrates that older age is an important risk indicator for periodontitis (Billings et al. 2018). As gingival recession increases, dental roots become noticeable, and exposure to dental caries on tooth roots becomes greater.

As the U.S. population ages and more older adults retain more teeth, they become more susceptible to periodontitis and its complications. In addition to the local effects of severe periodontitis, including discomfort, abscess formation, masticatory inefficiency, reduced quality of life, and tooth loss, the potential impact on general health is another important consideration. As a result, the dental profession will be required to provide dental care to people with more complex health histories who may have a reduced capacity to tolerate dental care and who take a range of medications that have direct and indirect effects on the oral cavity, including xerostomia (Barbe 2018).

Salivary Gland Dysfunction and Xerostomia

Over the past 20 years, progress has been made in better understanding salivary gland dysfunction and xerostomia (dry mouth). These conditions now can be described and measured more specifically than before, resulting in more valid and reliable estimates of their occurrence. There also is considerable evidence confirming the major impact of dry mouth on day-to-day lives, with this condition being one of the most common reported factors in oral health–related quality of life (OHRQoL). The role of various drugs and associated polypharmacy in causing dry mouth also is better understood and is the most common cause of xerostomia in older adults.

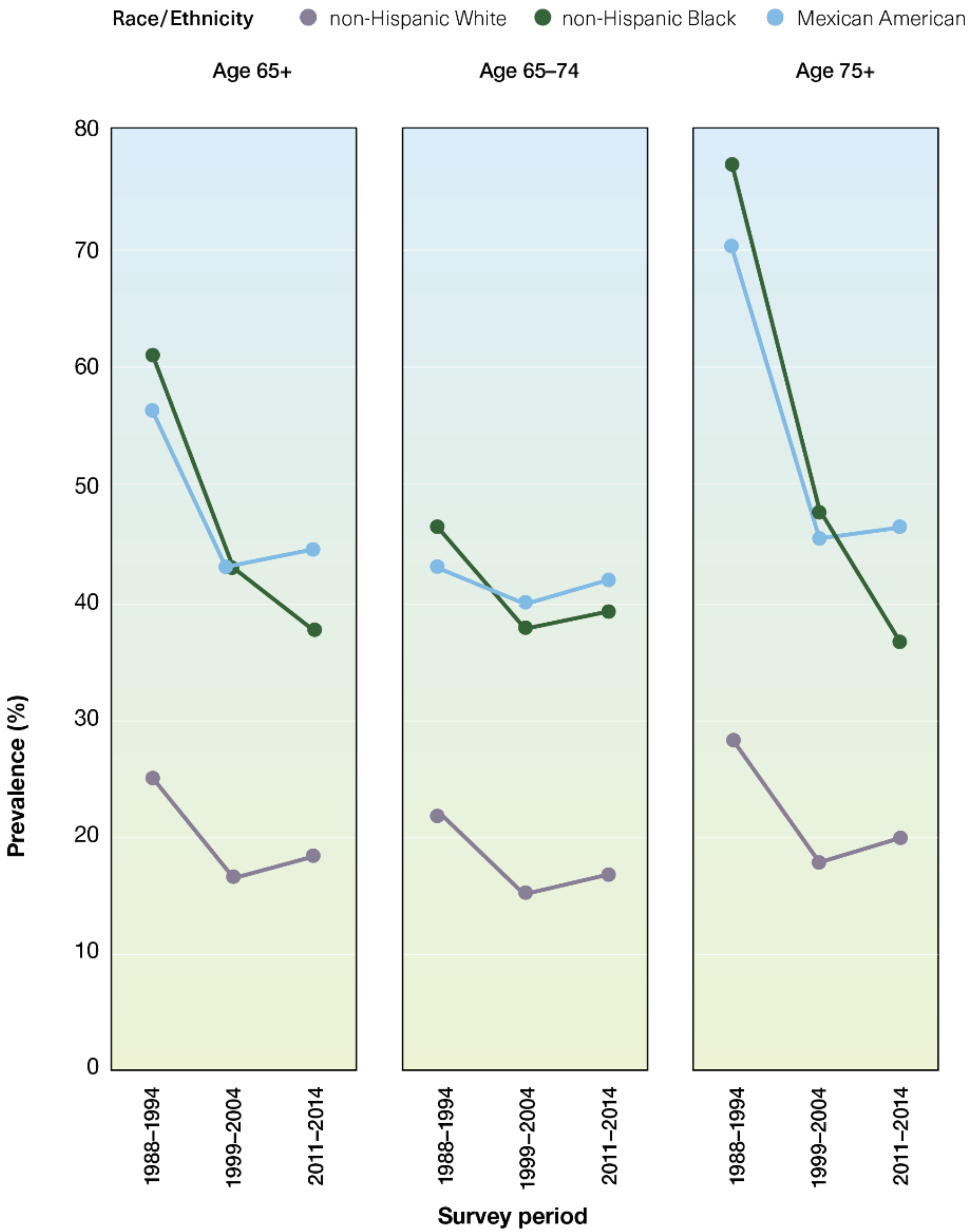
Figure 11. Percentage of adults ages 65 and older with untreated dental caries in permanent teeth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

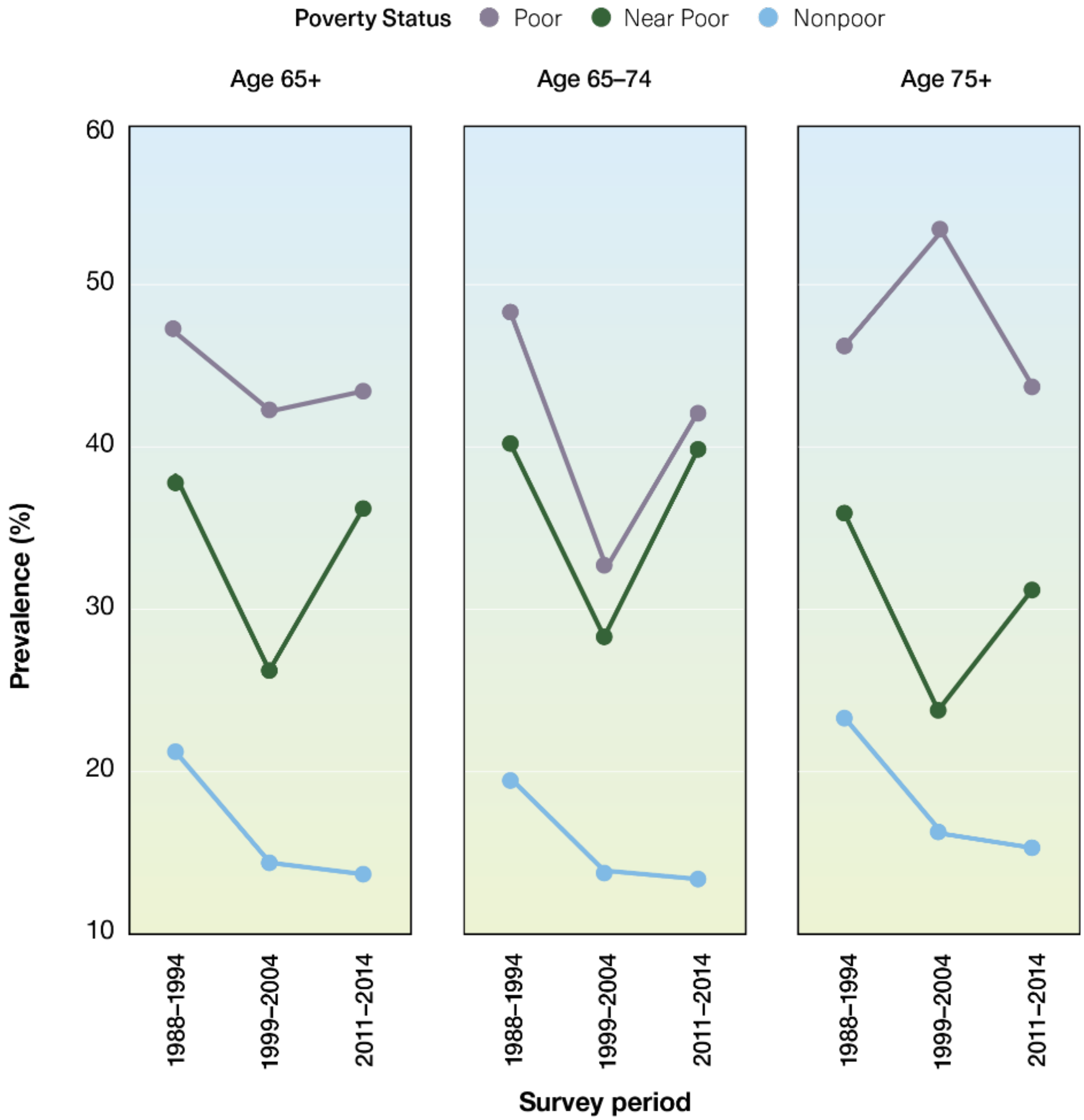
Figure 12. Percentage of adults ages 65 and older with untreated dental caries in permanent teeth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Note: Prevalence of untreated dental caries in permanent teeth (DT > 0).

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

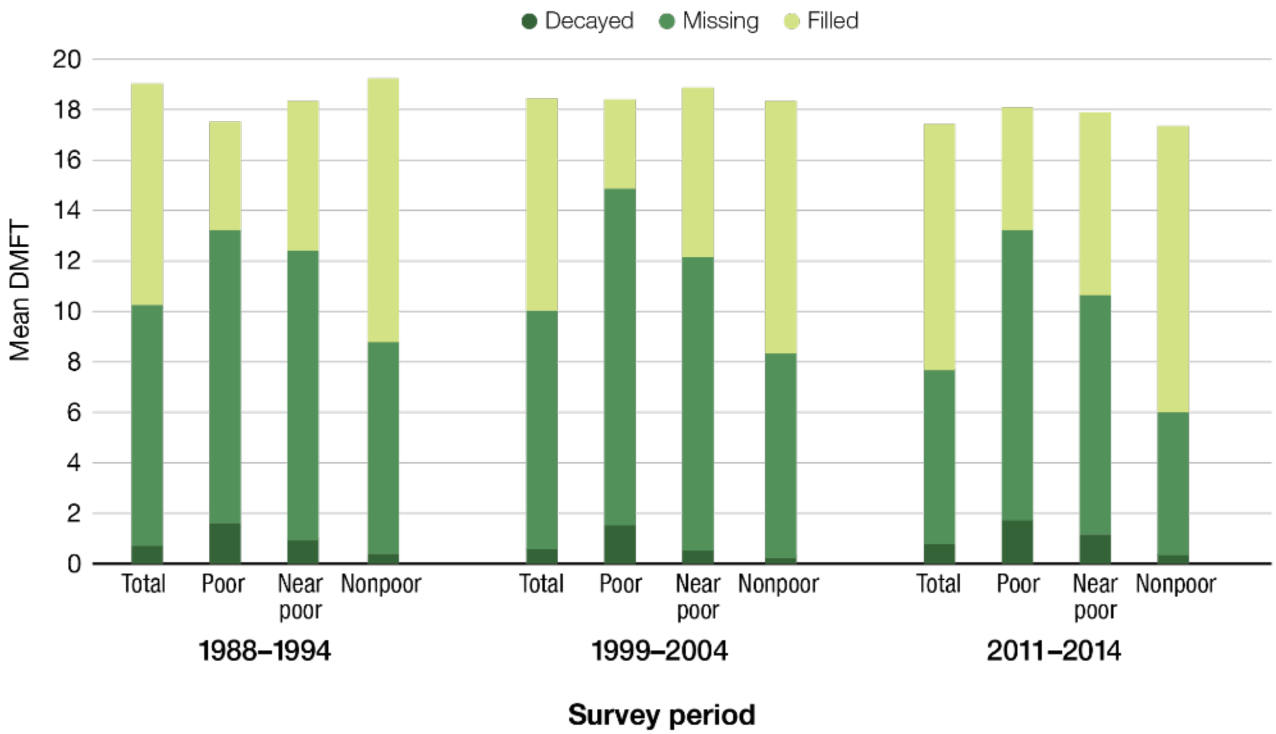
Figure 13. Percentage of adults ages 65 and older with untreated dental caries in permanent teeth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Prevalence of untreated dental caries in permanent teeth (DT > 0). **FPG** = Federal Poverty Guideline: < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 14. Mean DMFT for adults ages 65 and older by poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Mean DMFT = Sum of the means of decayed (DT), missing (MT), and filled (FT) permanent teeth. FPG = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

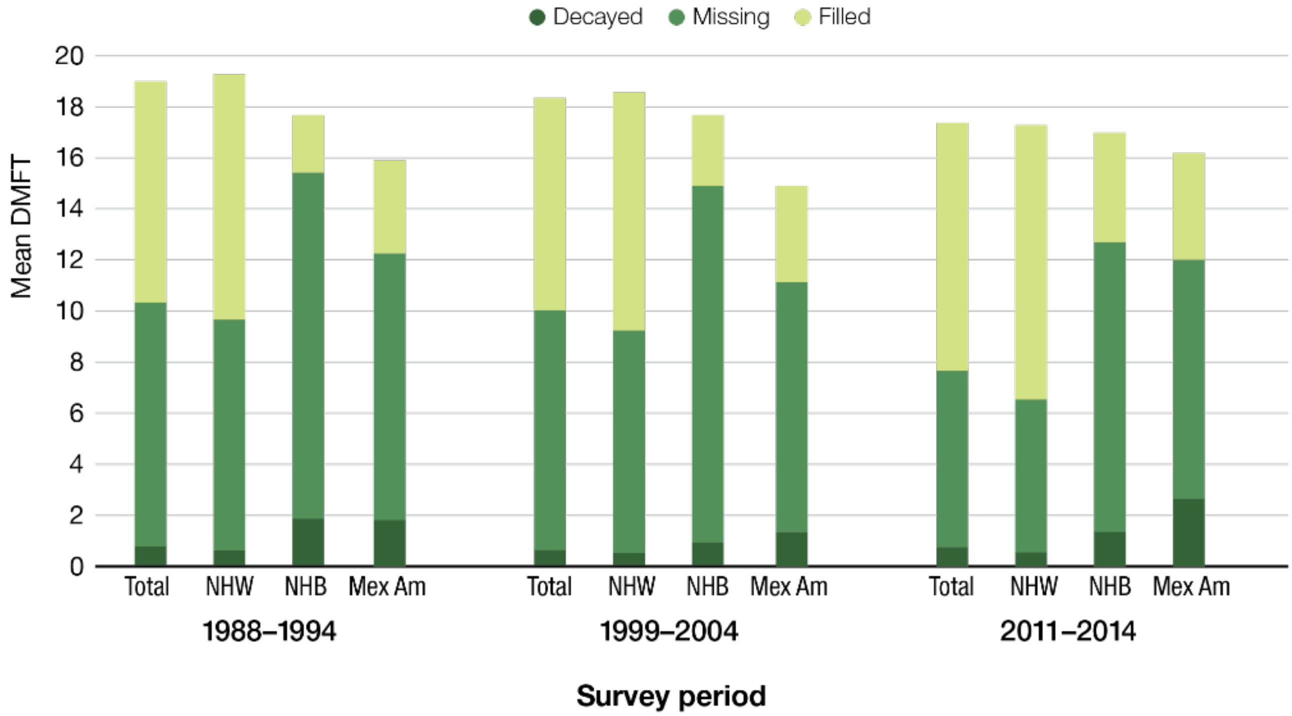
Whenever possible, reducing or modifying medication routines can help to lower the prevalence of xerostomia. Raising awareness among health professionals, including physicians, nurses, and pharmacists, about the negative oral health effects of dry mouth due to polypharmacy remains a challenge (Marcott et al. 2020). Older adults admitted to the hospital should be asked about dry mouth as part of the standard medical history obtained at hospital admission.

Current challenges for conducting research on and treating dry mouth include obtaining valid, reliable, and representative data on salivary flow rates; understanding the natural history of dry mouth; and managing polypharmacy at the population level. Measuring salivary flow rates in epidemiological studies is difficult and time consuming. Researchers would benefit from a standardized saliva collection technique for population studies because there is no current guidance in the most widely used oral epidemiology manual (World Health Organization 2013). Understanding the natural history of dry mouth requires data from prospective cohort studies, particularly studies that measure both xerostomia and salivary flow. Little is known about how the condition manifests throughout the life course. Data from some cohort studies of older adults have shown variable degrees of incidence and resolution over time (Locker 1995; Thomson et al. 2006c; Johansson et al. 2009; Enoki et al. 2014), but the knowledge base for younger or middle-aged adults is limited.

Loss of Teeth

Edentulism, the loss of all natural teeth, decreased from about 32% to 17% among adults aged 65 and older over the past 20 years (Figure 16). Among those 75 and older, substantial declines in edentulism also were observed, with a decline from about 38% to 22% overall.

Figure 15. Mean DMFT for adults ages 65 and older by race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Mean DMFT = Sum of the means of decayed (DT), missing (MT), and filled (FT) permanent teeth. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American.

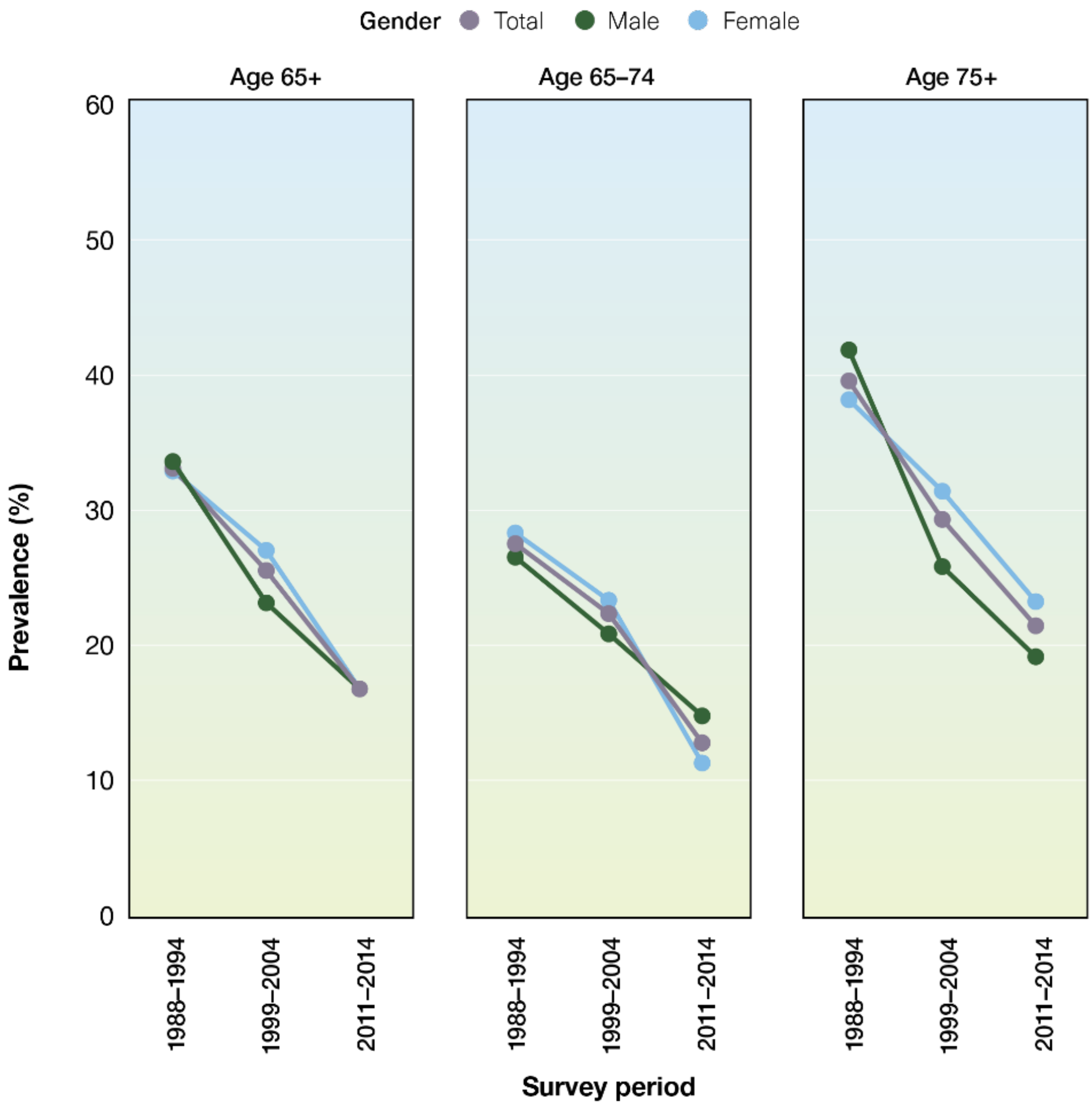
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Edentulism has declined substantially for all older Americans, regardless of sex, race/ethnicity, and poverty. For example, among older non-Hispanic Black adults, edentulism decreased from 37% to 26% and from 51% to 33% for those age 75 and older (Figure 17). Significant improvements were observed for older adults living in poverty (45% to 30%) and for adults age 75 and older living in poverty (51% to 36%) (Figure 18).

The prevalence of older adults aged 65 to 74 years with a complete dentition has improved over time, doubling since the year 2000, from about 8% to 17% (Figure 19). However, this good news is tempered by the significant increase in disparities based on race/ethnicity and poverty status. Substantial increases have occurred for non-Hispanic Whites (improving from 8% to 20%), but the increase observed for non-Hispanic Blacks was not significant (3% to 5%), and there was no change for Mexican Americans in this age group. Although increases observed across poverty strata were significant for all groups since 2000, disparities between the poor and the more affluent older adults aged 65 to 74 years have increased.

Having a functional dentition (more than 20 teeth) also has improved markedly among older adults since the publication of the 2000 report on oral health, increasing from 46% to 65% (Figures 20–22). Improvement was observed across sex, racial/ethnic, and income groups. Although key subgroups of older Americans experienced significant increases, substantial disparities observed at the time of the last Surgeon General's Report on oral health in 2000 did not improve during the last 2 decades. For example, although non-Hispanic Blacks and Mexican Americans improved from 24% to 33% and from 38% to 49% respectively, because, non-Hispanic Whites improved from 48% to 72%, the observed disparity for this important oral health metric worsened during the last 2 decades.

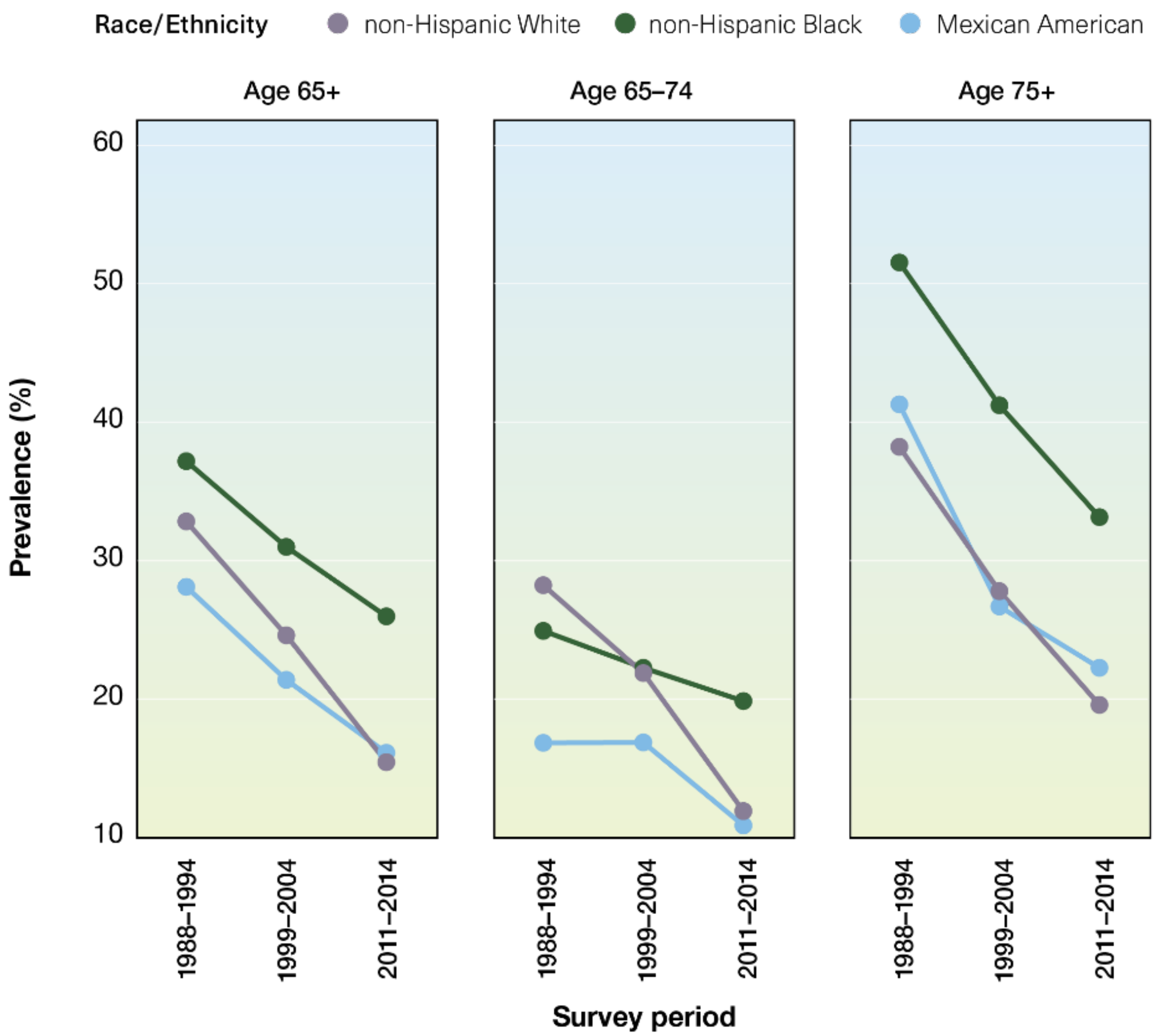
Figure 16. Prevalence of edentulism among adults age 65 years and older by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Edentulism is complete loss of all natural permanent teeth.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

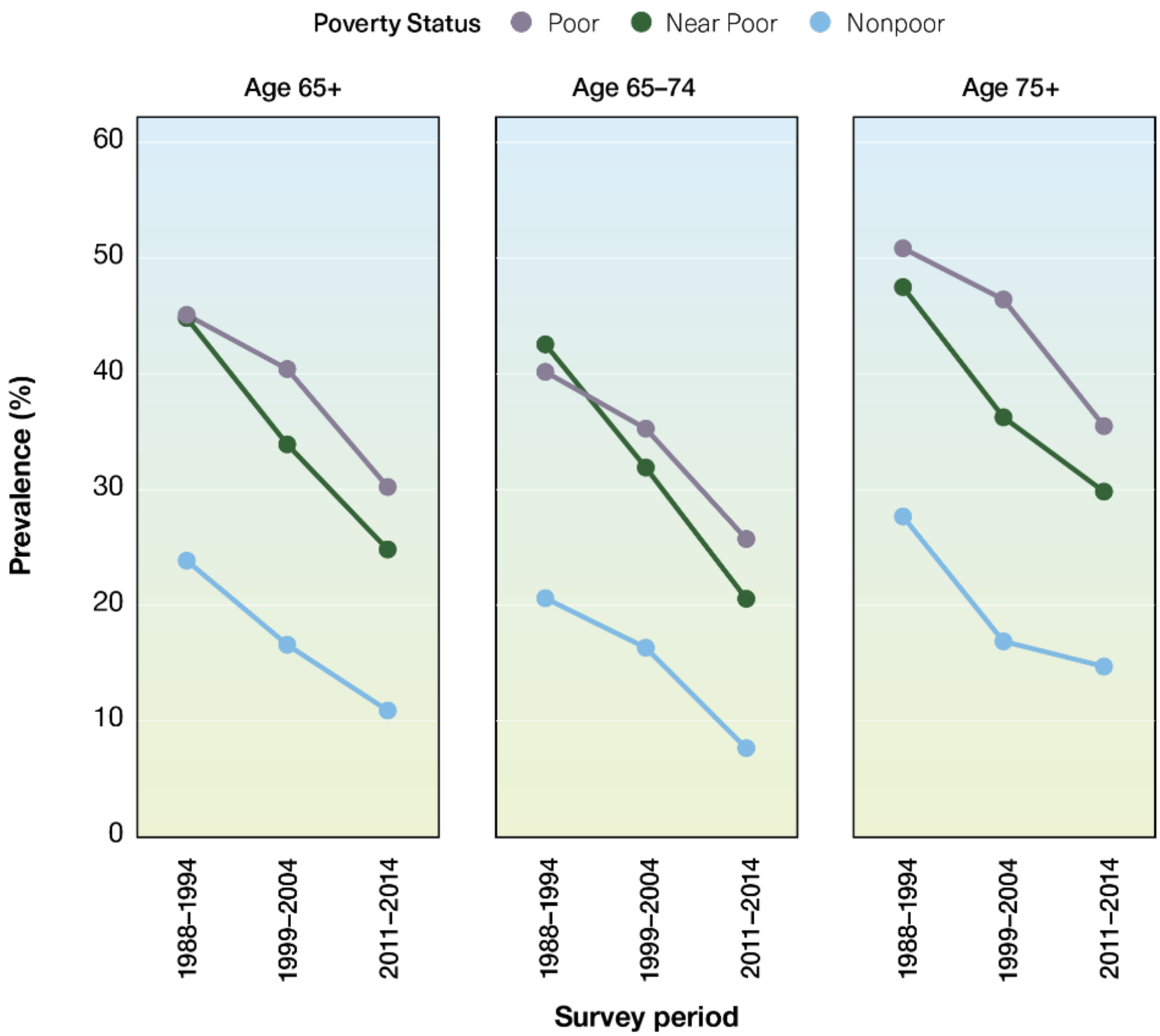
Figure 17. Prevalence of edentulism among adults age 65 years and older by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Edentulism is complete loss of all natural permanent teeth.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

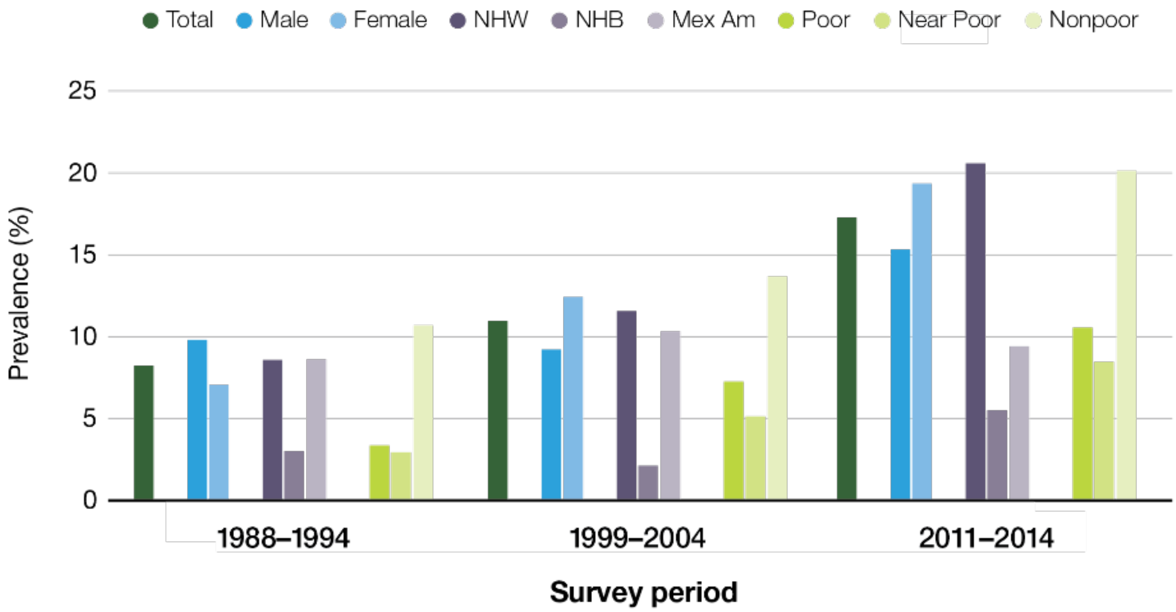
Figure 18. Prevalence of edentulism among adults age 65 years and older by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Edentulism is complete loss of all natural permanent teeth; FPG = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 19. Percentage of adults ages 65–74 with a complete permanent dentition by gender, race/ethnicity, and poverty status: United States, 1988–1994, 1999–2004, 2011–2014.



Notes: Complete dentition is having all natural teeth remaining (total = 28), excluding third molars (wisdom teeth). FPG = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. NHW = non-Hispanic White, NHB = non-Hispanic Black, Mex Am = Mexican American.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Differences by income were even more pronounced. For all older Americans living in poverty, the prevalence of having a functional dentition increased from 32% to 41%. However, prevalence increased from 52% to 74% for older, nonpoor Americans. Among older adults age 75 and older, there was no significant improvement for those living in poverty (29% vs 35%), whereas there was substantial improvement for nonpoor adults age 75 and older (44% vs 69%) (Figure 21).

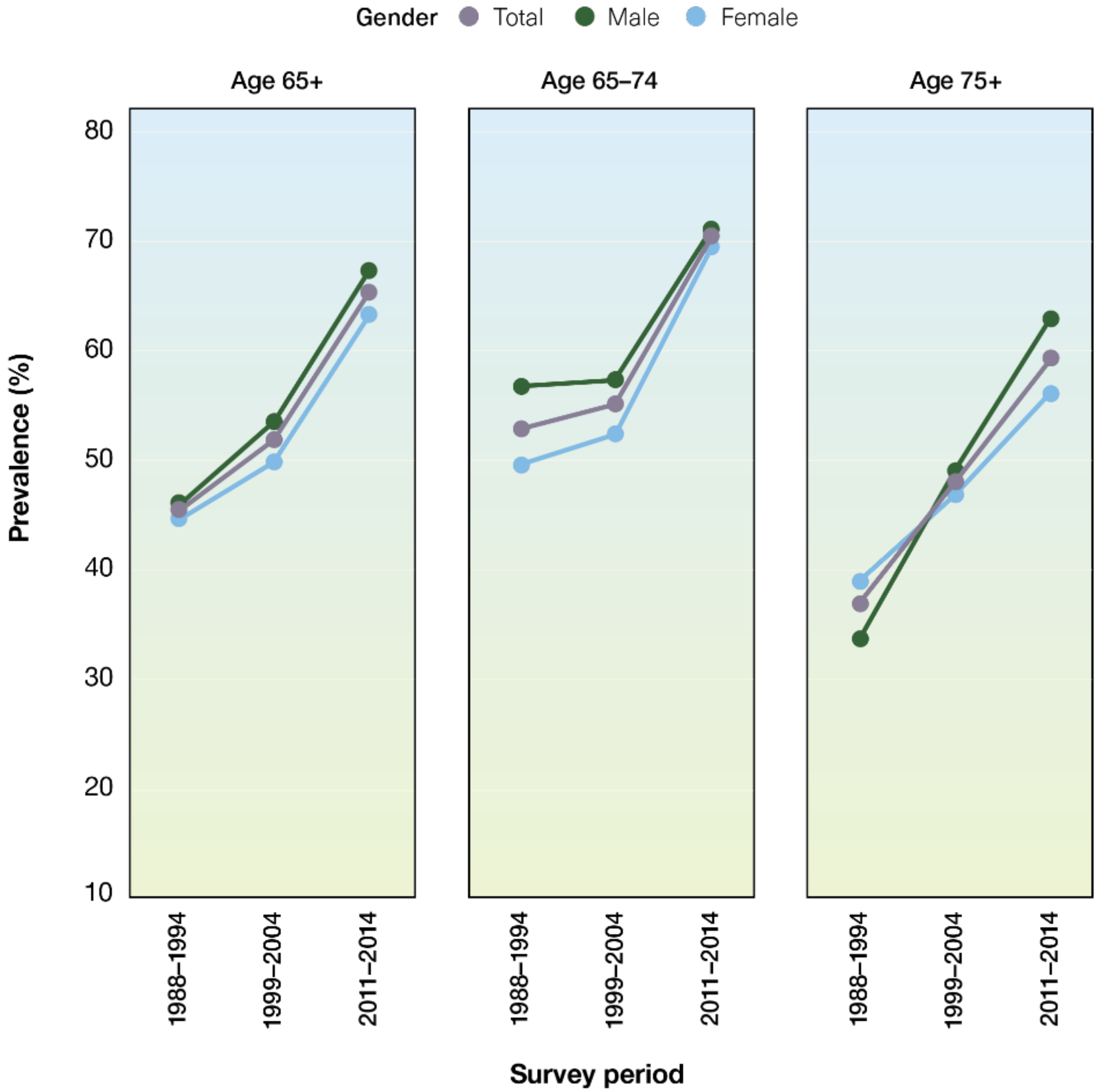
High-Risk Behaviors Affecting Oral Health in Older Adults

Dietary Behaviors, Nutrition, and Food Insecurity

Oral health and nutrition are interrelated challenges for older adults (Gerontological Society of America 2020). The associations between tooth loss (with or without dentures), cognition, diet, nutrient intake, and nutrition status are multidirectional and become even more complex for older adults who are managing multiple comorbidities. As oral health declines, individuals might not even realize they are making changes to their diet by choosing softer, less varied, and less nutritional foods that can present a risk to their dentition and health.

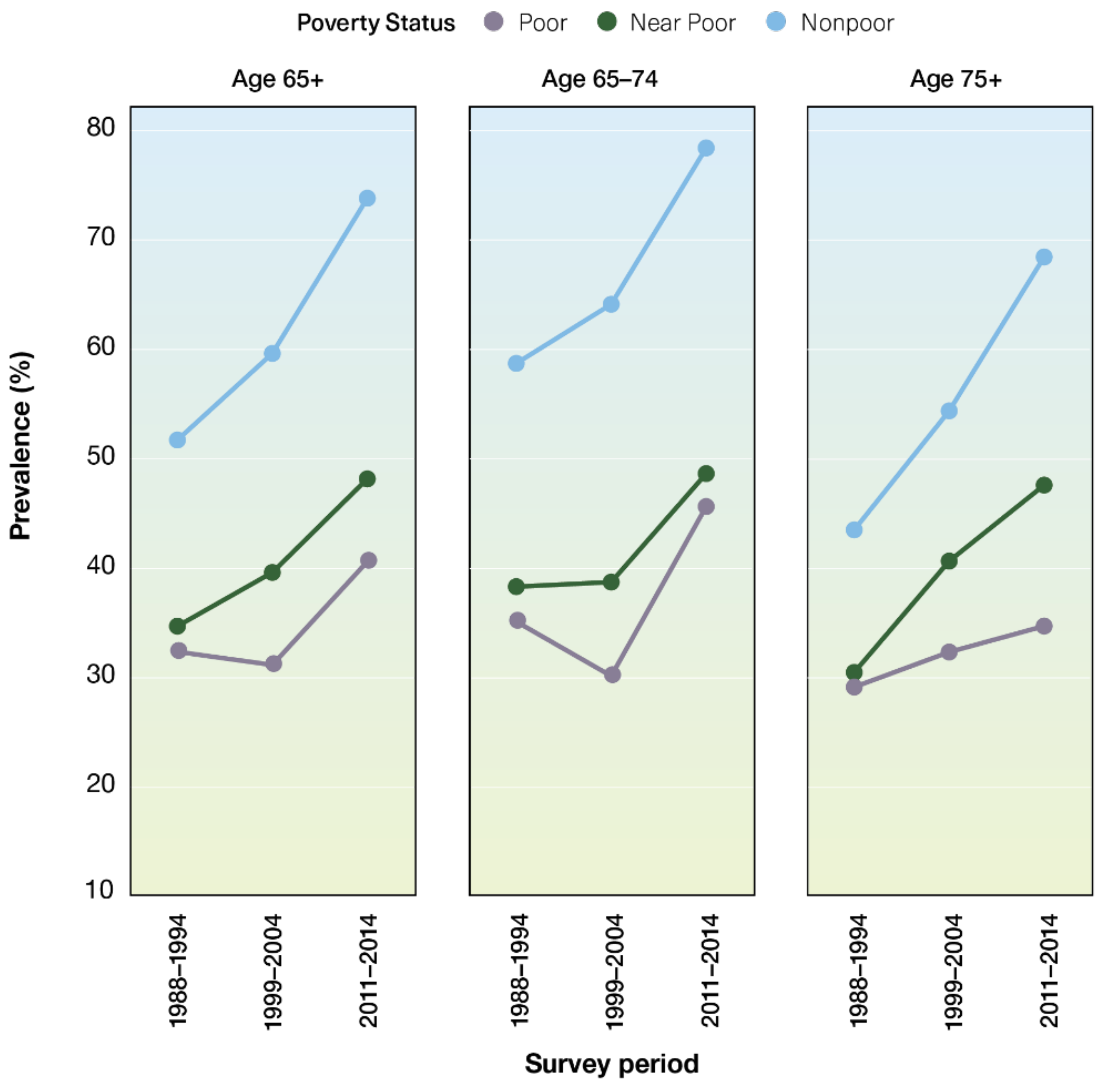
Both oral and systemic conditions can impact dietary choices and dictate food texture (Chavez et al. 2018). People who have had a stroke or have Alzheimer's disease, for example, may have chewing and swallowing problems that restrict their diet to soft textures or thickened liquids. These types of diets, combined with increased frequency of intake over the day, can present a challenge to oral hygiene and the prevention of caries and periodontal disease progression. When the diet is altered specifically because of dental pain or missing teeth, then restoration of the dentition could resolve the issues, and diet could be improved. Older adults can experience changes in smell or taste that are associated with normal aging; or they may result from dental disease, oral pathology, or the use of multiple medications. Such chemosensory changes can affect enjoyment of food and, subsequently, nutritional status (Chavez et al. 2018).

Figure 20. Percentage of adults age 65 years and older with a functional dentition by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

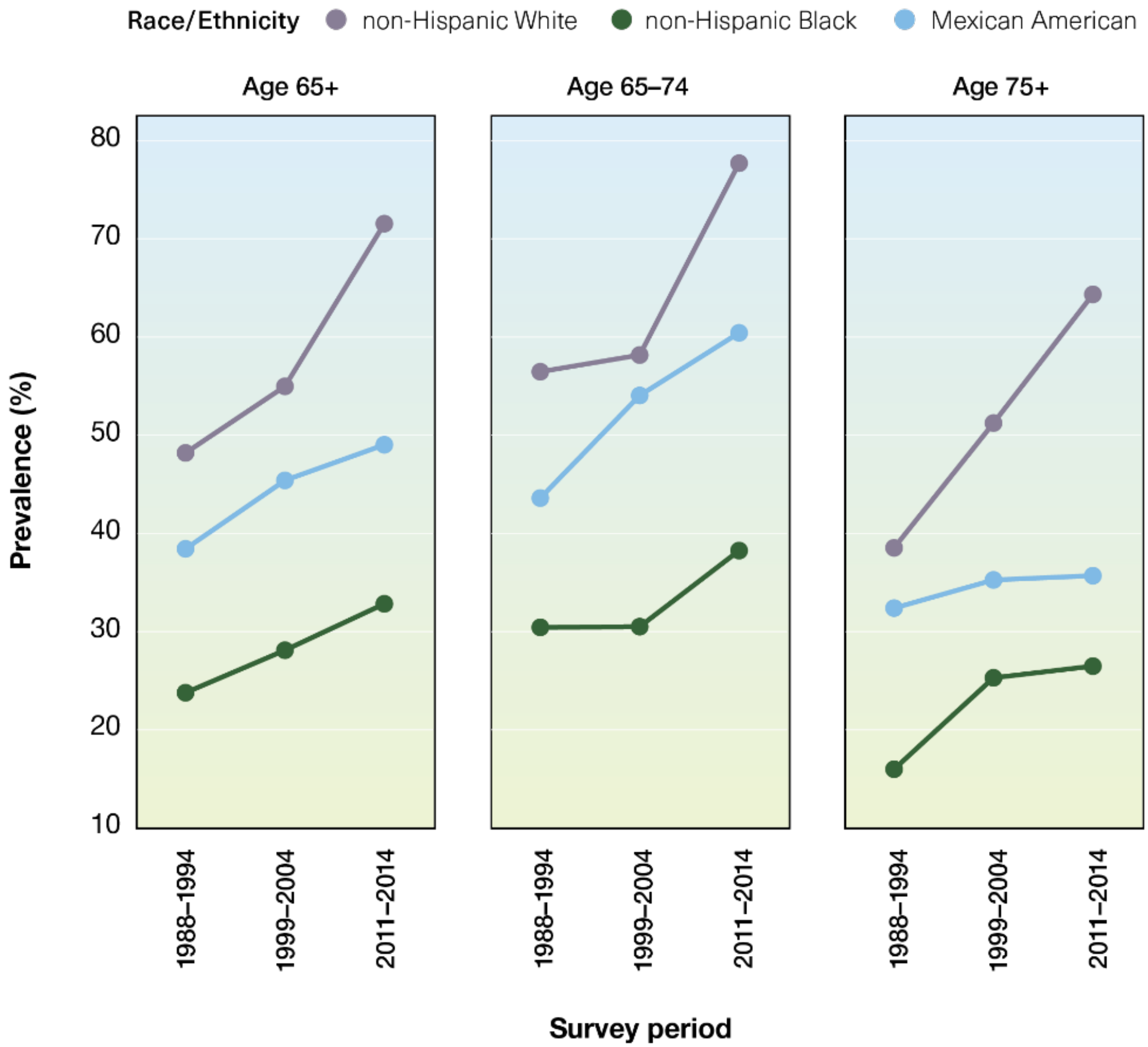
Figure 21. Percentage of age 65 years and older with a functional dentition by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth). FPG = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 22. Percentage of adults age 65 years and older with a functional dentition by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Note: Functional dentition is having 21 or more permanent teeth remaining, excluding third molars (wisdom teeth).
Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Social and economic issues may be at the center of nutritional deficiencies in older adults (Gerontological Society of America 2020). For those who rely on social opportunities to access a nutritious meal, social isolation can affect their nutritional status. Identifying and making an appropriate referral for assistance can be an important element of care for those who lack access to nutritious meals as a result of eating alone, have a limited ability to shop, or experience difficulty preparing meals for themselves. This can be as important as restoring a dentition that may be a source of embarrassment for an older individual who might be isolating as a result. Many older adults with limited incomes who suffer disproportionately from oral and systemic diseases also may experience food insecurity (Gerontological Society of America 2020). Referral to appropriate social services or enlisting the help of family or friends—with the individual's permission, or even through Adult Protective Services in cases of abuse or neglect—are important opportunities for intervention that can occur when oral health providers are an integral part of a larger interdisciplinary team (Chavez et al. 2018). Effective approaches are needed to manage the impact of medications or of nutritional deficits on oral health, as well as tooth loss and/or tooth replacement on diet, nutrition status, and the eating experience.

Social Determinants of Health

Older adults who are disadvantaged or marginalized face additional challenges. For example, among hundreds of factors considered, emotional and systemic factors—such as chronic stress and limited health literacy— were the strongest predictors of self-reported poor dental health among urban Hispanics (Yoon et al. 2018). Older American Indian/Alaska Native adults, many of whom live in rural communities with limited transportation, also face emotional and systemic factors that contribute to persistent poorer oral health compared to the general U.S. population.

The lack of research on social inequities among older adults has been recognized in regard to overall health. The National Institute on Aging, for example, published a report in 2015 detailing a framework for health disparities research, particularly on older adults (Hill et al. 2015; National Institute on Aging 2018). In 2017, to address this lack of focus, the National Institute of Dental and Craniofacial Research encouraged partnerships among researchers in aging and oral health disparities and interdisciplinary research collaborations to address disparities among older adults (Fischer et al. 2017).

Interrelated Effects of Oral Health with General Health

The scientific literature exploring the relationships between oral health and general health has grown substantially during the past 20 years. Overall, the literature suggests an important relationship between chronic oral infection/oral inflammation as a result of periodontal disease and the risk for some noncommunicable diseases, primarily cardiovascular disease, diabetes, respiratory disease, and cognitive impairment. A growing body of evidence implicates inflammation as playing an important role in this relationship, particularly with the association between cardiovascular disease and periodontitis (Carrizales-Sepulveda et al. 2018). Emerging research is now pointing to the possibility of a hyperactive immune response occurring after an overabundant production of a particular type of white blood cell, or neutrophils, in response to bacterial infections responsible for periodontitis (Fine et al. 2021). There continues to be a need to define the relationship between periodontal disease and systemic health.

Furthermore, the knowledge gathered over the past 2 decades indicating an association between various dental conditions and diabetes, cardiovascular disease, and cancer also have underlying effects related to poor nutrition. An almost century-old hypothesis on nutrition is gathering support: nutritional interventions associated with improved oral health may reduce the risk for some non-oral chronic diseases. A review by Moore and colleagues (2018) of nutrition and cognitive decline and late-life depression concluded that B vitamins, n-3 polyunsaturated fatty acids, and polyphenols may exert strong protective effects in preserving cognition and preventing depression. Conducting clinical research to identify effective dietary interventions is an ongoing challenge, but it is essential for discovering new and promising preventive interventions directed toward reducing the U.S. burden of chronic noncommunicable and dental diseases.

Prevention and Management of Oral Diseases and Conditions

Since the publication of the 2000 Surgeon General's Report on oral health, evidence-based approaches to treatment planning and management of oral diseases and conditions in older adults have emerged. The Seattle Care Pathway is designed as a pragmatic approach to care for older adults based on a variety of factors, starting with assessing patients' functional status and then considering the potential risks to their oral health (Pretty et al. 2014). There are essentially five functional categories, with each having a set of prevention and treatment recommendations that is appropriate for each category (Table 4).

Many older adults experience difficulties in self-care and access to care, placing them at higher risk for oral diseases. Even something as basic as brushing one's own teeth and flossing may not be possible because of arthritis or the tremors of Parkinson's disease, for example. The use of electronic brushes and prethreaded floss, over-the-counter fluoride rinses, and prescription gels (1.1% NaF) are helpful. Yet, as people become more frail and dependent, they may require the assistance of a home health aide or family caregiver. Regular, more frequent professional care also may be needed, especially in persons who regularly experience dental decay or have periodontal disease, dental prostheses, or dental implants. Addressing many of these needs requires facing persistent and complex challenges that can be compounded when retired adults lack the financial resources to receive regular oral health care.

Management of Tooth Loss and Replacement with Dental Implants

Dental implant technology has markedly improved in the past 2 decades. Improved materials, procedures, and provider experience have made it possible for adults to replace missing teeth with implants faster and with higher success rates than ever before. Contemporary dental implants that are finished with a crown (Figure 27 in Section 3A) or a denture are very durable and aesthetically realistic. Their success rates are typically among the highest of any type of surgical implants. The survival rate of implant-supported dentures after 25 years is greater than 80% (Frisch et al. 2020). In addition, it was reported that most implants did not develop signs of periodontal inflammation around the implant (peri-implantitis) over the same time period. More information on dental implants is presented in Sections 3A and 6 of this monograph.

Because of improved durability, aesthetics, and support, dental implants are becoming the preferred treatment for many older adults who can afford them. During the last 2 decades, the prevalence of dental implants has increased from about 1% to more than 7%. (Figure 23). In addition, older adults are three times more likely to have a dental implant, compared to working-age adults. Older adults have an average number of 2.4 dental implants. This number has remained consistent as the percentage of older adults with a dental implant has increased.

Managing Salivary Gland Dysfunction and Xerostomia

Dry mouth is difficult to treat. The available therapies aim for palliation (symptom relief), stimulation (of salivary flow), and regeneration (of secretory tissue). The approach taken depends on whether dry mouth is due to medications, radiotherapy, or Sjögren's syndrome (Table 5). The past 20 years have seen more randomized, controlled clinical trials of interventions for the relief of dry mouth, enabling systematic reviews to determine their efficacy. To date, four Cochrane reviews involving 87 studies (Furness et al. 2011; Furness et al. 2013) have been undertaken. Slightly more than one-third of these studies were assessed as being at high risk of bias, indicating a need for better quality studies and more careful reporting. Even so, those reviews have been useful in assessing the likely efficacy of the various therapeutic and preventive approaches.

While there is no sound evidence yet for the efficacy of medication review in treating medication-induced dry mouth, consistent evidence about the role of polypharmacy in causing dry mouth suggests a logical starting point. Oral health professionals, medical providers, and community pharmacists working together could raise awareness of dry mouth and ensure that affected individuals are managed and advised in a timely and appropriate manner. The evidence for palliation using water sprays, chewing gum, and sucking lemon drops remains relatively weak, although these options may be useful for some individuals.

Table 4. Seattle Care Pathway (SCP) overview

	No dependency	Predependency	Low dependency	Medium dependency	High dependency
Implementation	They are the most fit in their age group	The disease(s) is controlled but with the potential to impact oral health	The systemic disease(s) is impacting oral health but no obvious dependence	The systemic disease is impacting oral health; requires some support to access care and maintain oral health	The systemic disease impacts oral health and prevents oral health care
Assessment of risks to oral health	Recall and risk assessment to standard of care	Specific risks to oral health from the disease(s) and its management and reevaluation of the current prevention plan	Identify cause of dependency and associated risk(s), increased recall, and prepare for change in prevention plan	Recognition that increased dependency increases risk; include other providers, that is, interdisciplinary team (IDT) to address risks, reassess prevention plan	Identify barriers to care and monitor potential for abuse
Prevention plan	Patient performs routine homecare	Possible implementation of prescription (Rx) preventives and specific oral hygiene (OH) instruction and OH plan	Identify cause of risk, modify plan as needed, consider role of polypharmacy, Rx preventives, OH plan	Increased involvement of the IDT, review polypharmacy for risks, Rx and professionally applied preventives, daily OH plan	Rx and professionally applied preventives, risk-specific daily OH
Treatment goals	Routine standard of care for dental need	Create a long-term plan for restorative and maintenance care	Restore and maintain function	Increased minimally invasive care and focus on preservation; however, viability of more complex care should be considered	Focus is palliative care, maintenance of dignity and comfort
Communication	Direct patient education	Discuss potential oral complications related to disease(s) or its management directly with the patient	Identify others who can participate in prevention with the patient	IDT focus on ensuring support for a daily care plan provided by the patient or caregiver as needed	All providers and caregivers involved to ensure well-being of the patient

Notes: Based on levels of dependency, SCP recommends risk assessments needed, appropriate preventive measures, and treatment considerations and a guide to what information should be provided to whom at each stage of dependency.
Source: Chávez et al. (2018). With permission from Elsevier.

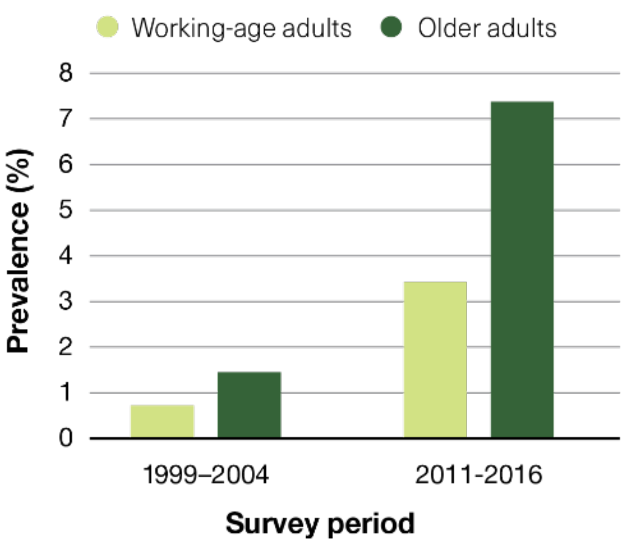
Topical lemon and citric acid can stimulate salivary flow, but excess use can result in the erosion of dental enamel. Systemic pilocarpine or cevimeline has been effective (Brimhall et al. 2013).

Patients who have undergone radiotherapy to the head or neck are at particular risk of dry mouth. While this is far less common than the medication-induced condition, it presents a clinical problem that severely compromises quality of life. Accordingly, therapeutic approaches have received greater research attention. Investigations of palliative approaches have used a range of methods—saliva substitutes, chewing gum, and water—but the evidence for their effectiveness remains weak. Stimulation using systemic pilocarpine has been effective, but not without side effects. The evidence for effectiveness is weaker for electrical stimulation and the medication bethanechol. Artificial saliva products face challenges in matching the consistency and properties of human saliva.

Gene therapy and stem cell therapy interventions have been investigated using animal models, but there is little progress to date. For Sjögren's syndrome, the evidence is weak for palliation using saliva substitutes. Gene therapy and stem cell therapy interventions have been investigated using animal models. Saliva-restoring gene therapy clinical trials currently are being conducted. However, the evidence is relatively strong for stimulation using systemic sialogogue, pilocarpine, and cevimeline (National Institute of Dental and Craniofacial Research 2018; Chiorini 2020).

Finally, managing dry mouth requires attention to the dentition and its supporting structures, including the oral mucosa. Preventing dental caries is an important part of such management and involves twice daily use of fluoride toothpaste and the avoidance of nonmilk extrinsic sugars (such as sugary beverages or sugar added to coffee), along with more intensive preventive measures, such as prescribed fluoride (1.1% NaF, 5500 ppm F) or mouth rinses, where appropriate. In older adults, dry mouth also can affect denture retention, and patients may need to use denture adhesives (Ship and Hu 2004). Not only can there be problems in retaining and using partial dentures, but the remaining natural teeth—especially abutment teeth—may be at increased risk of dental caries. Although the long-held assumption that older people taking xerogenic medications are at higher risk for caries has not thus far been supported by epidemiologic evidence (Thomson et al. 2002), prudence dictates the assumption that people who take many medications are at increased risk for dry mouth.

Figure 23. Percentage of adults age 20 and older with at least one dental implant: United States, 1999–2004 and 2011–2016.



Note: Working-age adults are ages 20–64 years; older adults are age 65 and older.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Managing Effects of Oropharyngeal Cancer Treatments

Efforts to Reduce Illness from Radiation Therapy

Radiation therapy affects normal tissue in the field of radiation by causing rapid cellular turnover in bone or soft tissue. The long-term side effects from radiotherapy include salivary gland hypofunction and dry mouth, resulting in extreme risk for dental caries. There also is the potential for osteonecrosis of the jaw related to radiation therapy and high-dose bisphosphonate/antiresorptive therapy, which may be administered intravenously to prevent or manage bony metastasis, as well as trismus (lockjaw) that severely limits oral range of motion, severe mucositis (ulceration and irritation of the oral mucosa), and significant tissue defects resulting in functional changes (Vissink et al. 2018). Trismus affects 23–45% of individuals who undergo radiation therapy and can significantly impact the muscles involved in chewing (Brennan et al. 2008). Development depends on such factors as age, dentition, primary cancer site, free-tissue transfer, re-irradiation, and chemotherapy (Rapidis et al. 2015). These conditions can result in significant short- and long-term or even permanent pain and discomfort, and have adverse impacts on nutritional intake, speech, and swallowing, as well as oral hygiene practices and OHRQoL. Aggressive preventive measures and frequent dental visits are required to prevent deterioration of the oral cavity, which can occur rapidly.

A major shift over the past 20 years has been how radiation therapy is delivered. Intensity-modulated radiation therapy (IMRT) was invented in 1996 to treat prostate cancer, with the goal of minimizing radiation to healthy tissue. IMRT was modified for the treatment of oropharyngeal cancer (OPC) using a parotid-sparing protocol (Murdoch-Kinch et al. 2008; Duarte et al. 2014). The goal was to save at least one of the parotid glands to decrease the degree of salivary gland hypofunction, minimize risk for osteoradionecrosis (ORN), or destruction of bone due to radiation, and reduce other tissue involvement that could increase discomfort and risk discontinuing radiation. Future goals are to increase radiation distribution precision and to more clearly identify the amount of radiation received in dental areas (Tsai et al. 2019).

Reducing Extractions and Osteoradionecrosis

The traditional standard of care has been to act aggressively in removing diseased teeth prior to radiation therapy to minimize the risk for ORN, should extractions be needed at a later date. Before the turn of the century, it was highly likely that multiple extractions would occur due to the poor condition of the dentition and the high risks of decay and potential ORN. Poor condition of the dentition often was associated with the risk factors of the cancer—smoking and alcohol use—and patients typically reported minimal use of routine dental preventive services. Now that OPC is increasingly related to human papillomavirus (HPV), more individuals who receive radiation treatment have fewer dental problems and a history of regular dental care. Knowing that teeth can be maintained because of a reduced risk of ORN and the availability of preventive measures, such as silver diamine fluoride (Strohl et al. 2019), medical indication to remove teeth prior to radiation therapy has decreased.

The timing of extractions also has been studied, with the goal of maximizing the time between extractions and the start of radiation to allow for maximum wound healing (Strohl et al. 2019). This typically requires advanced communication and a team approach between the oncology and dental teams, which is a best practice. Ineffective or no collaboration may result in the need for multiple sessions requiring general anesthesia, resulting in additional costs and risks. The currently established interprofessional head and neck cancer team (dental, oncology, ENT, radiation) approach should be implemented nationwide to maximize individualized patient care. Implementing patient-specific plans would avoid aggressive extraction approaches and serve to better maintain the patient's quality of life. Strategies for team approaches should be investigated to improve long-term outcomes.

Oral Rehabilitation

Significant developments in both microsurgical techniques and osseointegration have generated new strategies for managing surgical defects after cancer surgery. Prior to 2000, mandibular surgery resulted in a continuity defect, in which the remaining mandible was unsupported and provided little potential for function. Today, mandibular defects are routinely reconstructed with soft or hard tissue, resulting in significant potential for function (Likhterov et al. 2019; Patel et al. 2019).

Survivors of Other Cancers

Over the past 20 years, oncologists and oral surgeons have identified the potential for osteonecrosis of maxillofacial bone in patients who have received intravenous bisphosphonate therapy for metastatic cancer, as well as in those who received radiation therapy. In addition, the potential impact on mucosa and salivary glands from graft versus host disease after a bone marrow transplant has been recognized.

Special Needs Populations

Older adults with disabilities and special health care needs continue to face challenges in obtaining oral health care, including physical disabilities, transportation challenges, and financial limitations. The development of a sustainable, interdisciplinary system of medical and dental care for older adults continues to be a priority. Progress in integrating oral hygiene care with home health care and mobile care provided collaboratively by dental team members is beginning to show promise (Langelier et al. 2017).

Homebound Older Adults

Advances in medicine and dentistry and better disease management have improved older adults' tooth retention and OHRQoL. Nevertheless, certain problems—namely, dental caries, periodontal disease, and tooth loss—are presumed to persist, especially among vulnerable and homebound older adults (Muller et al. 2017). In general, there is limited information about rates of tooth decay and edentulism among homebound people because of their living arrangements, the absence of a consistent definition of "homebound," and this population's reluctance to participate in household studies (Holm-Pedersen et al. 2015). Homebound and disabled individuals are perceived to have a high need for dental care but face multiple barriers in accessing care. Improving access to care requires an array of trained, community-based health providers and advocates who understand the importance of oral health, make appropriate referrals, and provide appropriate care for this population (Special Care Dentistry 2002; Ghezzi et al. 2017).

Unless dental care is delivered in their homes, access may be a problem for homebound elders living in urban areas. The issue becomes even more complex for people who live in rural or isolated areas, where distances are longer and health networks and support services are scarce (Holm-Pedersen et al. 2015). Gluzman and colleagues (2013) found that 92% of 125 homebound individuals in their study needed dental treatments beyond oral hygiene, and that 96% indicated that they had not seen a dentist since they became homebound.

Table 5. Overview of evidence for the various therapies for dry mouth

		Evidence level for the various therapies			
Type of dry mouth	Estimated population prevalence	Strong	Promising	Weak	On the horizon
Medication-induced	13%				
Palliation		–	–	Water spray	Medication review
Stimulation		–	Citric or malic acid Pilocarpine rinse	–	–
Regeneration		–	–	–	–
Secondary to cancer treatment	0.1%				
Palliation			–	Saliva substitutes, gum, water spray	–
Stimulation		Pilocarpine (systemic)	Acupuncture	Bethanecol, Electrical stimulation	
Regeneration		–	–	–	Gene, stem cell therapy
Sjögren's syndrome	1%				
Palliation		–	–	Saliva substitutes	–
Stimulation		Pilocarpine (systemic)	–	–	–
Regeneration		–	–	–	–

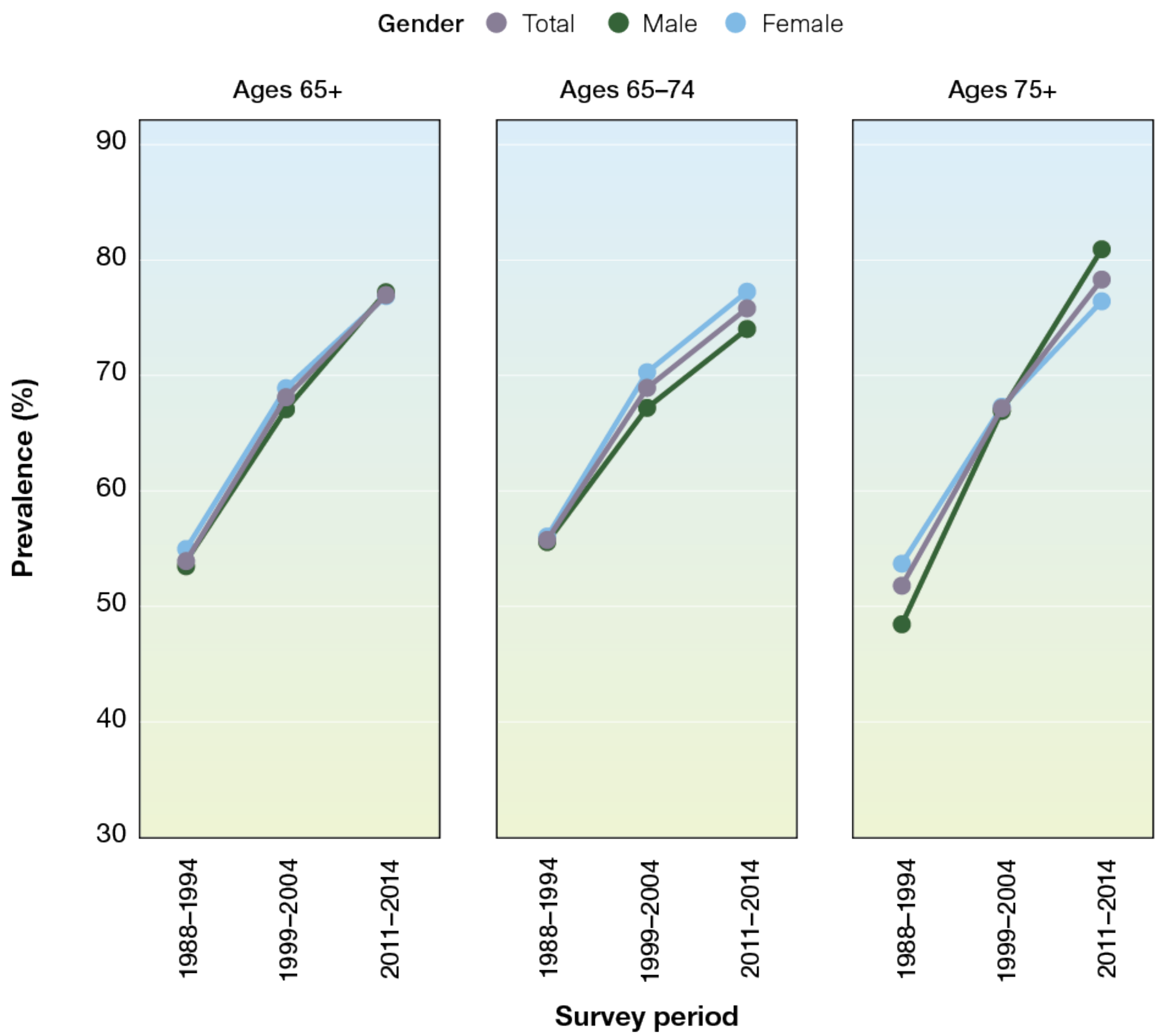
Sources: Davies and Thompson (2015); Furness et al. (2011); Furness et al. (2013); Riley et al. (2017).

Chamut and colleagues (2021) assessed dental visits in the past 12 months among community-dwelling adults who received home- and community-based services (HCBS), administered under the Older Americans Act. Among the five HCBS programs studied—case management, homemaker services, congregate meals, home-delivered meals, and transportation—the groups receiving case management and home-delivered meals, on average, had fewer annual dental visits. Low educational attainment (less than high school diploma) was the strongest indicator for not having had a dental visit (Chamut et al. 2021). Researchers also found that the oldest participants (aged 85 or older) who received home-delivered meals and transportation were more likely to have had a dental visit (Chamut et al. 2021). As an increasing number of older adults retain more of their teeth, meeting the needs and demands for oral care of this population will require additional resources and a skilled dental workforce that is an integral part of the health care system (Thomson and Ma 2014).

The failure to provide regular and preventive oral health care for this population underscores a major gap in the interprofessional model of health care, which does not routinely include oral health care providers (Holm-Pedersen et al. 2015; Critchlow 2017). A transformation of the oral health care system will be required to deliver dental care and prevent oral disease in this difficult-to-reach group, which also receives little attention from policymakers in regard to oral health (Thomson and Ma 2014).

Nursing homes and other long-term care facilities have a limited capacity to deliver needed oral health services to their residents, most of whom are at high risk for oral diseases (Dye et al. 2007). Although nationally accepted guidelines for anticipatory guidance and risk assessment and management—including oral health guidelines—are the standard of care in pediatrics, the adoption of similar standards for oral health in elders is lacking.

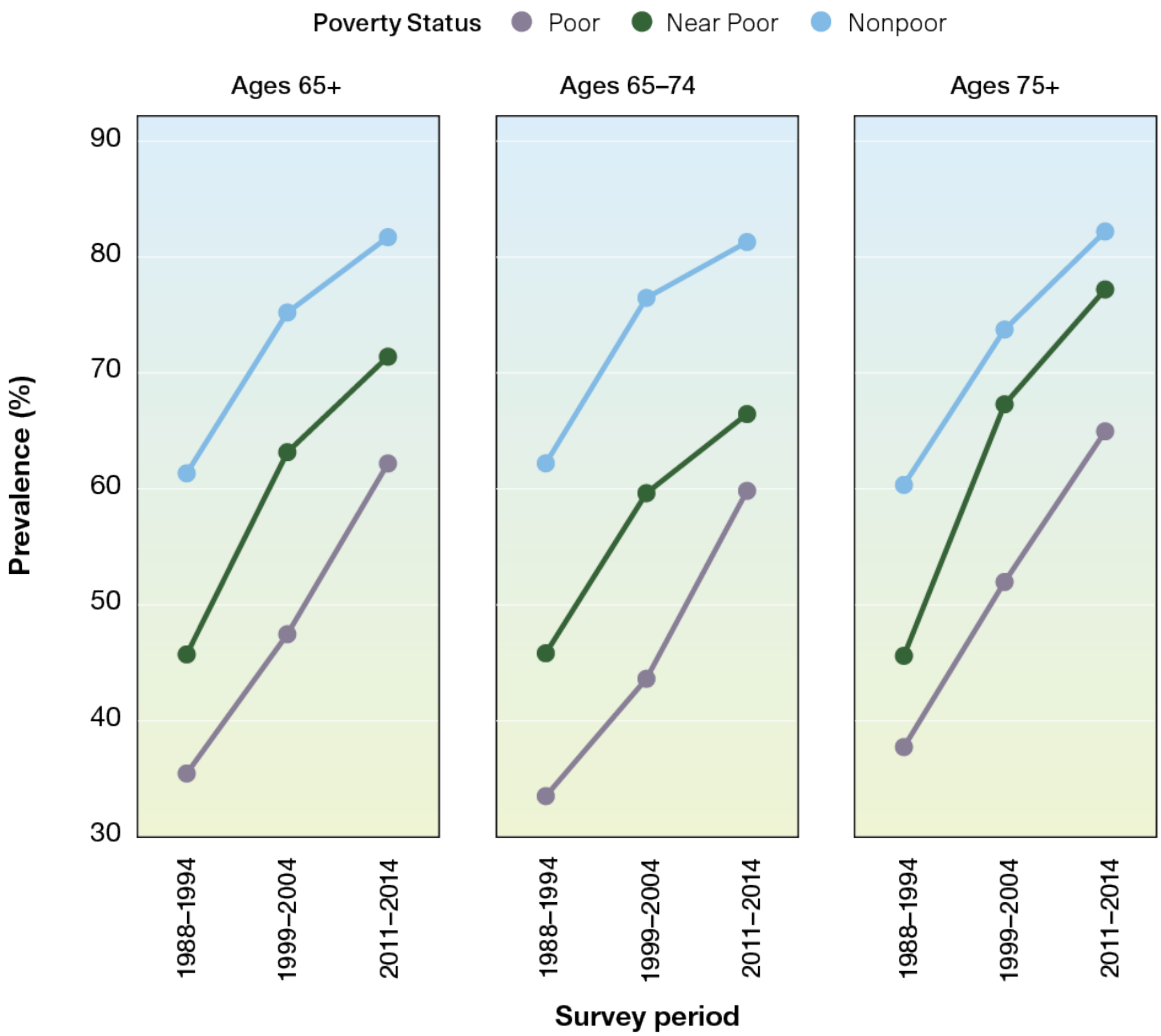
Figure 24. Percentage of adults age 65 years and older reporting overall satisfaction with their teeth and mouth by age group and gender: United States, 1988–1994, 1999–2004, 2011–2014



Note: Overall satisfaction is a self-report of excellent, very good, or good.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

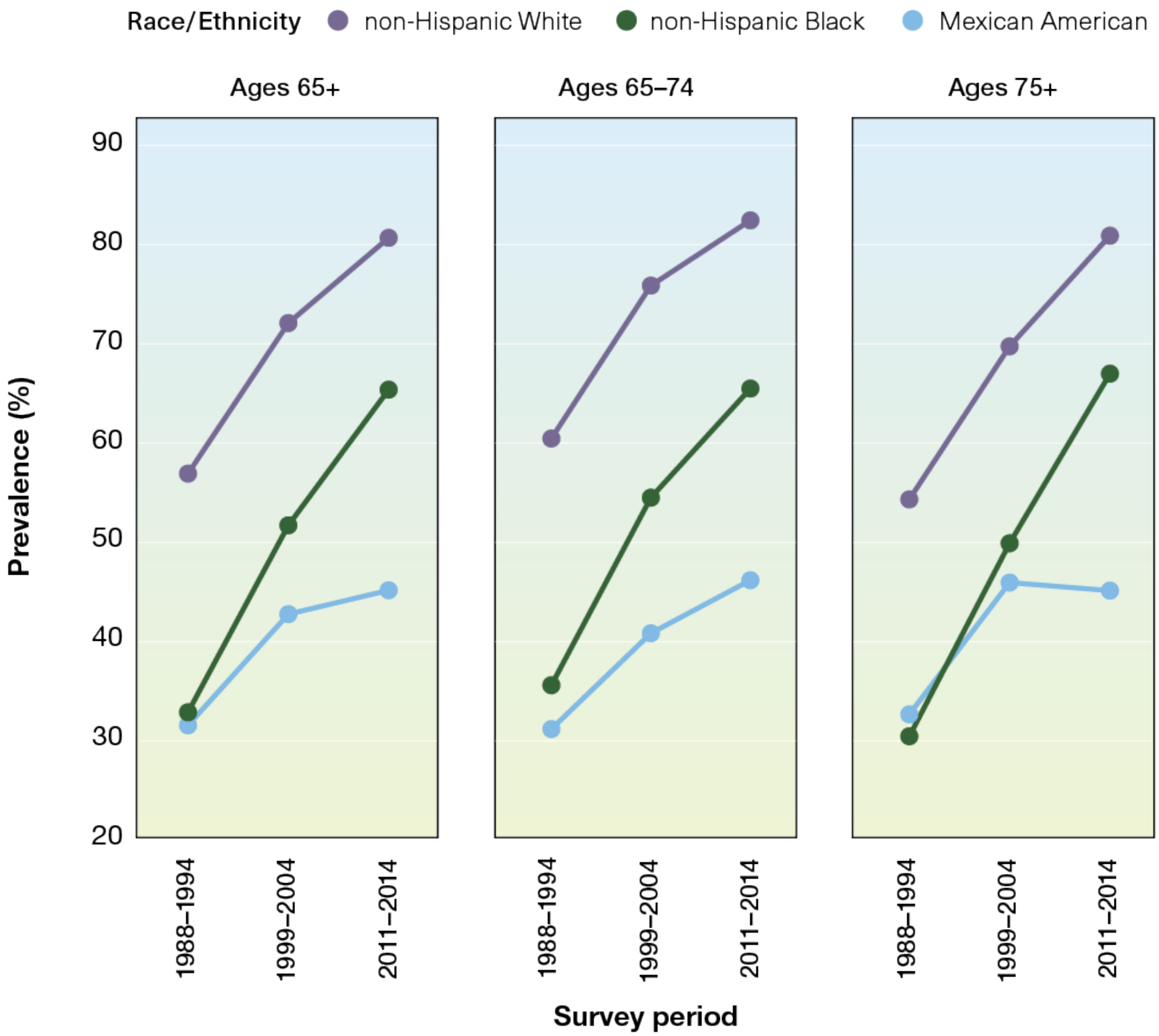
Figure 25. Percentage of adults age 65 years and older reporting overall satisfaction with their teeth and mouth by age group and poverty status: United States, 1988–1994, 1999–2004, 2011–2014



Notes: FPG = Federal Poverty Guideline; < 100% FPG = poor; 100–199% FPG = near poor; and ≥ 200% FPG = nonpoor. Overall satisfaction is a self-report of excellent, very good, or good.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Figure 26. Percentage of adults age 65 years and older reporting overall satisfaction with their teeth and mouth by age group and race/ethnicity: United States, 1988–1994, 1999–2004, 2011–2014



Notes: Overall satisfaction is a self-report of excellent, very good, or good.

Source: CDC. National Health and Nutrition Examination Survey. Public use data, 1988–1994,1999–2004, and 2011–2014.

Having guidelines for this population would facilitate an enhanced focus on older adult oral health and ensure that persons who cannot access oral care receive annual dental and oral cancer screenings, referrals, and prevention services, such as dental cleanings (teeth and dentures) and fluoride applications.

Systems of Care for the Frail Elderly

Studies indicate that current models are not meeting the need for oral care for older, frail adults. Analyses of insurance claims have shown that preventive dental care in older adults with chronic disease is cost-effective (Pourat et al. 2018). However, prospective studies (Sloane et al. 2013) to validate such programs do not exist at a scientific level comparable to geriatric medicine. As a result, the field lacks essential data and evidence-based programs. Critical evaluations are needed for existing models (e.g., inadequate and untrained workforce, limited reimbursement, lack of prevention), promising models (e.g., Program of All-Inclusive Care for the Elderly), and potential workforce models (e.g., role of dental therapists, expanded role for dental hygienists, inclusion of an oral health benefit in Medicare) (Haber et al. 2015).

Because the removal of cost and insurance barriers promotes the use of dental services by older adults (Lee et al. 2015; Slavkin 2017), the addition of an oral health benefit in Medicare would improve access to care nationwide, especially for low-income older adults and those of some racial/ethnic groups. A Medicare dental benefit also might facilitate evidence-based models of comprehensive care, similar to those in geriatric medicine. In 2020, a national coalition of more than 132 stakeholders from dentistry, aging, health care, and industry announced their support of Medicare coverage for medically necessary oral and dental health therapies. Federal legislation will ultimately be required to remove language that excludes the provision of most dental services from Medicare (Chavez et al. 2017).

Another challenge is the insufficiency of the dental workforce to fully address oral health care for older adults. A committee sponsored by the Institute of Medicine (2008) envisioned a future health care system for older adults in which health needs are addressed comprehensively, services are provided efficiently, and patients are encouraged to be active partners in their care. In addition, professional education needs to address the changing environment in which oral health professionals will be needed to provide services. For example, delivering dental care to older, frail adults will increasingly need to occur outside of the traditional dental setting. Moreover, oral health professionals will be called upon to have a greater role in collaborative, palliative, end-of-life care, and current limited training opportunities for the oral health workforce require expansion (Macdonald et al. 2020). This vision of comprehensive medical and dental care remains a viable goal that can be achieved with the right policies and training.

To improve the dental care workforce, the Institute of Medicine committee proposed enhancing geriatric competence, increasing recruitment and retention, and redesigning models of care (Institute of Medicine and National Research Council 2011). The traditional dental workforce—including dentists, dental hygienists, and dental assistants —is not currently able to manage the care of all U.S. older adults. New models are needed to expand the workforce, both within and outside the dental profession. In many states, new and expanded roles are being defined for dental hygienists and dental therapists; their training, licensure, and scope of practice vary by state. In addition, community liaisons and community health coordinators are being trained to address oral health issues as part of their whole-person assessments. Other medical professionals—such as physicians, nurses, occupational therapists, physical therapists, long-term care staff, and social workers—are also targeted for additional training.

Interprofessional education and collaborative clinical practice are needed to create a competent clinical workforce to provide oral health care to older adults. The Geriatric Research Education and Clinical Centers (GRECC) have a long-standing model of interprofessional care in the Veterans Health Administration system (U.S. Department of Veterans Affairs 2021). Development of guidelines and toolkits for education, as well as implementation of care using the GRECC model at a national level, are needed but will require the necessary funding. See Section 4 for more information on issues of integration affecting special adult populations.

Oral Health and Quality of Life

As noted throughout this monograph, oral health problems can significantly affect quality of life. For example, tooth loss and other oral conditions in older adults can affect eating and, by extension, nutritional status. Progress in understanding and treating specific conditions can alleviate problems with oral function and maximize OHRQoL. During the past 20 years, older adults have been feeling more satisfied with the overall condition of their teeth and mouth, with 77% reporting satisfaction, compared to 54% 2 decades ago (Figures 24–26). Non-Hispanic Black and White older adults reported substantially improved satisfaction (33% to 65% and 57% to 81%, respectively), whereas Mexican Americans reported the smallest improvement in satisfaction (32% to 45%), with the majority remaining unsatisfied with the condition of their teeth and mouth. Among those 75 years and older, satisfaction has improved during the last 20 years, but significant differences in oral health satisfaction exist by race/ethnicity and income. Although satisfaction improved for Mexican American adults aged 75 and older, the majority remain unsatisfied with the condition of their teeth and mouth (55%). Among those aged 75 and older living in poverty, satisfaction improved substantially, rising from 38% to 65%.

Cognitive decline affects daily function and is a common cause of social challenges and poor quality of life in older adults. Prevention and treatment of cognitive impairment are becoming increasingly important, given the aging population. Over the past 2 decades, considerable advances have been made in understanding the relationship between tooth loss and impaired cognitive functioning (Onozuka et al. 2002a; Gatz et al. 2006; Hirano et al. 2008; Ono et al. 2010), as well as the more general impact of oral health on cognitive function (Onozuka et al. 2002a; Gatz et al. 2006; Hirano et al. 2008; Ono et al. 2010). Several factors are associated with oral health status, including tooth loss, decreased mastication (chewing) and the resulting impact on sensory stimulation of the brain, poor nutritional pathways, and the role of periodontal disease (Cerutti-Kopplin et al. 2016).

In terms of tooth loss, human neuroimaging studies demonstrate that chewing is associated with activation of brain areas associated with memory and learning, increased cerebral blood flow, and better cognitive performance (Onozuka et al. 2002b; Miyamoto et al. 2005; Lin et al. 2017). These findings suggest a link between mastication and cognition. Prosthetic rehabilitation of toothless persons improved cerebral blood flow, indicating a possible protective influence of masticatory activities on cognitive functioning (Miyamoto et al. 2005). Recent work by Thomson and Barak (2021) suggests using a life-course approach to examine the apparent association between tooth loss and cognition.

Dental Services Utilization

During the past 20 years, the percentage of adults 65 or older who had a dental visit in the past 12 months has increased from 38% in 2000 to more than 44% in 2016 (Nasseh and Vujicic 2016; Yarbrough and Vujicic 2019). During this period, only about 1 in 4 poor older adults had a dental visit. Interestingly, the percentage of older adults with private dental insurance who had a dental visit in the past 12 months has increased from about 57% to 69%. However, for older adults who have some public dental insurance (mainly Medicaid) or who are uninsured, there has been no increase in dental services utilization in the past 20 years (Nasseh and Vujicic 2016; Yarbrough and Vujicic 2019).

Many older adults now receive a dental benefit through the purchase of a Medicare Advantage plan. Enrollment in these plans has increased from about 7% to 22%, with 2 out of 3 enrollees in these plans having a dental benefit (Jacobson et al. 2019). While the Patient Protection and Affordable Care Act of 2010 included dental care as an essential health benefit for children, it was not included for adults (Vujicic 2014). Medicare has never covered routine dental care, and the dental safety net for low-income adults remains limited, with only a few states offering comprehensive dental benefits to adults enrolled in Medicaid. Although the percentage of older adults with no dental insurance has declined from 64% to 57% over the past 2 decades, this age group continues to be the most likely not to have dental insurance compared to younger age groups, and older adults are the only age group that has seen an increase in out-of-pocket dental expenditures over the same period (See Section 1, Figure 13).

Studies have shown that a lack of dental insurance contributes to older adults having higher out-of-pocket expenses for dental care than other age groups. The mean out-of-pocket cost in 2015 for people who visited a dentist was $586 for retired adults 65 and older, compared with $264 for working adults and $220 for children and adolescents (Manksi and Rohde 2017). A lack of dental insurance is a major barrier to obtaining dental care and may account for the fact that 7.2% of older adults 65 and older—versus 4.3% of children—were more likely to report that they had forgone dental care in the past year because of cost (Vujicic et al. 2016). For more information on financing, see Section 4.

Another challenge for older adults is that they have more difficulty accessing dental care than younger adults or children because of physical and cognitive limitations. These limitations can make it difficult for them to maintain oral hygiene and withstand longer, complex dental procedures. Finally, lower perceived need for care is yet another barrier (Kiyak and Reichmuth 2005). Among adults with the same oral health status, those who are older consistently report lower perceived need for dental care than do younger adults (Griffin et al. 2012).

Provision of Older Adult Oral Health Care in Alternative Settings

Intergenerational and Family-Based Interventions

Progress over the past decade includes the development and implementation of intergenerational and family-based interventions for rural and immigrant communities that emphasize oral health promotion, disease prevention, and health literacy. These interventions include university-community partnerships, often employing community-based participatory research (CBPR) and qualitative approaches and methods (Huebner et al. 2014; Kavathe et al. 2018). Such interventions are based on the recognition that intergenerational influences—including caregivers' attributes, attitudes, and knowledge—may contribute to the oral health of family members, along with societal and community influences, particularly in disadvantaged communities (Milgrom et al. 2013; Northridge et al. 2017a).

Community-Based Interventions

Since the last comprehensive report on oral health in 2000, CBPR approaches have been especially valuable in advancing community-based interventions designed to improve the oral health of American Indian/Alaska Native (AI/AN) populations in diverse settings (Cidro et al. 2014; Cidro et al. 2015; Cidro et al. 2017; Tiwari et al. 2018). Cidro and colleagues (2014) recommend that local health experts be included in discussions about health programs, including those for older adults, because opportunities to share traditions are essential to restoring skills and pride, building family and community relationships, and cultivating intergenerational support in Native communities. Moreover, it is essential for oral health professionals to understand the cultural health traditions of elders and their families to ensure community acceptance of the interventions (Cidro et al. 2015). Finally, community-based researchers should effectively communicate with members of these communities in culturally appropriate, nonjudgmental ways when discussing oral health behavior (Cidro et al. 2017). Together, these findings underscore that preferred methods for improving oral health in AI/AN communities include CBPR approaches, culturally tailored strategies, and joint implementation of the developed initiatives (Tiwari et al. 2018).

Discrimination makes it difficult for older adults, racial/ethnic minorities, and immigrants to obtain oral health prevention and treatment services (Lamster and Northridge 2008; Northridge et al. 2017b; Bastos et al. 2018; Hebert-Beirne et al. 2018). Focus groups conducted with racial/ethnic minority senior center attendees underscored the importance of respectful treatment in oral health programs and settings (Estrada et al. 2018). A CBPR study of Somali and Oromo refugees revealed the following health assets that may be used in culturally relevant health interventions: religious beliefs, religious and cultural practices, a strong culture of sharing, interconnectedness, the prominence of oral traditions, traditional healthy eating and healthy lifestyles, traditional foods and medicine, and a strong cultural value placed on health (Lightfoot et al. 2016). In-person, hands-on demonstrations of how to brush with fluoride toothpaste and floss properly using models, games, and other adult learning techniques delivered by trusted community educators in familiar settings were valued by Sikh-South Asian oral health promotion program participants (Northridge et al. 2017a).

Access to oral health care may be facilitated through community-based outreach activities with follow-up by patient navigators, program coordinators, and community health workers to ensure that adults and their families enroll in eligible dental insurance programs and link them to local dentists who accept their dental insurance (Northridge et al. 2017a; Widström et al. 2018) or to Federally Qualified Health Centers that provide dental care regardless of the ability to pay for services (Institute of Medicine and National Research Council 2011; Crall et al. 2016). Educational interventions designed through the CBPR approach for African American men in Atlanta (Hoffman et al. 2017) and functional, context-specific oral health literacy interventions developed and implemented by Indigenous staff in a rural location in South Australia (Ju et al. 2018) resulted in improved oral health literacy and related outcomes in these vulnerable adult populations.

Community-based oral health promotion interventions that combine oral health education with brief motivational interviewing, demonstrations of oral hygiene behaviors, and facilitated access to oral health care are underway for targeted groups of low-income, racial/ethnic minority adults and their families (Weinstein et al. 2014; Northridge et al. 2017a) and older adults (Marshall et al. 2013; Widström et al. 2018). The purpose of motivational interviewing is to create a discussion that engages the participant in thinking about and planning how to make positive behavior changes using such techniques as open-ended questions, reflective listening, and affirmations (Miller and Rollnick 2013; Weinstein et al. 2014).

Chapter 3: Promising New Directions

Advances in prevention and treatment, as well as the desire of individuals to keep their teeth as they age through adulthood, has reduced complete tooth loss and increased tooth retention to historical highs in the United States. The practical implications of this are that oral health providers will continue to provide fewer denture services and more preventive and restorative dental procedures aimed at preserving as many natural teeth as possible. Consequently, many promising new directions are focusing on improving access to care and care coordination.

Oral Health and General Health

The Oral Microbiome

One of the most important advances in biomedicine during the past 2 decades is a more thorough understanding of the oral microbiome, which is discussed in detail in Section 6. This new knowledge holds great promise for the future. The oral cavity, including its microbiome, is connected anatomically, immunologically, and metabolically to the rest of the body. Changes in the oral environment—particularly changes in oral pH levels induced by diet, oral hygiene, salivary flow, and the immune system—can cause a state of imbalance in the microbiome, characterized by an overgrowth of potentially harmful bacteria and changes in metabolic activity. This imbalance can cause oral diseases, such as dental caries and/or periodontal disease, and also may impact other aspects of human health, including diabetes.

Recently, saliva testing has received considerable attention as a noninvasive diagnostic tool for diabetes and for monitoring glucose in the blood. Salivary glucose levels are significantly associated with blood glucose and HbA1c levels in persons with type 1 (Naing and Mak 2017) and type 2 diabetes (Mascarenhas et al. 2014), especially at high levels of hyperglycemia. The combination of a panel of four salivary biomarkers with body mass index was able to accurately distinguish between high versus low insulin resistance among healthy and prediabetic individuals (Zhang et al. 2017). Several other salivary biomolecules have been associated with diabetes, supporting the potential value of saliva in the diagnosis and monitoring of diabetes (Zhang et al. 2016). However, more research is needed in salivary diagnostics, including the enrollment of study participants of advanced age who may have diminished salivary flow due to disease or medications and/or might benefit from less invasive testing procedures because of disability or frailty.

Osteoporosis Risk and Oral Health

Panoramic dental radiographs are widely used to support dental examinations. This technique has the potential to predict osteoporosis risk in older adults (Calciolari et al.

2015; Ohtsuki et al. 2017). One study showed that mandibular cortical width and the extent of erosion on panoramic radiographs were significantly correlated with bone mineral density, as measured using ultrasound densitometry, in older adults. Recent evidence suggests that panoramic radiography has much better utility at detecting osteopenia, rather than osteoporosis (Kinalski et al. 2020). Nevertheless, additional work is needed to verify this finding and advance this or other densitometry devices to the stage of widespread use for osteoporosis risk screening by oral health providers.

Medications and Polypharmacy

There are several new directions to advance the science and clinical management of people who take multiple medications, especially older adults. These include mechanistic-based research studies focused on bone and oral mucosal biology and looking for genetic markers for those who would be at risk for developing medication-related osteonecrosis of the jaw. Population health studies on antibiotic prophylaxis for infective endocarditis and prosthetic joint infection represent another promising area of research. The development of health professional curricula focused on interprofessional education and practice to improve care for older adults who may be under the care of multiple health professionals prescribing many medications is a strong area of need as well. Finally, dental professions could substantially advance the oral health of older adults through advocacy and involvement in pharmaceutical research, in particular for populations with limited representation in clinical trials, such as those with multiple medical conditions.

Prevention and Management of Oral Diseases and Conditions

Prevention and Management of Dental Caries

Most adults will experience some periodontitis as they age through adulthood, and this can result in some gingival recession and dental root exposure, which makes the tooth more vulnerable to dental caries on the root surface. There has been a resurgence in the use of silver diamine fluoride (SDF) to noninvasively treat root caries. Although further research is needed—especially longitudinal studies to assess long-term effectiveness in the elderly—it has been shown to be effective, affordable, and safe for use in older adults for this purpose (Crystal and Niederman 2019). SDF holds great promise to treat caries in homebound or institutionalized older adults because of ease of application and minimal support equipment needed to deliver this dental care service. The chemotherapeutic use of SDF may be an effective treatment for the management of other types of dental caries affecting older adults, and future use is expected to be adopted by a range of primary health care providers (Hendre et al. 2017).

Dental Caries Prevention in Cancer Survivors

Although home-applied fluorides for oral cancer patients going through radiation treatment have been studied, newer office-applied fluorides, such as fluoride varnish and SDF, have rarely been studied for their effectiveness as anticaries agents following cancer treatment (Gibson et al. 2011; Dholam et al. 2013; Chu et al. 2014; Jurasic et al. 2014; Hong et al. 2018). A novel product called casein phosphopeptide-amorphous calcium phosphate—a nanocomplex derived from milk protein usually used to manage incipient lesions but more recently used for irradiated patients—shows promise, but study populations have been small. Table 6 reviews several studies of calcium phosphate (Papas et al. 2008; Sim et al. 2015; Sim et al. 2019; Wu et al. 2019). Although these interventions are promising, more research is needed to provide oral health providers with sufficient evidence to guide clinical decision making.

Special Needs Populations

Homebound Older Adults

Despite the challenges faced by homebound older adults, oral diseases in this population are preventable. Each member of the health care team who interacts with these vulnerable adults can promote the importance of toothbrushing, flossing, fluoride, nutrition, and diet (Critchlow 2017). Maintaining a healthy, functional dentition in homebound individuals is possible by using a collaborative, interprofessional approach to provide appropriate preventive measures and care and to address other barriers, such as minimal dental insurance, financial constraints, lack of perceived need, and functional dependency. Such individualized care can help prevent oral disease and maintain overall health, well-being, and quality of life (Yellowitz and Schneiderman 2014; Holm-Pedersen et al. 2015; Muller et al. 2017).

Table 6. Studies using calcium phosphate in irradiated patients

Modality	Author	Subjects	Intervention	Control	Main findings
Calcium phosphate	Sim et al., 2019 (1); Sim et al., 2015 (2)	24	10% CPP-ACP, 0.4% SnF2 gel and a 0.32% NaF toothpaste	0.4% SnF2 gel and a 0.32% NaF toothpaste	Lower caries progression. Statistically significant in Sim et al 2019 only.
	Papas et al., 2008 (3)		Calcium phosphate (Enamelon)	NaF 1100ppm toothpaste	Lower root surface increment with statistical significance, no coronal impact
Resin infiltration	Wu et al., 2019 (4)	60 teeth in vitro	CPP-ACP in vitro	Multiple	CPP-ACP and paired combinations had significant impact

Sources: Papas et al. (2008); Sim et al. (2015); Sim et al. (2019); Wu et al. (2019).

One example of collaboration involves meal delivery programs for homebound adults who have difficulty traveling to grocery stores or to senior centers for meals or who cannot cook because of mobility limitations or mental health problems. Recipients have had positive nutritional outcomes (Frongillo et al. 2010; Thomas and Dosa 2015). Using these interactions between the homebound and their meal deliverers as opportunities to discuss oral health would be a way to identify those who need oral health services and promote dental visits (Chamut et al. 2021).

Systems of Care for the Frail Elderly

The importance of oral health for older adults has caught the attention of those outside of dentistry who are working to improve systems of care for frail elders. For example, in 2017, the Gerontological Society of America proposed a variety of solutions for improving the oral health of older adults, including addressing barriers to access to dental care, identifying the need for interprofessional education and practice, promotion of an oral health benefit in Medicare, and creating coalitions and oral health champions for health promotion and public awareness campaigns while providing practical calls to action. An example of a current interprofessional solution is the MOTIVATE program (Maine's Oral Team-Based Initiative: Vital Access to Education), established by Massachusetts General Hospital and the Lunder-Dineen Health Education Alliance of Maine. The program develops cross-disciplinary teams to provide oral health care to seniors living in long-term care facilities (Box 1).

In addition, the FDI/World Dental Federation has focused on oral health for an aging population by developing the Roadmap for Healthy Ageing, which calls for reinforcing prevention activities throughout the life course and adapting health systems to establish evidence-based prevention and care strategies (FDI World Dental Federation 2018). The following eight core pillars were identified: (1) integration of oral care into general care, (2) promotion of oral health throughout the life course, (3) shaping of evidence-based oral health policies, (4) removal of financial barriers, (5) removal of physical barriers, (6) provision of appropriate oral health care, (7) mobilization of all stakeholders along the care pathways, and (8) fostering of community-based programs. The *Roadmap* is a valuable resource as new systems of care focusing on prevention and dental-medical integration are developed and evaluated.

As previously mentioned, Seattle Care Pathways provides a patient-centered, evidence-based approach to care for well elders, as well as for others who are vulnerable. The FDI approach adds value, in that the FDI has applied the concepts of the Seattle Care Pathways for dental professionals, health care professionals, caregivers, community agencies, and seniors themselves with specific focus on what each group can contribute to improving oral health across the spectrum of dependency. The resultant interprofessional collaborative approach to care serves as an important resource for moving forward (FDI World Dental Federation 2018).

Dental Services Utilization

Since publication of the 2000 Surgeon General's Report on Oral Health, more older adults have been able to access dental care through the purchase of a Medicare Advantage plan. Although this is an important mechanism for improving dental coverage for older

Box 1. How do communities train workers in long-term residential settings to improve the oral health care of seniors?

Because older adults who live in long-term care settings have unique risk factors and needs for oral health care, it is critical to provide them with evidence-based, routine oral health care. Organizations in Massachusetts and Maine collaborated to develop a program that provides interprofessional teams with education that advances knowledge, skills, and attitudes about the oral health needs of residents in long-term care. The MOTIVATE program (Maine's Oral Team Based Initiative: Vital Access to Education) was established by the Lunder-Dineen Health Education Alliance of Maine, an initiative of Massachusetts General Hospital. A pilot program was implemented in 2016 in six homes in the Maine Veterans' Home System that house 640 residents; more than 400 staff participated in the program. The Lunder-Dineen Health Education Alliance refined the program based on the pilot data, and the next phase involved expansion to a long-term care and rehabilitation system, increasing the number of involved residents to more than 900, and increasing participating staff to more than 700.

The curriculum for MOTIVATE targets a variety of staff: certified nursing assistants, dietary teams, facilities managers, housekeepers, nurses, pharmacists, social workers, and therapists (PT, OT, SLP, RT, ACT). These groups are trained to work as teams to provide oral health care, especially preventive services, for seniors. Every resident receives an oral health kit. The educational program includes online modules, live teaching sessions, and 6 months of onsite or virtual consultation. Online module topics include:

- Oral health leads to total health: Foundations of oral health care
- Tools of the trade: Steps in providing oral health care
- When to wait and when to act: Warning signs of oral health problems
- What to do when a resident has trouble with oral health care: Working together with residents and families

Partners include the University of New England College of Dental Medicine, University of Maine Center on Aging Research and Dental Hygiene Program, Maine Veterans' Homes, Oral Health Progress and Equity Network (OPEN), Maine Dental Association, American Dental Association, CareQuest Institute for Oral Health, The Cedars, Island Nursing Home and Northern Light Health, and Mars Hill.

adults, more than half of all older adults remain uninsured for dental services. More important, older adults are the only age group that has seen an increase in out-of-pocket dental expenditures during the last 2 decades (See Section 1 Figure 14).

National and local policy and systems changes are important for creating communities that support good health and eliminating health inequities for older adults. Health policies can target a multitude of upstream social determinants of health, such as taxing sugary drinks, reducing carcinogenicity of meals provided in nursing homes, providing elder day care and home-delivered options for seniors, and increasing the availability of affordable fruits and vegetables in food deserts. At the same time, access to dental care, which also improves oral health, is essential. Older individuals who have the highest need are more likely than others not to have dental insurance (Oral Health America 2014; Kohli et al. 2017).

One of the most promising new directions that directly impacts improving oral health in older adults is the growing call for the inclusion of a dental benefit in Medicare, which provides universal medical coverage for adults 65 years and older. Inclusion of dental coverage in Medicare would be an important step toward addressing the complex factors that result in substantial inequities and hardship that many older adults experience trying to access oral health care. Other helpful initiatives include enhancing the oral health literacy of individuals and organizations and integrating medical and dental care, especially for medically compromised people with special needs from low-income and minority groups, including those in long-term care (Patrick et al. 2006). Nationally accepted guidelines for risk assessment and management are the standard of care for several aspects of elder medical care. The adoption of similar standards for frail older adults focusing on their oral health to ensure that they minimally have access to basic dental screenings, referrals, and preventive services would be a very important and promising step toward providing compassionate oral health care in later life.

Provision of Older Adult Oral Health Care in Alternative Settings

Interprofessional Care

Because many older Americans have difficulties with mobility and accessing dental care in a typical dentist's office, options are now being explored using primary and interprofessional care. Many states already use venues such as congregate meal sites, assisted living facilities, and nursing homes to assess the oral health status of vulnerable older adults, using a simplified oral health screening tool from the Association of State and Territorial Dental Directors (Association of State and Territorial Dental Directors 2017). These programs can be expanded. Virtual dental homes also could increase access in dental shortage areas and among older adults who cannot easily visit a dental office. Teledentistry has been successful in providing virtual dental homes to adults of all ages (Glassman et al. 2012b). A study of nursing home residents found that remote dentists diagnosed dental pathologies with high accuracy (Queyroux et al. 2017).

Another promising direction is to promote the use of electronic health records, accountable care organizations, and coordinated care to better integrate oral health and medical care. Additional information on coordinated care is provided in Section 4. A 2011 Institute of Medicine report recommended that non-dental health care professionals take a more active role in the dental care of older adults living in long-term care facilities. The report found that with proper training, nurses, nursing assistants, and other health care workers could assess risk and screen for common oral conditions, educate residents about preventive oral care (such as daily brushing), and deliver preventive services, including daily oral hygiene care and fluoride varnish (Institute of Medicine and National Research Council 2011).

Comprehensive services using an interprofessional team may help reduce the prevalence of tooth loss for adults across age, racial/ethnic, and economic groups (Mertz and Wides 2016), which is a concern for older adults given the importance of a functional dentition and its relationship to overall well-being and quality of life. These services, including social and behavioral health services and diet/nutrition counseling, are needed to help prevent declines in nutrition status, poor health behaviors, and unhealthy dietary patterns that affect many older adults. To maximize the effectiveness of non-dental professionals in oral health roles, interprofessional education can teach them about the relationships between severe periodontitis and noncommunicable diseases, how to assess for periodontitis, and to make referrals to oral health care professionals for patients with poor oral hygiene or a suspected oral health problem.

Community-Based Interventions

Oral health equity for all adults will require embedding clear, culturally appropriate messages about the importance of oral health within community-based health interventions for other health concerns, such as tobacco prevention and cessation, improved nutrition, injury prevention, human papillomavirus vaccination, and diabetes prevention and control (Benzian and Williams 2015). Further, the broad reach of mobile technologies and digital lifestyles may provide opportunities for using remote monitoring and self-care tools to reinforce preventive oral hygiene behaviors that are critical to the maintenance of oral health (Shetty et al. 2018). Schensul and colleagues (2019) developed a protocol to implement a bilevel, community-based oral hygiene intervention among older adults and the disabled in low-income senior housing based on Fishbein's Integrated Model of Behavior Change and Bandura's concept of self-efficacy. The intervention consisted of a face-to-face tailored intervention based on adapted motivational interviewing and a building-based campaign developed and implemented by building residents. The campaign consisted of three oral health fairs. Six buildings were randomized to receive the individual-level intervention followed by the campaign. The cross-over research design addressed four questions: (1) Is the individual-based intervention more effective than the building-level intervention? (2) Does the sequence of the interventions matter? (3) What are the mechanisms that account for the differences? and (4) Are the improvements in outcomes sustainable? In addition to community-based participatory research and qualitative approaches, implementation science holds promise for addressing common barriers that limit the success of community-based oral health promotion (Simpson 2011).

Community Health Workers

A person's culture can influence his or her health beliefs and behaviors, including those related to oral health. For relatively isolated older adult immigrants, community institutions and community health workers may serve as cultural brokers or bridges that link immigrants in the community to needed oral health information and resources (Marino et al. 2014; Kavathe et al. 2018). For example, low-cost, community-based peer support employing older adults/seniors designed to prevent diabetes also may improve oral health among underserved older adult populations (Thankappan et al. 2018).

Chapter 4: Summary

Too many older Americans experience poor oral health. They need and should receive better oral health care—integrated within the health care system—and better ways to access that care. As in younger populations, health inequities, in the forms of health disparities and limited and inconsistent access to care, persist and must be addressed. Overall, the prevalence of untreated decay in adults aged 65 and older has declined six percentage points since the year 2000, from approximately 28% to 22%. Unfortunately, untreated caries did not significantly decrease for older adults living in poverty (48% to 43%), whereas for more affluent older adults there was a significant decline (21% to 14%). Nearly 1 in 10 older adults has some form of severe periodontitis, with a much higher prevalence among men, lower-income seniors, and racial/ethnic minorities. Older adults continue to be the age group most often without dental insurance and with the highest out-of-pocket dental expenditures.

The older adult population in the United States is on course to outnumber the child/adolescent population (those 18 and younger) by 2034 (Vespa et al. 2018). By 2060, nearly 1 in 4 Americans (23.4%) will be 65 years or older. This burgeoning population puts pressure on a fragile oral health care infrastructure that has unequal distribution of services and prohibitive costs. Older adults at the highest risk for poor oral health tend to lack insurance and reside in underserved urban and rural areas, which also are factors shared by those who are economically disadvantaged and members of minority groups.

Resolving these inequities and barriers to care requires national legislation and other changes. Key actions are to add dental benefits to Medicare, to attract and retain skilled providers, to use evidenced-based care to achieve better outcomes, to offer adequate provider reimbursements, to establish nonemergency preventive and restorative dental services as an essential health component, and to support community-based oral health programs where older adults live and congregate. State and local legislative changes are needed to address transportation challenges, expand community outreach programs that increase health literacy, and boost oral health education. These initiatives have the potential to transform oral health care for older Americans.

Several key themes influencing older adult oral health have been described in this monograph (Box 2). Since the 2000 Surgeon General's Report on oral health, new opportunities have emerged that focus on addressing shared risk factors and improving the management of noncommunicable diseases, improving interprofessional education and delivery of care, and identifying mechanisms to include oral health care as an integral part of our health care system. Specific gains in oral health over the last 20 years include a decrease in overall tooth loss, more research looking at periodontal disease as a source of chronic systemic inflammation, more clinical trials and analyses of treatment success for dry mouth, the identification of human papillomavirus as a risk factor for oropharyngeal cancer, and advances in the care of patients with oral cancer to decrease illness and death for those diagnosed at early stages. There also is better recognition of the potential impact of treatments for other types of cancers on oral health, more studies of systemic relationships between tooth loss and cognitive function and between the microbiome and diabetes mellitus, and new models for delivering dental care in nontraditional settings.

Many challenges to optimal oral health lie ahead for the rapidly increasing number of older adults in the United States, especially racial/ethnic minorities and those with lower incomes. Only 31% of older adults aged 65 to 74 and living in poverty have a functional dentition, compared to 74% of nonpoor older adults. Too many older adults face financial, logistical, and other barriers that keep them from improving and maintaining their oral health and accessing adequate oral health care.

Box 2. Key summary messages for Oral Health Across the Lifespan: Older Adults

- Today, very few older adults lose all of their teeth as a result of improvements in disease prevention and treatment.
- Dental implants increasingly provide a safe and effective method for replacing lost teeth and for aiding in the retention of lower dentures; however, they remain a costly procedure and are out of the reach of most older adults.
- As working-age adults transition into retirement, most lose their employer-provided dental insurance, and Medicare does not provide an oral health benefit. This puts their oral health at risk.
- Older adults are living longer than ever before, many with chronic diseases and complex health conditions that would be best managed by medical and oral health professionals working together.
- Older adults have a higher risk for poor oral health than any other age group because many of them lack dental insurance, have underlying health conditions, lack convenient access to care (especially those living in underserved urban and rural areas), and have limited financial resources. These factors result in the higher prevalence of many oral diseases in older adults, compared to younger adults.
- Receiving appropriate oral care can be especially difficult for older adults who are frail, disabled, homebound, cognitively impaired, or who reside in long-term care facilities. A coordinated team of caregivers is essential to address their care.

Call to Action:

- A policy that mandates dental coverage in Medicare would reduce health inequities for older adults by assuring access to preventive and other oral health services for all, including those who are place-bound or in need of caregiver assistance.

These difficulties are evident in the higher prevalence of many oral diseases in older adults than in younger adults. Systemic diseases and the medications used to treat them present specific and unique risks to oral health. For older adults who are disabled or homebound, achieving and receiving appropriate oral care can be a daily struggle.

Daunting and complex as they are, these challenges can be overcome. Targeted efforts in prevention and health literacy and novel approaches to make care more accessible and affordable are beginning to make inroads. Further, interprofessional approaches are emerging to better manage oral health within the broader health care system.

To be successful, however, barriers to oral health care must be more effectively addressed. Although older adults maintain more of their dentition into old age than ever before, many find themselves without the resources to afford dental care. Medicare, the primary form of health insurance for older Americans, specifically excludes dental services except in extremely limited circumstances. An estimated 70.8% of adults 65 and older had no dental insurance in 2017, and that percentage increases with age (Kramarow 2019). Removal of this exclusion and the inclusion of a universal and meaningful dental benefit available to all Medicare enrollees is essential for older adults to obtain needed care. This action would also establish oral health care as an essential element of health care systems.

For both researchers and clinicians, a better understanding of the underlying associations between oral diseases and medical diseases has revealed common risk factors and presented opportunities for treatment through interprofessional education and practice. A recent comprehensive review of systematic reviews has shown that additional research and evidence-based information are needed across most areas of geriatric oral health care, including in other disciplinary areas related to oral health (Ástvaldsdóttir et al. 2018). With the graying of America accelerating, this should be considered an urgent priority to improve the health and well-being of all Americans.

Integrated health teams that include dental providers will help eliminate oral health disparities and reduce health inequities among older adults. Too many older adults suffer disparities—in tooth loss, untreated decay, periodontal disease, and more—often related to social determinants of health, such as race/ethnicity and socioeconomic status. Using tooth loss as an example, the mean number of missing teeth decreased from about 14 to fewer than 11 missing teeth on average for non-Hispanic Blacks, whereas for non-Hispanic Whites, the decrease was nearly 9 to 6 missing teeth (Figure 15). For Mexican Americans, the decrease was from about 10 to 9 mean missing teeth. Even for older adults with the financial means to access dental care, there can be other barriers. Physical or cognitive disabilities, limited oral health literacy, and living in rural or underserved areas also present challenges in access to care, but none are insurmountable. Nontraditional models of care that focus on providing oral health promotion, prevention, and services in places where older adults live and gather show promise. Teledentistry and other innovations in oral care delivery are starting to make a difference, but additional resources and coordination are needed to expand their reach.

Our goal must be to ensure that older adults obtain appropriate oral health care, so that as they reach an advanced age or become frail or dependent, the primary focus can be on maintenance and prevention, rather than complex, invasive procedures that become a necessity after years or even decades of neglect. Achieving this goal will require improved access to care and maintenance of oral health for all older adults at all stages of health and dependency. Better oral health and oral health care for older Americans is achievable and critical to avoid new and recurrent oral diseases, to maintain dignity and quality of life, and to ensure general health and well-being through a lifetime.

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Oral Health in America: Advances and Challenges
Section 4: Oral Health Workforce, Education, Practice, and Integration

Chapter 1: Status of Knowledge, Practice, and Perspectives

The overarching goal of the U.S. oral health workforce is to meet the population's oral health needs. It meets this goal through the efforts of professionals and others in supporting roles who provide direct care and preventive services in a variety of settings. The composition of this workforce is influenced by the oral health needs of the public, patients' oral health literacy and preventive health behaviors, and the policy and regulatory environments in which oral health providers are located. The need to improve access to care is driving efforts to develop new workforce models and extend existing ones, including the development and training of new allied health professionals.

The nation's oral health workforce is educated in state and state-related, private not-for-profit, and private for-profit institutions. The diversity of students attending these programs, the length of training, and the degrees or certificates offered vary, as does the cost of attendance. Professionals who have completed their education or training also must complete licensure and registration requirements to be able to provide patient care. These licensure and certification programs regulate the activities of all workforce members engaged in direct patient care. Oral health education programs generally prepare three levels of providers (dentist provider level, allied provider level, and assistant/support level) and continue to evolve.

The oral health workforce is employed in a wide variety of settings, from private and public dental practices, health clinics, hospitals, and prison clinics, to dental school and industry clinics. A dentist may be an owner, an employee, or a contractor providing dental services. Dental hygienists may be employees or contractors of dentists and, in some states, may practice independently or as members of medical care teams. Increasingly, oral health care is being integrated with general medical care. There are a variety of models in which providers deliver dental care as part of an overall health care system, with some providers in the same place and others linked through referral networks. This has created an environment for exploring and conducting research into the benefits of integrated health care, with the goals of improving oral health and general health outcomes, patient experiences, and costs.

Workforce

The U.S. oral health workforce comprises dentists and allied professionals, including dental hygienists, dental therapists, dental assistants, dental laboratory technicians, and community dental health coordinators (CDHCs). These oral health professionals deliver care to patients in team arrangements and settings that include solo and group dental practices, community clinics, academic settings, commercially owned clinics, hospitals, and federal, state, or local government settings. As the most highly trained of these providers, dentists diagnose and treat oral diseases, manage their patients' oral health, educate patients on proper oral health behaviors, and refer patients to other health care providers as needed.

In 2020, according to the American Dental Association (ADA), there were 201,117 dentists actively practicing in the United States. California and Texas had the largest numbers at 31,059 and 15,872, respectively, while Wyoming and Vermont had the smallest at 306 and 348, respectively. Overall, there were 61 dentists per 100,000 U.S. residents in 2020. This number varied substantially by state, however, ranging from 104 in the District of Columbia to 41 in Alabama (American Dental

Association 2021a). Although there is no optimal measure for the dentist-to-population ratio, available estimates indicate solo practice dentists manage about 1,350 patients annually, and group practice dentists manage about 2,100 (Bailit 2017).

Most dentists are general dentists. In 2020, there were 158,520 general dentists in the United States and 42,597 other dentists who reported additional education and training, including work in the following specialties: orthodontics and dentofacial orthopedics (10,885), pediatric dentistry (8,561), oral and maxillofacial surgery (7,529), periodontology (5,723), endodontics (5,745), prosthodontics (3,733), dental public health (823), oral and maxillofacial pathology (431), and oral and maxillofacial radiology (164) (American Dental Association 2021a). Dental anesthesiology, orofacial pain, and oral medicine were added as specialties in 2019 and 2020.

The oral health workforce also includes dental hygienists, dental assistants, dental laboratory technicians, and more recently, dental therapists and CDHCs. Dental hygienists perform oral health screenings and health history reviews, teach health promotion techniques, make dental radiographs (x-rays) and intra-oral images, remove hard and soft deposits from tooth surfaces, and apply preventive materials. A few states allow hygienists with additional training to perform expanded functions (Beazoglou et al. 2012), such as delivery of local anesthetics and specific restorative services as permitted under state practicing laws (American Dental Hygienists' Association 2018).

The U.S. Bureau of Labor Statistics (BLS) employer survey estimated there were 194,830 full- and part-time dental hygienists employed in the United States in 2020, although some part-time hygienists may work in multiple settings (U.S. Bureau of Labor Statistics 2020a). The BLS estimated that 312,140 individuals were employed as dental assistants in 2020 (U.S. Bureau of Labor Statistics 2020b). About 25% of those dental assistants reportedly served in an expanded-function capacity (for example, polishing teeth or applying sealants) (Baker et al. 2015). In 2020, there were 30,800 dental laboratory technicians in the United States (U.S. Bureau of Labor Statistics 2020c).

In addition, denturists, dental health care professionals who provide denture care directly to the public, currently are legally allowed to practice in Arizona, Colorado, Idaho, Maine, Montana, and Oregon (National Denturist Association 2021).

In response to a lack of access to dental care, ADA launched the CDHC program in 2006 to provide community-based prevention, care coordination, and patient navigation. CDHCs work in underserved rural, urban, and Native American communities to connect those who might not otherwise receive dental care to professional providers (Grover 2017). Currently, state dental professional associations, such as the California Dental Association, are working with their state legislatures to recognize the CDHC program, and 460 program graduates are working in 45 states (American Dental Association 2020a).

Dental therapists, the most recently established midlevel providers in the field, work under the general and direct supervision of dentists to deliver routine preventive and restorative care. A dental therapist's scope of practice is about one-quarter that of a general dentist; the precise role depends on the therapist's education and state regulations. Although the models vary, dental therapists currently are authorized to practice in 13 states: Alaska (tribal territories), Arizona, Connecticut, Idaho (tribal territories), Maine, Michigan, Minnesota, Montana (tribal territories), New Mexico, Nevada, Oregon (tribal territories), Vermont, and Washington (tribal territories), with proposals or legislation under consideration in Florida, Kansas, Massachusetts, New York, North Dakota, and Wisconsin. Six states approved legislation in 2019; many combined the dental therapist with the registered dental hygienist credential, so individuals are dually trained. Currently, therapists are active in Alaska, Arizona, Minnesota, Oregon, and Washington (American Dental Hygienists' Association 2020).

Among the states developing and implementing new midlevel provider models for oral health care, Alaska has had the most experience. The Community Health Aide Program is a workforce program in Alaska that has expanded in scope to improve access to care by creating four types of non-dentist oral health providers: primary dental health aides (PDHAs), expanded-function dental health aides (EFDHAs), dental health aide hygienists (DHAHs), and dental health aide therapists (DHATs). PDHAs provide oral hygiene, toothbrush prophylaxis, fluoride application, and nutrition and disease management counseling. They may receive additional training to provide dental imaging, prophylaxes, sealants, and atraumatic restorative treatment. EFDHAs are dental assistants with training either to place restorations after a dentist or therapist has removed decay or to provide prophylaxis (without root planing). An EFDHA with additional training may perform more complex work. For both PDHAs and EFDHAs, training reflects 2 weeks of structured instruction followed by a period of direct supervision until their preceptorship is completed. DHAHs are registered dental hygienists who have completed a local anesthetic course approved by the Commission on Dental Accreditation (CODA) that enables them to provide local anesthesia while working remotely from a supervising dentist. DHATs complete a 2-year education program that enables graduates to provide basic dental restorative procedures, extractions, and prevention services. These four new classes of providers are supervised dental team members and may be allowed to work remotely from their supervisors to bring care to small villages with no dentists.

Dental assistants perform a variety of activities in the dental office. Depending on the state, responsibilities may include taking health histories, imaging, teaching health promotion techniques, performing office management tasks, and communicating with patients and suppliers (American Dental Association 2021b), as well as assisting the dentists with procedures. Some states support the use of expanded-function dental assistants to help dentists provide direct patient care (Beazoglou et al. 2012), and their continuing education is supported through the American Dental Assistants Association (American Dental Assistants Association 2021).

Dental laboratory technicians follow dentists' detailed written instructions to create full and partial dentures, bridges, crowns and veneers, and orthodontic appliances (American Dental Association 2021c). Technicians typically receive their education and training through a 2-year program within a variety of educational settings, and graduates receive either an associate degree or a certificate. In addition, a small number of programs offer a 4-year baccalaureate program in dental technology.

In addition, health professionals trained in fields other than dentistry provide a range of oral health care services. Physicians, nurses, and others provide oral health care to women as part of perinatal care, as well as to children, older adults, and other populations with special needs (Institute of Medicine and the National Research Council 2011). These activities may include reviewing health histories, oral health screening, risk assessment and charting, education and nutrition counseling, care coordination, and other services that typically fall within the dental hygiene scope of practice (Maxey et al. 2017). In addition, some may provide fluoride varnish to prevent tooth decay. However, a combination of lack of training or experience, inadequate infrastructure support, and systems limitations often restrict the potential of many of these professionals to become more engaged with promoting oral health. There are no estimates of the number of health care workers, other than dentists, providing oral health services.

Gender and Age Distribution

The gender distribution of the U.S. oral health workforce differs by professional type. As of 2019, U.S. dentists were predominantly male; women accounted for only 33% of active dentists (American Dental Association 2020b), but their numbers are increasing as older dentists retire and a more gender-balanced group of dental school graduates moves into practice. An estimated 95% of dental hygienists and assistants are female (Health Resources and Services Administration 2018a).

The distribution of currently practicing dentists is relatively balanced across age groups but varies considerably by gender (Table 1). Among female dentists, approximately 56% were under 45 years of age, and 5% were 65 years and older. By comparison, nearly 32% of male dentists were under 45 years of age, and 22% were 65 years and older (American Dental Association 2021a). Among dental hygienists, 30% are under 35 years of age, and 52% are 35 to 55 years of age; 50% of dental assistants are under 35 years, and 40% are 35 to 55 years (Health Resources and Services Administration 2018a).

Table 1. Distribution of dentists by age group and gender: United States, 2018

Age/Years	All Dentists (%)	Male Dentists (%)	Female Dentists (%)
Under 35	16.9	12.2	24.8
35 to 44	23.4	19.6	31.0
45 to 54	21.1	20.2	23.7
55 to 64	22.8	26.4	16.2
65 and older	15.8	21.6	4.3

Source: American Dental Association, Health Policy Institute Masterfile (2019).

Racial and Ethnic Distribution

Overall, the oral health workforce is predominantly White and non-Hispanic, but this varies by professional type (Table 2). Federal data from 2017 indicate that 75% of dentists are non-Hispanic White, 14% are Asian, 6% are Hispanic, and 3% are Black/African American. A 2017 study of underrepresented minority dentists found that fewer than 1% of dentists are American Indian/Alaska Native (AI/AN) (Mertz et al. 2017a). Dental hygienists are 83% non-Hispanic White, 7.5% Hispanic, 4% Asian, and 3% African American. Dental assistants are 62% White, 22.7% Hispanic, 7% African American, and 6% Asian (Health Resources and Services Administration 2018a). It is commonly understood that increasing the health care workforce's diversity will also increase that workforce's ability to effectively address all Americans' health care needs, leading to a healthier nation (Cohen et al. 2002).

Employment Settings

Dentists, dental hygienists, and dental assistants work mainly in dental offices, whereas laboratory technicians most often work in offices and laboratories of medical equipment and supplies manufacturers. Other employment settings include academia, hospitals, or industry and state and federal government. Private dental practices deliver the majority of oral health care. In a growing business model for delivering health services, dental support or service organizations (DSOs) contract with dentists to provide administrative support services, enabling dentists to focus primarily on providing dental care (Association of Dental Support Organizations 2021). Dental services also may be provided in clinics within retail stores or via mobile clinics at job sites, schools, and nursing homes.

Private and Public Practices

More than 9 out of 10 dentists actively practice in privately owned, nongovernment settings (Table 3). The remaining 9% of active dentists are distributed among federal services (e.g., U.S. Department of Veterans Affairs, U.S. Public Health Service) (1%), academic settings (2%), armed forces (2%), state or local government (less than 1%), and other settings, such as other health or dental organizations and hospitals (1%). A small proportion (2%) of these dentists are either graduate students or residents or professionals working part-time, either as faculty or in private practice (American Dental Association 2019a). Practicing dentists are solo practitioners (50%), group-practice owners (30%), employees (17%), or independent contractors (4%) (Table 4). As of 2019, a small but increasing percentage of dentists (10%) are affiliated with large, multigroup DSOs, either as employees or owners (American Dental Association 2019b). DSOs provide business management, technology services (e.g., imaging and dental records), and nonclinical operations support to dental practitioners (Association of Dental Support Organizations 2021). In 2017, DSO-affiliated dentists were more likely to be female than male (12% vs. 7%, respectively). Large group settings and DSOs may appeal to younger dentists with high debt levels and those who are especially interested in work-life balance or exclusive focus on patient care activities (Parker 2012; Cole et al. 2015).

Academic Teaching and Research Settings

Currently, there are 4,724 dentists employed by dental schools and research institutes (American Dental Association 2019a). These dentists provide graduate and postgraduate training in dentistry, conduct research, and deliver oral health services through faculty practices and clinics.

Table 2. Distribution of dentists, dental hygienists, and assistants by race/ethnicity: United States, 2011–2015

	Dentists (%)	Dental Hygienists (%)	Dental Assistants (%)
Hispanic/Latino	6.1	7.5	22.7
White	74.8	83.4	62.1
Black and African American	3.0	3.1	6.9
Asian	14.3	4.2	5.5
American Indian/Alaska Native	< 0.1	< 0.1	< 0.1
Native Hawaiian and other Pacific Islander	NR	NR	< 0.1
Multiple/other race	1.7	1.5	2.1

Note: **NR** = not reported.
Source: Health Resources and Services Administration (2017).

Dentists and hygienists employed in academic settings educate students, provide oral health services, conduct research, and serve as administrators.

Federal and State Government Settings

The U.S. Department of Health and Human Services (HHS) funds direct patient care to underserved populations in federally qualified health centers (FQHCs), Health Resources and Services Administration's (HRSA) Ryan White HIV/AIDS Program-funded clinics, and other nonprofit clinics, as well as in the Indian Health Service (IHS), the Federal Bureau of Prisons (BOP), the U.S. Coast Guard (USCG), the U.S. Immigration and Customs Enforcement (ICE) Health Service Corps, and the U.S. Department of Veterans Affairs (VA). Federal agencies hire dentists, dental hygienists, dental assistants, and dental therapists to provide dental services for unique patient populations. Among the federal agencies mentioned, IHS employs the largest proportion of oral health professionals (an estimated 1,000 dentists, 400 dental hygienists, 2,400 dental assistants, and 16 other professionals) to provide dental care in a comprehensive health service delivery system for an estimated 2.56 million AI/AN individuals from 574 federally recognized tribes in more than 350 facilities across 37 states (Indian Health Service 2020). The IHS dental clinics are predominantly located in rural communities, with an estimated 65% of the oral health care programs directly managed by tribes or tribal organizations and the remainder managed by IHS. Within the BOP, 157 dentists, 121 hygienists, and 178 dental assistants work to provide quality care consistent with evidence-based practice within 141 facilities serving 150,000 inmates (U.S. Department of Justice 2016); Federal Bureau of Prisons 2021). USCG dental personnel serve more than 56,000 members in 15 states. U.S. Department of Homeland Security personnel provide onsite direct patient care to about 15,000 ICE detainees.

In 2018, the VA provided oral health care to more than half a million veterans in 1.7 million visits. Some veterans with service-connected disabilities have access to full dental benefits within the VA. The majority of veterans, however, have limited or no access. Those not qualifying for VA care can purchase discounted dental insurance through the VA Dental Insurance Program (U.S. Department of Veterans Affairs 2020). VA dental clinics provide care at 236 sites, staffed by more than 1,000 dentists, 400 dental hygienists, and 1,500 dental assistants (Boehmer et al. 2001; Jurasic et al. 2014).

Federal dental personnel serve as dental directors and chief dental officers at local, regional, and national levels to deliver effective and efficient dental services. Other dental personnel manage programs and grants at the National Institutes of Health; develop and manage programs and interventions intended to provide oral health resources to state and local dental institutions at HRSA; enforce regulations for dental devices and dental drugs at the U.S. Food and Drug Administration (FDA); and develop guidelines to improve oral health and monitor population oral health at the Centers for Disease Control and Prevention (CDC). At the state level, in 2021, 40 states employed dentists (32 states) or dental hygienists (8 states) to plan public dental programs for their states (Association of State and Territorial Dental Directors 2021).

Table 3. Distribution of working dentists by practice setting: United States, 2018

	Number of dentists	Percent of professionally active dentists
Total professionally active	**199,486**	**100.0%**
Private practice	181,121	90.8%
Dental school faculty/staff member	4,724	2.4%
Armed forces	3,672	1.8%
Other federal services (e.g., Veterans Affairs, Public Health Service, Federally Qualified Health Centers)	1,852	0.9%
State or local government employee	753	0.4%
Hospital staff dentist	436	0.2%
Graduate student/intern/resident	2,365	1.2%
Other health/dental organization staff member	1,245	0.6%
Part-time dental school faculty/part-time private practice	3,318	1.7%

Notes: Some values are estimates based on the most recent data. In this table, each dentist is counted toward one category, based on primary occupation/status, although they may qualify for multiple categories.

Source: American Dental Association, Health Policy Institute, unpublished data.

Table 4. Distribution of working dentists in private practice by ownership status: United States, 2018

	Number of dentists	Percent of dentists in private practice
Total professionally active in private practice	**181,121**	**100.0%**
Private practice - solo owners	89,655	49.5%
Private practice - nonsolo owners	54,548	30.1%
Private practice - employees/associates (nonowners)	29,875	16.5%
Private practice - independent contractors (nonowners)	7,043	3.9%

Notes: Some values are estimates based on the most recent data. In this table each dentist is counted toward one category although they may qualify for multiple categories. “Solo/nonsolo” and “owner/nonowner” characteristics have been reported only for dentists in private practice.

Source: American Dental Association, Health Policy Institute, unpublished data.

Other Dental Professional Employment

In 2017, 95% of 211,600 dental hygienists worked in dental offices. In 2016, 91% of 327,290 dental assistants worked in dental offices. In 2018, 79% of 34,480 dental laboratory technicians worked in medical equipment and supplies manufacturing; 17% worked in dental offices. The remainder in each of these categories worked in physicians' offices or outpatient care centers, federal government agencies, or other settings (Table 5).

Burnout, Well-Being, and Resilience

Dentistry is a demanding and stressful profession. About 1 in 5 dentists report feeling burned out (LoSasso et al. 2015). Burnout is a state of emotional exhaustion, depersonalization, and loss of a sense of personal accomplishment associated with impaired job performance, including absenteeism and turnover (Chapman et al. 2017). Burnout and work dissatisfaction can lead to emotional distress for dentists and other oral health professionals, as well as disengagement from work and patients and a reduced quality of care and patient compliance (Hakanen and Schaufeli 2012; Starkel et al. 2015).

There is little published information on burnout in the U.S. dental profession compared to that for medical professionals, but studies have reported high levels of burnout among dentists internationally. Between 8% and 44% of dentists and dental students report stress beyond their ability to cope (Calvo et al. 2017). Burnout also is found among dental hygienists, as demonstrated by a study of dental hygiene educator/administrators. More than 40% of respondents in that study reported a moderate to high level of burnout and called for training in stress management (Hinshaw et al. 2010).

Burnout occurs when a training program or job overwhelms an individual's ability to manage the resulting stress. Occupational stressors, detailed work under time pressure, frequent emergencies, and clinical mistakes can have serious consequences. One survey found that about 58% of solo and small group practice dentists reported feelings of job stress, whereas only 38% of dentists in group practices were stressed (LoSasso et al. 2015). The same survey found that 20–23% of dentists experienced work-related burnout. A systematic review of poor well-being and moderate burnout reported a significant correlation with patient safety problems. Thus, the consequences of burnout are serious for employees, patients, and institutions (Hall et al. 2016).

Providing Dental Services During a Public Health Emergency

Every dentist's academic preparation includes instruction in basic medical principles and practices, including taking a medical history, diagnosis, radiographic (imaging) interpretation, wound suturing, and formulating a medical diagnosis on the basis of clinical signs and symptoms. Because these are valuable skills in any catastrophic event, dentists can make substantial contributions in collaborative efforts to assist communities affected by natural disasters. The National Disaster Medical System (NDMS) is a federally coordinated system that augments the nation's medical-response capability (U.S. Department of Health and Human Services 2020a). Its purpose is to provide a single integrated national medical response that assists state and local authorities in dealing with the medical impact of major peacetime disasters. The NDMS has six special teams, each with a particular field of expertise, including forensic dentists and dental hygienists. Members are required to maintain appropriate certifications and licensure within their discipline. Activated members are temporary federal employees who work under the guidance of local authorities.

Dental officers within HHS agencies (e.g., IHS, CDC, FDA) and those within non-HHS agencies staffed by U.S. Public Health Service dental officers (e.g., BOP, USCG) also are available to provide oral health care services to disaster survivors, once a disaster is classified as a federal emergency (U.S. Department of Health and Human Services 2020a).

Education and Training

Oral health education and training programs prepare three levels of providers—allied, doctoral, and specialist—with each encompassing a specific range of skills and responsibilities. The educational programs for these professionals range from months-long certificates for dental assistants to years-long doctoral and advanced specialty training for dentists. Programs are offered by state, community college district, private not-for-profit, and private for-profit colleges and vocational or technical institutions.

Table 5. Distribution of dental hygienists, assistants, and laboratory technicians by employment setting: United States, 2016–2018

Employment setting	Dental Hygienists N (%)	Dental Assistants N (%)	Dental Laboratory Technicians N (%)
Total	211,600	327,290	34,480
Dentist offices	200,710 (94.9%)	298,320 (91.1%)	5,890 (17.1%)
Physician offices	1,940 (0.9%)	6,670 (2.0%)	–
Medical equipment and supplies manufacturing	–	–	27,180 (78.8%)
Outpatient care centers	1,420 (0.7%)	4,270 (1.3%)	60 (0.2%)
Federal executive branch	790 (0.4%)	3,930 (1.2%)	520 (1.5%)
Other settings	2,580 (1.2%)	3,410 (1.0%)	830 (2.4%)

Source: U.S. Bureau of Labor Statistics, Occupational Employment Statistics 2016–2018; 2020a-c.

CODA serves the public by primarily ensuring the educational quality of dental schools and programs, including allied programs and advanced dental education programs, in the United States (Commission on Dental Accreditation 2020a). It was established in 1975 and is the only agency the U.S. Department of Education recognizes to accredit dental and dental-related education programs in the United States.

Allied Provider Programs

In the United States, there are 256 accredited dental assisting programs, 330 accredited dental hygiene programs, 3 dental therapy programs (with 3 additional programs seeking accreditation), 2 denturist programs, and 15 dental laboratory technology programs (Brickle and Self 2017; Commission on Dental Accreditation 2020b; National Denturist Association 2021).

Dental assisting certificate programs vary in length from 39.5 weeks (public institutions) to 57.3 weeks (private for-profit institutions) (American Dental Association 2019c). Dental hygiene programs are offered by public, private nonprofit, private for-profit, and private state-related institutions and can grant either an associate degree (an average of 84 credit hours) or a baccalaureate degree (4 years, an average of 120 credit hours). Hygienists who have an associate degree from a community college also can enroll in a program designed for them to complete a bachelor's degree (American Dental Education Association 2021a). Master's degree programs also are available to prepare hygienists for specialized careers, such as in public health dentistry or dental hygiene education.

The ADA Survey of Allied Dental Education for dental assisting schools in the 2018–2019 academic year showed that of 6,222 students, 47.7% were non-Hispanic White, 19.5% were Hispanic or Latino, 16.9% were Black/African American, 1.7% were Asian, 1.7% were AI/AN, and 5.9% were of unknown race; the remainder were members of two or more racial groups or were nonresident aliens (American Dental Association 2020c). Of the first-year student body, 93% of students were female and 7% were male.

The same survey reported first-year enrollments of 8,286 dental hygiene students in the 2018–2019 academic year, of which 94% were female and 6% were male. The report on race or ethnicity showed that 64.3% of the total number of dental hygiene students were non-Hispanic White, 15.4% were Hispanic or Latino, 8.2% were Asian, 4.7% were Black/African American, and the remainder were AI/AN, Native Hawaiian or other Pacific Islander, members of two or more racial groups, or nonresident aliens, and unknown race (American Dental Association 2020d).

First-year enrollment in dental laboratory technology programs in 2018–2019 was 306. Of students enrolled in these programs, 25.6% were non-Hispanic White, 14.8% were Hispanic or Latino, 11.2% were Black/African American, 14% were Asian, 0.2% were Native Hawaiian or other Pacific Islander, 1.3% were members of two or more races, and 3.4% were nonresident aliens (American Dental Association 2020e).

The profession of dental therapy in the United States is still in its infancy; there are three dental therapy programs in the United States, one in Alaska and two in Minnesota (Mertz et al. 2021). Nationwide data on these programs have not been collected, so demographic and other information is not available. In Minnesota, for example, there are two educational programs for dental therapy, and as of December 2018, a total of 92 dental therapists had licenses to practice. In that state, dental therapists are primarily women (86%); 82% are White, 5% are Hispanic, 4% are American Indian, and 2% are Black/African American (Minnesota Department of Health 2019).

Dental Programs

Dentistry is a highly technical profession. Depending on their level, students must attain established levels of basic, clinical, materials, and social science foundational knowledge in addition to clinical experience and skills. In the United States, the typical educational pathway to become a dentist includes completing a 4-year undergraduate study leading to a baccalaureate degree followed by a 4-year professional (predoctoral) program leading to a Doctor of Dental Surgery (DDS) or Doctor of Medicine in Dentistry (DMD). After obtaining degrees, graduates of dental schools may go into practice or may opt to attend one of 12 recognized advanced training programs, obtain research degrees, or attend postdoctoral training to enhance their general dentistry skills.

As of 2018, there were 66 dental schools in the United States, including 40 in public institutions, 22 in private institutions, and 4 that were private, state-related. CODA requires all U.S. dental schools to provide the equivalent of 4 years of training for the DDS/DMD degrees offered for dental programs; one school achieves this in a 3-year period. Total first-year enrollment of dental students for the 2018–2019 academic year was 6,250, of which an estimated 49% were male and 51% were female. Ten percent were Hispanic or Latino; 24% were Asian; 6% were Black/African American; 4% were AI/AN, Native Hawaiian, or two or more races; and 4% were nonresident aliens (American Dental Association 2019d). There were 627 advanced-standing and international dentists enrolled in the 38 international programs to become eligible for licensure in the United States (American Dental Education Association 2020a). There are two dental schools at Historically Black Colleges and Universities and a few schools that are members of the Hispanic Association of Colleges and Universities that provide programs, scholarships, and research training to assist underrepresented minority students to become competitive for admission to dental school and to develop research competence.

Pathways to U.S. Dental Practice for Foreign-Trained Dentists

States set the licensure requirements for dentists, which typically include graduation from a U.S. or Canadian CODA-approved educational program. For dentists from other countries seeking a U.S. dental license, there are three commonly used methods to facilitate licensure within the United States. The first two pathways lead toward a U.S. dental degree. Applying to a U.S. dental school that admits students with undergraduate education from a non-U.S. or Canadian school can lead to a U.S. dental degree. There were 325 Canadian and other non-U.S. students in first-year dental classes for 2019–2020 (American Dental Association 2021d). In addition, there were 708 international dental school graduates admitted with advanced standing to the 41 U.S. dental schools that offered programs in 2019–2020 to graduate candidates with a U.S. degree who would then become eligible for licensure in the United States (American Dental Education Association 2020a). The third pathway to prepare for licensure is for international dentists to apply to advanced education or specialty residency programs that admit international dental student graduates without a U.S. dental license. In many states this enables the individual to then be eligible to apply for licensure. There were 1,112 such international dental student graduates admitted to the 303 accredited programs that admit international dental school graduates without a U.S. dental license (American Dental Association 2021e; 2021f).

Specialty and Advanced General Dentistry Programs

Dentists may enroll in further training to become specialists, in intensive residency training for general practice, or for additional degrees. In the 2019–2020 academic year, there were 493 accredited specialty and 270 postgraduate dental education programs, of which 177 were General Practice Residency (GPR) programs and 93 were Advanced Education in General Dentistry

(AEGD) programs (American Dental Association 2020f). GPR and AEGD programs are 1- or 2-year programs that enhance general dentists' skills. They have similar goals, with GPR programs having an additional goal to "function effectively within the hospital and other health care environments" (Commission on Dental Accreditation 2020c, p. 8).

As of April 2020, there were 12 ADA-recognized specialties in dentistry requiring 1 to 6 years of training in a university or hospital (Table 6). Accredited programs for these specialties are required to train residents in research, and many specialty programs require residents to obtain a master's degree (e.g., Master of Science in Oral Science, Master of Medical Science in Oral Biology, Master of Science in Dentistry) or a doctoral degree (e.g., Doctor of Philosophy, Doctor of Medical Science, Doctor of Science) concurrently with a certificate in specialty training. There are 100 accredited Oral and Maxillofacial Surgery (OMFS) programs, 46 offering a medical degree; 51 OMFS programs are housed in dental schools.

In academic year 2019–2020, there were 1,237 GPR and 924 AEGD enrollees. Of these enrollees, 52.4% were male and 47.5% were female. Their racial and ethnic composition included 52.6% non-Hispanic White, 22.8% Asian, 8.9% Hispanic, 4.7% Black/African American, less than 1% AI/AN or Native Hawaiian, 1.2% members of 2 or more races and not Hispanic, and 7.3% nonresident aliens (American Dental Association 2020f). A total of 5,082 graduate students and residents were enrolled in the 12 recognized specialty programs. Of these enrollees, 56% were non-Hispanic White; 23% were Asian; 7% were Hispanic or Latino; 4% were Black/African American; less than 1% were AI/AN, Native Hawaiian, or other Pacific Islander; 1% were members of two or more racial groups, and 7% were nonresident aliens; 63% were male and 37% were female, and 1% identified as other (American Dental Association 2020f).

Educational Cost and Debt

The cost of education varies by type of school (public, private, or private state-related, and for some allied programs that take place in community colleges) and by whether the tuition the student is paying is in district or out of district. The cost also varies for those attending vocational schools that train students for specific occupations.

Allied Providers

The average estimated total cost of tuition and fees in accredited dental hygiene programs for the 2018–2019 academic year ranged from $29,018 for in-district students attending community college programs, to $32,325 for out-of-district students in those same programs, to $42,839 for out-of-state students (American Dental Association 2020d). Costs vary by the type of educational institution (community college, vocational or technical school, and university or 4-year college) and by whether or not the student resided within the institution's state or district. Average first-year in-district tuition in accredited dental hygiene programs was $4,612 at community colleges, $26,436 at vocational schools, $6,889 at technical schools, and $13,411 at 4-year universities and colleges (American Dental Association 2020d). The average estimated total cost of tuition and fees in accredited dental assisting programs for the 2018–2019 academic year ranged from $9,222 (in-district students) to $10,182 (out-of-district students) to $15,261 (out-of-state students).

Among the 14 colleges that offered dental laboratory technology or dental technician vocational programs, the average cost of tuition and fees for academic year 2018–2019 was $12,724 for in-state students, $14,934 for out-of-district students, and $25,900 for out-of-state students (American Dental Association 2020e).

Dental Programs

The rising total cost of an undergraduate college and dental education plus the slowing of dentist income has raised questions of a dental career's value and what is expected from the social contract between dentists and the public. Dentists typically have the highest debt among major health professionals (currently approaching $300,000) after completing dental school training (American Dental Education Association 2019b). However, veterinary medicine (163%), optometry (130%), and pharmacy (111%) have higher debt-to-income ratios, compared to dentistry (99%) and family medicine (84%) (Asch et al. 2013; American Dental Education Association 2015; Nicholson et al. 2015; Formicola 2017).

Table 6. Specialty and advanced general dentistry programs in the United States

Program	Minimum length*	Allowed program locations^	Number of programs
Dental Approved Specialties			
Dental public health***	2 years	University, Public Health Department, Federal Agency	15
Endodontics	2 years	Community or Hospital	55
Oral and maxillofacial radiology	2 years	Community or Hospital	9
Oral and maxillofacial surgery	4–6 years	University and Hospital	101
Oral and maxillofacial pathology	2 years	Community or Hospital	14
Orthodontics and dentofacial orthopedics	2 or 3 years	Community or Hospital	67
Pediatric dentistry	2 years	Community or Hospital	82
Periodontics	3 years	Community or Hospital	57
Prosthodontics	3 years	Community or Hospital	47
Oral medicine****	2-3 years	University and Hospital	9
Orofacial pain****	1-3 years	University and Hospital	12
Dental anesthesia**	3 years	University and Hospital	9
Advanced General Dentistry Programs			
General practice residency	1–2 years	Hospital	177
Advanced education in general dentistry	1–2 years	Community	93

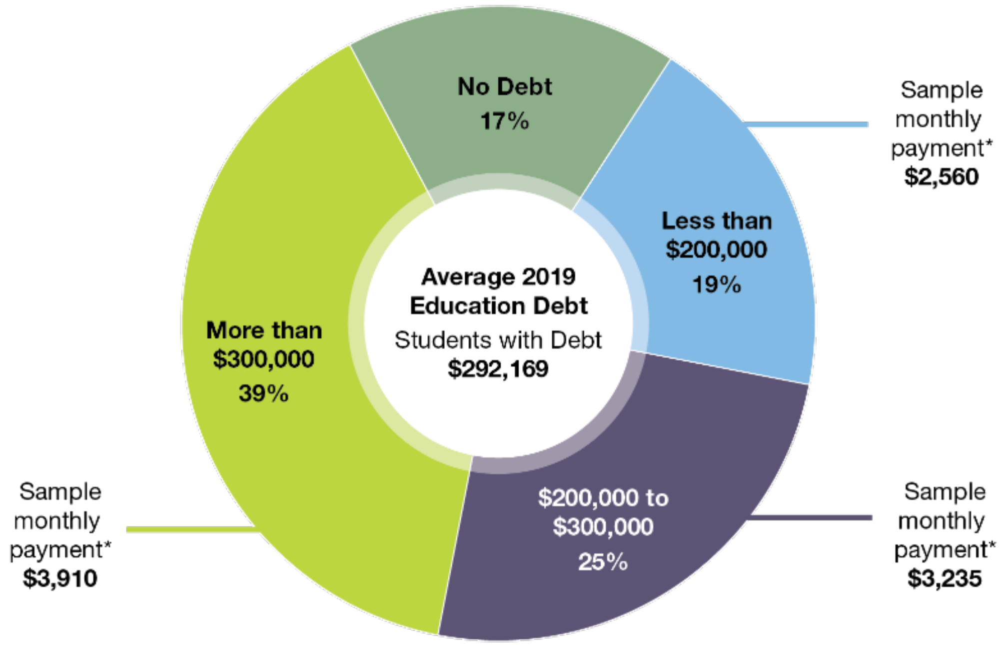
Notes:
* Defined by CODA standards.
** Approved as a dental specialty in March 2019.
*** Minimum length can be 1 year if individual enters residency with a graduate degree in public health.
**** Approved as a dental specialty Sept. 2020.
^ All specialty programs are regionally accredited.
Source: National Commission on Recognition of Dental Specialties and Certifying Boards (2021).

The first year of dental school for the 2018–2019 academic year ranged from a resident's cost at the University of Puerto Rico of $12,000 or $18,288 at Texas A&M University to $111,925 at the University of the Pacific. The average annual tuition and fees for first-year students at a U.S. public dental school was $49,537 for residents and $66,440 for nonresidents (American Dental Association 2021g). The average total tuition and fees for all 4 years of dental school in academic year 2018–2019 ranged from $251,223 for students attending a dental school within their state of residency (regardless of whether it was public or private) to $321,575 for students attending dental school as a nonresident (regardless of whether it was public or private). The average debt level in 2017 for students graduating from a private dental school was $341,190 and from a public dental school, $239,895. The average debt of all students with debt for all dental schools was $292,169 in 2019 (Figure 1) (American Dental Education Association 2019a). The high cost of dental education is an important factor in where graduates choose to practice.

Specialty and Advanced General Dentistry Programs

The majority of GPR programs, which are primarily hospital-run, and a smaller percentage of AEGD programs are funded through graduate medical education funds that include stipends paid by hospitals to residents who provide clinical care during specialty training.

Figure 1. Reported total educational debt of graduating dental school seniors: United States, 2019.



Note: *Standard 10-year term (120 level payments).
Source: American Dental Education Association, Survey of Dental School Seniors, 2019 Graduating Class (2019).

For academic year 2019–2020, an estimated 7% of GPR and 18% of AEGD programs charged tuition (American Dental Association 2020f). Stipends and the average tuition and fees varied depending on the specialty and the institution. Among the 82 pediatric dentistry programs, the average stipend for the 76 programs that pay a stipend was $50,788. A total of 311 specialty programs offered a stipend; of these, 179 programs offered a stipend while charging tuition and fees, and 382 programs provided a stipend without charging tuition and fees. Another 141 programs charged tuition and fees without providing stipends, and 66 programs neither charged tuition and fees nor provided stipends (American Dental Association 2020f). Stipends are sometimes available to help graduates continue their education because government support is available for some primary care residencies, such as pediatric dentistry and dental public health, though not for others, such as geriatric dentistry. However, some GPR and AEGD programs do provide a concentrated experience in geriatric dentistry leading to a certificate (Levy et al. 2013), while providing a stipend.

Curriculum, Licensure, and Certification

Program-specific education standards guide the curricula of all CODA-accredited dental education programs. Advances in technology and factors related to licensure and national board examinations, as well as social changes, have resulted in new approaches to education and new content in basic, behavioral, and clinical or technical sciences. Some schools have adopted online education programs, electronic health records (EHRs), and increased problem-based or case-based education (i.e., more active learning, less lecture-based activity). Some have introduced competency-based assessments and use them to evaluate a broader set of skills (self-assessment, critical thinking, use of evidence-based resources, and lifelong learning). In clinical areas, some schools have introduced interdisciplinary "group" practices to prepare students to work in the practice environment, and schools have been placing students in a wider variety of community-based practices (Kassebaum and Tedesco 2017). The majority of dental schools and dental hygiene schools provide intraprofessional and interprofessional experiences (didactic, laboratory, and clinical). Some encounter barriers as a result of scheduling, geographic distances, workforce limitations, timing of courses and clinics, and facility limitations (American Dental Education Association Council of Deans and Council of Allied Dental Program Directors 2016).

States regulate the pathway for dental and allied licensure and may set the professional standards they deem necessary to protect patients. For example, New York requires a postgraduate year of training before a graduate is eligible for licensure (see Chapter 3 for more detail on licensure). State dental boards require that dental hygienists and dentists graduate from CODA-approved programs and successfully complete a written and clinical license examination (American Dental Association 2020g). States also define the scope of practice for dentists and midlevel providers. By completing continuing education courses and clinical cases, general dentists can earn certification in areas such as aesthetic dentistry or implant dentistry. All states specify the amount of continuing education courses required to maintain licensure, and most depend on courses certified by ADA (American Dental Association 2020h).

Continuity of Education and Training During a Public Health Emergency

Training and education programs would be wise to consider the impact of natural disasters or public health crises on their ability to continue functioning and provide needed emergency health care for local jurisdictions and to develop needed guidelines. For example, on August 29, 2005, Hurricane Katrina caused extensive damage to the city of New Orleans, with extensive damage to the Louisiana State University medical campus, destroying medical and dental facilities and closing the health sciences campus for about 2 years. During that time, the university conducted academic operations in borrowed facilities in Baton Rouge (Armbruster et al. 2011). Fourth-year students were sent to private practices to complete their clinical competencies (Fidel and Pousson 2007).

Hurricane Maria, the worst catastrophic event to hit the island of Puerto Rico in nearly 100 years, produced physical damage that closed the University of Puerto Rico for 3–4 weeks in fall 2017 and left the island with an unstable power grid and scarce provisions. The school adjusted its academic calendar and worked on repairing structural damage. With support from the profession, it provided personal hygiene products, support, and headlights, plus water and one hot meal a day, to students and staff for about 3 months.

In early 2020, as the novel coronavirus (COVID-19) health crisis was developing, many dental schools worked quickly to limit the virus's spread in a large population with persons interacting in proximity (students, residents, staff, faculty, and patients). Dental professional schools have large open spaces with numerous clinical operatories, elevators, and classrooms. Schools and academic health centers sent students home, if possible, to reduce the on-campus census. They also stopped providing elective surgeries to prepare for an influx of patients needing specialized care and to preserve personal protective equipment (PPE). In addition, some schools initiated teledentistry and teledentistry training during the pandemic (Weintraub et al. 2020). All nonessential faculty and staff were transitioned to work from home, and plans were made for faculty to deliver instantaneous remote education.

During a 6-week time frame, four phases were proposed to manage the pandemic's course. During phase 1, many states issued stay-at-home orders to avoid community spread of the virus. Schools developed online education programs for the didactic components of their curriculum, curtailed their preclinical programs, and closed their clinics except for patient emergencies. Research activities were curtailed except for essential research. CODA offered flexibility in revising programs to allow graduating students and residents to complete "equivalency assessments."

The second phase was one of continuity. Schools maintained emergency services with rigorous PPE on the basis of revised clinical guidelines from ADA, CDC, and the Occupational Safety and Health Administration. Academics and operations continued, employing virtual classrooms, exercises, and remote secure "assessments" (computer-based examinations with self-proctoring tools). Clinical licensing examinations and national board examinations were suspended.

A third phase evolved in which states offered guidelines as schools and dental practices reopened using newly developed protocols. Schools resumed some nonemergency services, research, and didactic and preclinical education while maintaining social distancing and utilizing updated PPE guidelines. The timeframe for opening depended on the COVID-19 situation within each state. Patient screening protocols maintained social distancing. Priority was given to completing care, rather than to seeing new patients. Admissions protocols for candidates to dental school also had to change because dates for the Dental Aptitude Test were delayed, preventing applicants from taking an examination that dental schools often require for screening.

In the fourth phase, dental education programs were adapted, beginning with early laboratory courses in which student dentists developed their skill in using dental handpieces to offer restorations, root canals, and teeth cleaning. Because most uses of the handpiece results in the generation of aerosols, affected courses had to be altered with corrective actions submitted and approved by local public health agencies to accommodate social distancing and protection from aerosols. New protocols were developed to screen patients before they came to school clinics; to reduce the numbers of patients within buildings to maintain social distancing and protect patients and dental personnel from dental aerosols; and to rotate students, faculty, and staff through spaces in teams to enable team members to isolate in case a COVID-19 infection was identified within a team. Materials were developed to reassure patients about treatment safety and to allay patient, staff, and student concerns about coming to dental clinics.

Oral Health Practice

Oral health care is provided in privately and publicly owned dental practice settings, as well as in nontraditional practice settings (schools, long-term care facilities, and even work venues) and a variety of community settings. The majority of dentists (80%) work in private practices (Vujicic 2017a) (see Workforce, Private, and Public Practices). Publicly owned and managed dental practices or clinics are operated by a local, state, or federal governmental entity; by not-for-profit organizations; or by educational institutions (Guay et al. 2014). Nontraditional dental settings may be either not-for-profit or privately-owned practices. The types of patients and services differ by practice setting.

Privately Owned Dental Practices

Privately owned dental practices typically serve patients who have dental insurance, purchased either individually or through employers, or who personally pay for dental care. In 2017, 51% of dentists worked as solo practitioners, ranging from 32% in South Dakota to 65% in Utah. The percentage of dentists who owned a solo practice in 2017 varied by gender. Fifty-six percent of solo practice owners were men, and 39% were women. Sixty-three percent of solo practice owners were aged 55 to 64 years, and 21% were younger than 35 years of age (American Dental Association 2017a). DSOs employed 7% of all dentists in private practice, although the percentage was twice that for dentists aged 21 to 34 years (Garvin 2017). The number of dentists per DSO ranged from 6 to 1,500, with a mean of 213 (Langelier et al. 2017a). Dentists are attracted to DSOs because they offer guaranteed salaries, an ability to transfer management responsibilities, and a more favorable work-life balance.

Publicly Owned Dental Practices

Publicly owned dental practices or clinics provide safety nets for the country's underserved populations—the uninsured, Medicaid recipients, and other vulnerable populations who may not always have been well served by private dental practice settings. These practices include FQHCs, community clinics, and dental school clinics. In 2020, nearly 93% of all FQHCs provided preventive dental services to nearly 5.2 million patients (Health Resources and Services Administration 2021a). Nongovernment community clinics often receive community funding and grants and sometimes rely on volunteer providers. These safety net providers offer oral health care for many underserved children and adults who ordinarily would not receive these services because of their socioeconomic status, geographic location, or lower levels of health literacy. In addition, specialized government dental clinics offer care for active-duty members of the military, veterans, AI/ANs, and incarcerated populations.

The dental safety net also includes dental schools and education centers that train dentists, dental assistants, hygienists, and therapists. These academic institutions serve as dental care sites for those with Medicaid, the Children's Health Insurance Program (CHIP), or no insurance. In 2016–2017, dental students provided care during more than 3.1 million dental visits in community settings (Contreras et al. 2018).

Nontraditional Settings

Not all patients can access private or public dental settings—for example, if they are homebound, institutionalized, or lack transportation. Some organizations and entities are taking a proactive approach by providing oral health services where members of the community live and learn. Nontraditional dental locations include settings where children learn—including day care centers, Head Start centers, and schools attended by underserved groups of children—and where persons live, including assisted living, group homes for persons with disabilities, nursing homes, rural community centers, and even where individuals shop or work. Such place-based care may use dentists or allied providers with expanded functions, such as dental hygienists working under general supervision to perform preventive procedures or dental therapists providing onsite routine restorative care. Integrated managed-care organizations have explored the value that interprofessional practice can add to patients' overall health. For example, pediatric medicine clinics are providing oral health examinations, and dentists are addressing broader health concerns by discussing preventive oral health behaviors or providing tobacco cessation guidance (Rindal et al. 2013; Kranz et al. 2015; Mosen et al. 2016).

A goal of these scenarios is for the entire dental team to work at the total capacity of their licensed scope of practice, meaning that the team members provide the full scope of services that they have been taught and are licensed to provide. Other nontraditional types of practice may include the use of teledentistry to facilitate place-based care via telecommunication, with a remote supervising dentist as needed. Patients in such settings who have more complex dental needs may be referred to a traditional dental clinic.

School-Based and Head Start Centers

Dental teams provide an array of health promotion and prevention services, including screenings, dental sealants, preventive and therapeutic fluoride applications, and subsequent referrals or coordination of follow-up care. Some programs may be able to provide more definitive dental care, including restorations. Trained laypersons have implemented effective health promotion programs in Head Start programs, using materials designed for low-literacy populations, in which teachers show children how to brush their teeth and educate families about the importance of oral health and dental visits (Herman et al. 2013).

Many school-based and Head Start facilities use mobile dental equipment to reach vulnerable populations, thus removing potential barriers such as travel or parents' or caregivers' inability to leave work for dental appointments. One example of such care is a coalition of the Wisconsin Department of Health Services, Children's Hospital of Wisconsin, American Family Children's Hospital, and Delta Dental of Wisconsin that brings school-based oral health preventive services to more than 60,000 children annually across the state. Teams of dental hygienists work in more than 850 high-risk schools to provide preventive services and referrals to ensure that children in these schools have access to high-quality oral health services (Children's Health Alliance of Wisconsin 2020).

Group Homes and Other Community-Based Sites

Providing care in residential homes where adults with special needs live ensures care in a familiar and comfortable place that supports access and cooperation, enhancing efficiency for both patients and providers. Nonprofit group dental practices provide examinations and preventive care to at-risk individuals to help them maintain their oral health. Community partnerships enable the co-location of onsite dental services in long-term care facilities, schools, hospitals, and other settings using an accessible care network linked by a fully certified EHR.

Medical Provider and Medical Settings

Health promotion and prevention are increasingly provided by oral health professionals in locations other than the dental office or by non-dental health providers. Dental hygienists can educate pregnant women about oral health during prenatal and postpartum visits in medical clinics (Atchison et al. 2019). When dental hygienists educate parents about the benefits of dental sealants, the number of signed consent forms returned to school-based dental sealant programs increases (Children's Dental Health Project 2017). Pediatricians provide oral health education to caregivers while applying fluoride varnish during children's well-child visits (Kranz et al. 2013). Training of nurses in long-term care facilities improves their knowledge and attitudes about oral health and ultimately improves residents' oral health (de Lugt-Lustig et al. 2014). These examples highlight the importance of promoting oral health education and health literacy training by a diverse group of professionals in a wide variety of settings.

Use of the Emergency Department

ADA reports that more than 2.2 million visits to the hospital emergency department (ED) in 2012 were made for nontraumatic dental conditions (Allareddy et al. 2014; Okunseri 2015), mostly by persons who were uninsured or receiving Medicaid (65%) (Rampa et al. 2016). These individuals used the ED for nontraumatic dental problems for a number of reasons, including the lack of private practice appointments available during evenings or weekends, lack of dental insurance, difficulty finding dental providers who accept Medicaid, and poor oral health literacy that includes not knowing how to access the dental system (Koziol-McLain et al. 2000).

Using EDs for these types of visits is inappropriate, inefficient, and expensive. The average cost of a visit to the ED for dental treatment is three times as much as a visit to a dentist (Sun et al. 2015). More important, medical facilities rarely have appropriate diagnostic equipment or trained staff to properly identify and treat dental conditions, and EDs generally do not provide definitive treatment, such as extractions or restorations. Although prescriptions for antibiotics and opioid medications do not resolve the underlying dental problem, individuals are up to five times more likely to receive an opioid prescription for a dental problem if they are treated in an ED rather than in a dental office (Janakiram et al. 2018). In addition, more opioid prescriptions for acute pain, including dental pain, are provided on weekends (Janakiram et al. 2019a). Consequently, patients may return repeatedly to the ED for the same problem. In fact, an estimated 21% of those who had one ED dental visit in a year returned two to four additional times (Sun et al. 2015).

Services Provided

Dental practice largely focuses on preventing disease through regular dental services, including examinations, imaging, dental cleanings or prophylaxis, and applying preventive agents such as fluoride and dental sealants. More than three-quarters (76%) of all dental procedures are diagnostic and preventive, with only 12% of procedures representing restorative dental care (Guay 2016). Dental clinics also provide other preventive health care services, including tobacco cessation training, because many manifestations of tobacco use are in the oral cavity (Brown et al. 2019; Chaffee et al. 2020). Dental offices in some states screen for diabetes, and Oregon now allows dental practitioners to administer vaccines, including for influenza and human papillomavirus in the dental setting (Solana 2019). In 2020, states began implementing regulatory changes to allow oral health professionals to provide COVID-19 vaccines, and in March 2021, the 7th Amendment to the Public Readiness and Emergency Preparedness (PREP) Act permitted dentists in every state to administer COVID-19 vaccines (Health Resources and Services Administration 2021b; Machado 2021).

Dental Practice Technology

Dental practice uses an array of technology, including computers; lasers; scanning and milling technology; updated radiographic technology to enhance diagnostic information; and EHRs. Computers are a foundational technology within dental offices, connected with scanning technology to create new restorations, and used to manage EHRs. Digital scanning for orthodontics has largely replaced alginate dental impressions. The scanning eliminates the need for study models to be poured in stone and enhances treatment planning. The resulting models are easily passed to insurance companies through secure means when orthodontics is being completed for medically necessary reasons and must be reviewed by an insurer. Lasers are used to whiten teeth, to remove decay from a tooth, or to remove soft tissue. Scanning and milling technology is a part of the growing computer-aided design/computer-aided manufacturing (CAD/CAM) technology used to fabricate new bonded ceramic and resin-based composite restorations within the dental office (Trost et al. 2006).

The use of chairside CAD/CAM systems is promising in all dental branches in terms of minimizing time and effort made by dentists, technicians, and patients for restoring and maintaining patient oral function and aesthetics, while providing high-quality outcomes (Baroudi and Ibraheem 2015). Dental cone beam computed tomography is a novel X-ray technique used to make three-dimensional images of teeth, bones, and soft tissue (U.S. Food and Drug Administration 2020). For more information on advanced dental technologies, see Section 6 of this monograph.

An EHR is an information system that can accomplish many tasks for a busy dental practice, including creating dental records; storing billing, payment information, and radiographs; and sharing information with other providers' EHRs. Dental practices are increasingly using EHRs to: (1) improve quality, safety, and efficiency; (2) reduce health disparities; (3) engage patients and family; (4) improve care coordination and population health; and (5) maintain the privacy and security of patient health information (Office of the National Coordinator for Health Information Technology 2019). Many large dental institutions such as dental school clinics, FQHCs, and group practices have transitioned to an EHR, but fewer than half of dental practices utilize the full potential of EHR chairside (Moffitt and Steffen 2018). Section 6 offers more discussion on EHRs.

Telehealth includes the use of technology to facilitate the delivery of health care services at a distance, as well as patient and health professional education, and to conduct public health and administrative activities (Daniel et al. 2015). Teledentistry encompasses a wide array of oral health services that can be delivered from a remote setting, both live and through a "store and forward" method. For example, an oral surgery specialty consultation can be conducted using teledentistry so that a patient does not have to travel a long distance before a procedure (see Section 6 for additional information). It can reduce the cost and time of care and improve access to specialists (Banbury et al. 2014; Acharya and Rai 2016; Powell et al. 2017). Optimal telehealth systems are fully integrated into the health record. Telehealth collaboration reduces the risk for redundancies in patient care, such as duplicate tests and treatments (Fathi et al. 2017).

Provision of Dental Services During a Public Health Emergency

Whereas publications may have described the impact of public health crises on access to and delivery of medical care in affected communities, they often have ignored the impact on access to and delivery of dental care, and they generally have not described dental professionals' roles and contributions as crisis event responders, including provision of dental care and victim identification. A number of disasters and public health crises have affected dental practices during the past 20 years (Box 1). In 2005, Hurricane Katrina affected the lives of an estimated 1,185 licensed dentists in Louisiana and Mississippi (Mosca 2007). The affected dental professionals experienced prolonged displacement and disruption of their practices, and patients lost a vital workforce. Since Hurricanes Maria and Irma in 2017, the oral health systems in Puerto Rico and the U.S. Virgin Islands have faced numerous challenges, including an increase in demand for dental services and shortages of oral health professionals (Hall et al. 2018; Sharac et al. 2018). In 2018, more than 58,083 wildfires burned 8.8 million acres in California, destroyed an entire town, and killed 85 persons, making 2018 the deadliest wildfire season in that state's history (Insurance Information Institute 2020). The 2018 California wildfires displaced at least 17 dentists and 47 dental office staff members in the disrupted area.

Box 1. Unforeseen, major events that lead to a community health emergency or public health crisis also affect access to oral health care and dental education.

Several profound and consequential public health crises have occurred since 2000 in the United States:

- The 9/11 terrorist attacks on New York City and Washington, D.C., and the Anthrax bioterrorism attacks in 2001
- Hurricane Katrina in New Orleans and the Gulf Coast region in 2005
- Hurricanes Maria and Irma in Puerto Rico in 2017
- Wildfires in California in 2018 and 2019
- Viral infectious diseases such as the SARS outbreak in 2003, H1N1 in 2009, and Zika in 2015–16
- Ongoing opioid crisis culminating into a national public health emergency declaration in 2017
- Ongoing COVID-19 pandemic beginning in 2020

Unlike regional crises, the COVID-19 pandemic, which began to affect the United States in early 2020, disrupted access to dental care for the entire nation. While the pandemic is still ongoing, COVID-19 resulted in closure of dental offices for all but emergency care for many months; this varied by state. Necessary PPE was difficult to access for hospitals and unavailable for most dental offices. Because of the national shortage of PPE, dental providers made a concerted national effort to donate their stock to local hospitals. State and federal agencies requested that elective medical and dental care be deferred because of fears the virus would spread. Under ADA recommendations, dental offices limited their services to emergency care or were closed (O'Reilly 2020). The closure of an estimated 80% of dental offices, at least temporarily, increased the number of patients going to the ED for dental care.

Nationwide, states viewed dentistry through different lenses, with 30 states designating dentistry as essential and 20 allowing only emergency dental procedures. Sixteen states allowed the provision of essential procedures, and 7 states had no mandate regarding dental practice (American Dental Association 2020i). After 6 weeks of COVID-19 challenges, states started to allow dental practices to reopen. Most states determined that dentistry is essential and offices could reopen. Even states with shelter-in-place initiatives began to prepare for the reopening of dental practices.

Governors and CDC raised a number of considerations that guided states' decisions to reopen various businesses and services, including dental practices: (1) regional COVID-19 infection rates and the impact on health facilities, especially hospitals; (2) whether health systems had an adequate supply of PPE; (3) local availability of testing that provided prompt results; (4) local public health officer rulings for the state, city, or county; (5) availability of qualified staff within the practice team; and (6) existence of a COVID-19 infection control plan (California Dental Association 2020).

ADA's Health Policy Institute polled dentists nationwide to gather information on plans regarding COVID-19 closure and reopening. An early survey conducted in April 2020 showed that 80% of dentists had closed their practices, and 95% or more reported a significant financial impact as measured by practice collections (Carey 2020). The April data further showed that the proportion of dentists fully paying staff salaries had dropped from 27% in March to 11% in April and that the proportion paying no staff salaries had risen from 28% to 44% during the same period. A number of COVID-19 relief bills established under the Coronavirus Aid, Relief, and Economic Security Act offered federal loan programs to help small businesses, including dental practices, cover up to 8 weeks of payroll costs, interest on mortgages, rent, and utilities.

According to the ADA Health Policy Institute, more than 90% of the 19,000 surveyed dentists had applied for one such program, the Paycheck Protection Program (Garvin 2020a). On October 1, 2020, HHS announced that an additional $20 billion in government funds would be available to offset revenue lost because of the COVID-19 pandemic. This new funding, the Provider Relief Fund, applied to dental providers as well (Garvin 2020b).

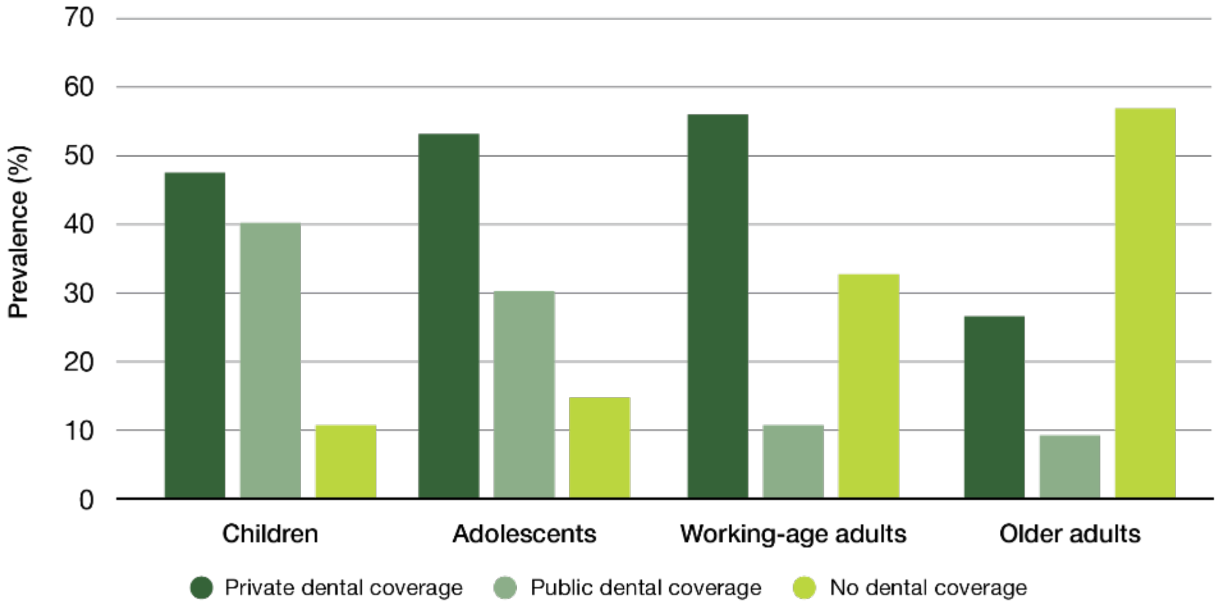
Financing Dental Care

The services that dental insurance pays for are referred to as *dental benefits*. Comprehensive dental benefits include dental prevention, such as twice-a-year examinations and dental cleanings, as well as major restorative procedures such as fillings, crowns, dentures, and bridges. Limited dental benefits, in contrast, usually cover only examinations and treatment related to urgent dental conditions, such as tooth extraction. Dental disease is far too common for insurers to offer coverage for all occurrences; thus, the term *dental benefit* is more accurate. This report, however, uses the more common term *dental insurance*.

Private dental insurance is an employee benefit, and both private and government dental insurance plans usually are separate from medical insurance, thereby distancing oral health care from the rest of the health care system. The current dental financing model does not afford all Americans equal access to dental care and diminishes oral health's value in the overall health care system. For additional discussion on financing dental care, see Section 1.

Insurance appears to increase access to dental services, and the type of insurance matters as well. Individuals with dental insurance are more likely to have an annual dental visit (Nasseh and Vujicic 2016a) than those without such insurance, and those with private dental insurance are more likely to have a dental visit than those with government-sponsored insurance such as Medicaid. In 2011–2014, 56% of individuals with private dental insurance had a dental visit in the past 12 months; among those with some public dental insurance 33% had a dental visit, and only 26% of uninsured Americans had a dental visit in the past 12 months. Figure 2 shows the distribution of dental benefit status in the United States by key age groups.

Figure 2. Percentage of individuals ages 2 and older by age group and dental insurance status: United States, 2011–2014



Notes: Children (ages 2–11), Adolescents (ages 12–19), Working-age adults (ages 20–64), Older adults (65 and older).
Source: Agency for Healthcare Research and Quality, Medical Expenditure Panel Survey (MEPS), Public use data, 2011–2014.

Nearly 9 in 10 children have either private or public dental insurance coverage, whereas more than half of older adults have no dental insurance coverage.

In 2018, an estimated $135.9 billion was spent on dental care. Of this amount, private dental insurance paid an estimated $62.2 billion (46%); patients paid another $54.9 billion, or an estimated 40%, out of pocket; Medicaid and Medicare paid $14 billion (10%); and other sources paid the rest (3%) (Figure 3) (Centers for Medicare & Medicaid Services 2020a). In short, dental care is expensive, and even though insurance rarely provides complete coverage, it is an important factor for ensuring access to dental care when it is needed.

Dental Insurance Coverage

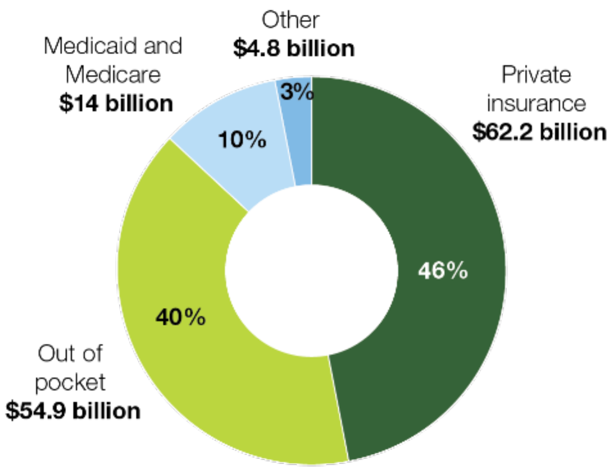
At the end of 2016, an estimated 249 million Americans, or 77% of the population, had some form of dental insurance. Two-thirds of them (164 million) had private or commercial dental coverage, and another 84 million had dental benefits through public programs such as Medicaid, Medicare Advantage, CHIP, or IHS. An estimated 47% of Americans received dental coverage from their employers, 27% received such coverage from Medicaid or another public program, 4% had private insurance but were self-paying patients, and 22% had no dental coverage in 2018 (Figure 4).

Cost sharing is a normal part of dental insurance and takes the form of deductibles, copayments, and other costs for dental procedures that exceed an insurance plan's defined benefits. Even for those with dental insurance, cost can be a barrier to care. Vujicic and colleagues (2016a) reported that financial barriers play a larger role in access to dental care than for any other type of health care. Almost 25% of adults with incomes below 100% of the federal poverty level deferred needed dental care in 2014–2015 because they could not afford it (Vujicic et al. 2016a). A substantial portion of the $55 billion consumers paid out of pocket in that same year was in the form of deductibles and copayments under dental benefit plans.

Impact of Dental Insurance on Access to Care

Dental benefits increase preventive care use by 19% and the use of restorative services by about 16% (Meyerhoefer et al. 2014). Moreover, private insurance (not government) alone has been shown to increase demand for dental services (Mueller and Monheit 1988).

Figure 3. Dental expenditures by source of payment: United States, 2018



Source: Centers for Medicare & Medicaid Services, National Health Expenditure Survey 2018 (2020).

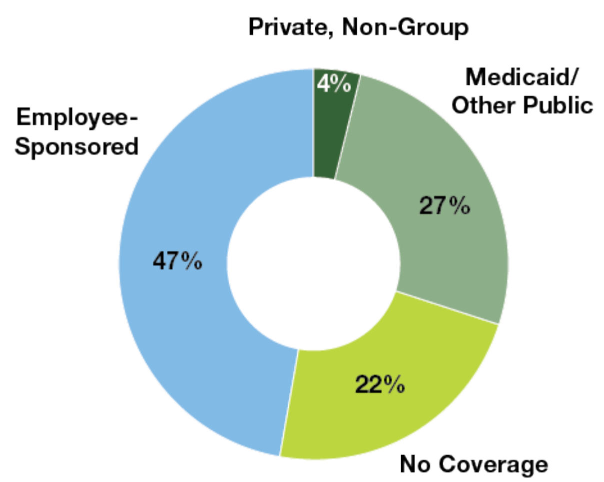
For government programs such as Medicaid, increasing reimbursement to dentists tends to increase utilization of preventive services (Nasseh and Vujicic 2015). Research has shown that increased reimbursement to dentists is necessary, but not sufficient, to persuade dentists to sign up to accept Medicaid patients or expand the numbers of such patients they accept. This means that increasing the numbers of dentists who accept Medicaid patients is complex and cannot be explained by reimbursement alone (California Health Care Foundation 2008).

FQHCs treat underserved populations and charge for services differently. For patients who lack dental insurance, some community clinics and FQHCs use a sliding-fee schedule to discount fees in accordance with a patient's ability to pay, usually calculated with reference to the FPL for income and family size. The sliding fee makes dental care more affordable but still requires those seeking care to make payments.

In addition, FQHCs are paid differently when they treat Medicaid patients and receive reimbursement from the federal government. Federal law requires Medicaid payers to use a prospective payment system (PPS) to reimburse FQHCs. States also can establish an Alternative Payment Methodology (APM) as long as the APM pays an FQHC at least as much as the PPS reimbursement (Medicaid and CHIP Payment and Access Commission 2017). Sometimes this system is referred to as payment according to *encounter rates*, whereby the center receives one lump payment for each valid patient visit. The Medicare, Medicaid, and SCHIP [State CHIP] Benefits Improvement Act of 2000 created the PPS methodology used in reimbursing FQHCs. The CHIP Reauthorization Act of 2009 enacted similar PPS rate language for CHIP (Medicaid and CHIP Payment and Access Commission 2017).

Medicare generally provides medical coverage for those aged 65 years and older and some younger who have specific disabilities or diseases. Medicare beneficiaries have the option to stay in traditional Medicare, administered by the Centers for Medicare & Medicaid Services, or to opt for a Medicare Advantage Plan (MAP), administered by one or more private companies. MAPs are required to offer all the same benefits as traditional Medicare, but they can add additional benefits such as dental or vision as an incentive for members. In 2019, 22 million persons were enrolled in a MAP, of which 67% had an extra dental benefit (Jacobson et al. 2019). Although Medicare Advantage dental coverage can vary from plan to plan, they normally include dental examinations, cleanings, and imaging (e.g., x-rays).

Figure 4. Dental insurance enrollment based on coverage sponsor: United States, 2018



Source: National Association of Dental Plans (2018). Reprinted with permission.

Nonmonetary Benefits of Dental Insurance

In addition to directly supporting dental care, dental insurance has indirect benefits for both patients and dental practices. For the latter, participating in a dental benefits program directs consumers to them, because consumers gain value by seeking their care from a dental provider within their insurer's network. Dental insurance also affords consumers a right to appeal the quality of dental care provided within the insurance network. In addition, dental insurers may offer programs to educate consumers about when and why to use their dental benefits and the importance of maintaining regular examination and prevention schedules. Some dental benefit programs provide coordination of care between dental and medical plans. In addition, dental benefits play an important role in ensuring quality by requiring providers to adhere to specific standards of care, as well as other patient safety rules and regulations.

Access to Dental Care

Unfortunately, all Americans do not enjoy equal access to care as a result of financial, mobility, and insurance restrictions, as well as other difficulties. More than 30% of Medicaid-enrolled adults reported that they had not visited a dentist in the preceding few years, compared to 16.1% of non-Medicaid-enrolled adults (Yarbrough et al. 2014). In 2015, only 39% of working-age adults (21–64 years) reported having visited the dentist within the preceding year, with only 28% of people with incomes of less than 100% of the federal poverty level reporting a dental visit (Manski and Rohde 2017). Twenty-eight percent of young adults reported that their mouth and teeth affect their ability to interview for a job (American Dental Association 2015). In 2019, about 43% of U.S. dentists reportedly accepted Medicaid patients (American Dental Association 2020l). By contrast, almost 70% of office-based physicians accept Medicaid patients with the percentage varying by state, ranging from 39% in New Jersey to 97% in Nebraska (Paradise 2017).

Another barrier to care access relates to how well providers are geographically distributed for a defined population. A defined geographic area with a shortage of providers for the entire population within the area is commonly referred to as a *health professional shortage area* (HPSA). Rural adults are more likely to have poorer oral health compared to adults residing in urban areas in the United States (Vargas et al. 2002; National Advisory Committee on Rural Health and Human Services 2018), and with 3 out of 5 U.S. dental HPSAs having a rural designation, this directly affects 20 million people. Furthermore, 65% of the 3,100 U.S. counties are designated as both primary care medical and dental professional shortage areas. An additional 55 counties have adequate numbers of physicians but lack sufficient dental professionals (Health Resources and Services Administration 2020a). Integrating dental professionals, such as dental hygienists or dental therapists, into medical clinics could begin to bring preventive oral health care to these dentally underserved areas, offering the opportunity to improve overall health for adults with chronic diseases.

Populations with Problems Accessing Care

Many Americans have difficulty accessing regular dental care, particularly those with limited financial means, those with no dental insurance or with limitations in veterans, Medicare, and Medicaid health insurance, among others. Collectively, identifiable groups of individuals who cannot access the dental care needed for adequate oral health are considered underserved. These underserved populations may be defined as poor and may include some racial or ethnic minorities; children under the age of 5 years; those with disabilities; place-bound older adults; many veterans; lesbian, gay, bisexual, transgender, queer, and other (LGBTQ+) individuals; persons with special health care needs; and those with complex medical conditions such as HIV/AIDS. Other underserved groups are those that lack adequate access to dental care because providers are unwilling to accept payments from federally funded programs such as Medicaid and those who reside in areas with professional workforce shortages, such as inner-city or rural areas. Other factors that can affect access to care include the lack of professionals trained to care for patients needing complex care, the inability of government programs to attract dental providers, poorly integrated health systems, and the fact that persons with limited means may lack the ability to pay out of pocket for preventive and restorative dental care (Yarbrough et al. 2014; Allen et al. 2017).

The Institute of Medicine (renamed the National Academy of Medicine) report, *Improving Access to Oral Health Care for Vulnerable and Underserved Populations* (Institute of Medicine and the National Research Council 2011, p. 1), described "persistent and systemic" barriers, including "social, cultural, economic, structural, and geographical" barriers to receipt of oral health care. The report concluded that:

- Improving access to care is critical to improving oral health outcomes and reducing disparities.
- The lack of integration of oral health care with medical health care contributes to poor access to care.
- The sources of financing for vulnerable and underserved Americans are limited and tenuous.
- Multilevel solutions are required not only at the provider level, but also by the organizational, community, and policy sectors.

Patients with Special Health Care Needs

One in every five persons in the United States has a disability (Centers for Disease Control and Prevention 2019a). It is understood that the treatment needs for some of these persons may require more time and specialized facilities; reimbursement rates rarely take this into consideration. Moreover, a 2010 study of dental professionals indicated that only 7% believed their predoctoral dental education prepared them for managing patients with special health needs, cognitive disabilities, and autism (Weil and Inglehart 2010). The amount of education dental professionals receive to guide them in treating persons with special health care needs correlates highly with their willingness to treat such individuals and, more important, their overall attitude toward individuals with disabilities. This suggests that the difficulties of obtaining adequate dental care for those with disabilities may be largely attributable to the inadequacy of training provided within dental education programs.

People with HIV/AIDS

Nearly half of people with HIV or AIDS report a high rate of unmet oral health care needs since testing positive for HIV (Fox et al. 2012). HRSA's Ryan White HIV/AIDS Program supports training programs, reimbursement for dental care and access to Ryan White funded clinics (Health Resources and Services Administration 2019b). Nevertheless, persons with HIV/AIDS report difficulty accessing regular dental care, and 52% of those surveyed had gone without a dental visit for more than 2 years. In addition, 63% reported that their oral health was only fair or poor. Stigma remains a barrier to care and affects even the most privileged of individuals in this population (Brickhouse 2018). Safety-net clinics, including community health centers, dental schools, hospitals with dental residency programs, and community colleges with dental hygiene programs, provide care for many people with HIV/AIDS (Health Resources and Services Administration 2019c).

Lesbian, Gay, Bisexual, and Transgender Patients

Social determinants of health are critical to understanding health issues related to sexual orientation and gender identity (DeSalvo and Galvez 2015). An estimated 4.5% of the U.S. adult population identifies as LGBTQ+; more than half of these individuals are younger than 35 years of age. LGBTQ+ adults are at high risk for comorbidities with oral diseases, such as sexually transmitted infections, substance use, disordered eating, and suicidal ideation (Hafeez et al. 2017). Although these individuals may not have significantly different clinical needs than the general population, they are at elevated risk for discrimination on the part of health care practices, including dental offices (Institute of Medicine and the National Research Council 2011). Nevertheless, much more information is needed to ensure that LGBTQ+ people receive appropriate health care, including oral health care, to fully promote their well-being (National Academies of Sciences, Engineering, and Medicine 2020).

Older Adults

Older adults now retain more of their natural teeth, yet access to oral health care is a challenge for many adults older than 65 years of age (Dye et al. 2019a). Medicare does not provide routine dental care (Centers for Medicare & Medicaid Services 2013; 2021), and only about 43% of older adults visit the dentist annually, with lower utilization rates among low-income older adults and those living in long-term care facilities (Griffin et al. 2012; Nasseh and Vujicic 2016b). Periodontal disease, root caries, a reduced level of saliva, and the risk of developing head and neck cancers increase with age (Griffin et al. 2012). The prevalence of chronic diseases also increases with age, as do the side effects of medications and potential cognitive and physical limitations that put older adults at greater risk for oral disease (Griffin et al. 2012). Add to these health problems having low income, no or low insurance coverage, and a lack of willing or trained providers, and it is no surprise that elderly Americans encounter problems in obtaining needed oral health care.

Oral Health Integration

Observers have noted that the disconnection of oral health from the broader health care system begins with the separation of dental from medical education, a process that produces providers unaccustomed to working together on patients' behalf. The inevitable outcomes have been the separation of oral health care from general health care, providers who function independently of other health care, and a separate dental insurance industry (Mertz 2016).

The integration of oral and general health care delivery, not yet widespread, is based on evidence that many oral and general health conditions are related and that coordinating treatment is important to maintain overall health. Across all areas of health, social determinants, which include socioeconomic, cultural, and environmental factors, are important influences on health and health care (see Figure 3, Section 1). Separate delivery structures limit the ability to take advantage of a broad systems approach to address and change these factors. Strategies for the integration of oral and general health care delivery are emerging as part of an overall framework for meeting the population's health needs effectively and efficiently. As a result, multiple models of integrated medical-dental care, in which providers deliver dental care as part of a health care system that includes primary medical care, specialty medical care, and related medical services, are being implemented. Most often, these services are co-located in FQHCs, VA clinics, and private Accountable Care Organizations (ACO), where dental and medical providers use a common EHR. Sharing a common medical record creates an environment in which oral health professionals provide services within a health care system that improves both oral and general health outcomes, as well as the patient experience and cost, as defined by the Institute for Healthcare Improvement's Triple Aim initiative to improve care delivery and patient outcomes and reduce the cost of care (Berwick et al. 2008; Suter et al. 2009).

Either population-based or patient-based primary care delivery guides integrated care, and the chosen orientation usually determines the focus of efforts to integrate care (Valentijn et al. 2013; Valentijn et al. 2015). A focus on population health leads to strategies that emphasize expansion of access to health care for underserved or at-risk populations, such as increasing access to care for children younger than 5 years to prevent oral diseases or to address them at an early stage. In contrast, a person-focused strategy emphasizes coordination of care for individuals with high levels of medical or dental need, such as patients with complex care needs, within a health care system. Both approaches share the overall goal of improving care (Starfield et al. 2005; Valentijn et al. 2015) and link clinical, professional, organizational, and system-wide processes (Valentijn et al. 2015; Harnagea et al. 2017).

Population-Focused Integration Models

Two integration frameworks developed in the United States since the 2000 Surgeon General's Report on oral health emphasized safety net populations and partnerships with private and public health organizations, governments, and academic institutions (Harnagea et al. 2017; Harnagea et al. 2018). HRSA proposed the first model, Integration of Oral Health and Primary Care Practice (IOHPCP), in 2014. The IOHPCP model includes risk assessment, oral health evaluation, preventive interventions, communication and education, and interprofessional practice collaborations. A team of primary care physicians, dentists, policymakers, and professional associations commissioned by the National Interprofessional Initiative on Oral Health developed the second model, the Oral Health Delivery Framework, which has been implemented in some medical offices and community clinics to coordinate oral and primary care providers in a convenient location.

The primary population-focused strategy has been the extension of the patient-centered medical home (PCMH) to include oral health care (Brownlee 2012; Braun and Cusick 2016). Linkage to payment has primarily driven the uptake in PCMH practice transformation. As of 2018, 29 states had implemented payment reform that provided incentives for PCMH practice transformation (most often through National Committee for Quality Assurance recognition), generally by paying providers a per-member per-month fee in addition to regular fee-for-service payments for Medicaid patients (Gifford et al. 2018). In addition to PCMH models that focus on primary medical care, other "health home" models have been developed to target either specific populations or medical specialties.

The health home model developed under the Affordable Care Act targets improvement of care for high-need, high-cost individuals with multiple chronic conditions.

ACOs use fixed global budgets and quality metrics to manage patient care and reduce costs while maintaining care quality (Shortell et al. 2015). As of 2018, 21 states had adopted health home programs, which receive an enhanced 90% federal match for services provided to this population during the first eight quarters of the program. Most ACOs do not include primary dental services (Mayberry 2017). Oregon is an exception, having enrolled 90% of its Medicaid patients in a program that includes comprehensive dental care for children (McConnell 2016). FQHCs frequently serve as health homes for Medicaid and uninsured populations, and many have co-located dental offices (Atchison et al. 2019).

Patient-Focused Integration Models

Health systems with well-defined populations have sought to integrate dental and medical care as a strategy to address the Institute for Healthcare Improvement's Triple Aim initiative, particularly for patients with chronic conditions or special needs. Suter and colleagues (2009) described key principles for successful health systems integration, including offering a comprehensive range of services with shared goals and organized interprofessional teams providing a standardized set of services that focus on the needs of a large, defined population. Other aspects of patient-focused integration models include clearly defined roles and responsibilities for team members, professional autonomy, system processes, and communication strategies to support the coordination of patient services. These structures generally support the provision of care and evaluate care quality and cost using modern electronic records and information systems. Distributing primary oral and medical care tasks to meet patients' current needs wherever they are seen can increase access to care (Institute of Medicine and the National Research Council 2011; Atchison et al. 2018), improve quality (Mosen et al. 2021), and reduce health care costs (Jeffcoat et al. 2014; Nasseh et al. 2017). These changes will require broadening the scope of clinical competencies to support the distribution of tasks among dental and medical providers. The full impact of these changes on workforce demand and supply are still unknown.

Insurance companies, integrated commercial health systems (HMOs, PPOs), and public health systems with well-defined patient populations, such as the VA and the U.S. Department of Defense, have proposed integration strategies (Joskow 2016; Atchison et al. 2018). The goals are to use vertical and horizontal integration to distribute care delivery activities among clinical staff, who employ the full range of their skill sets and scopes of practice. Health systems providing dental and medical care have the ability to integrate oral and systemic health care delivery by taking advantage of clinic co-location, integrated information systems, and shared management and financial systems. Access to care remains a concern, which is reflected in efforts to limit patient wait times for nonemergency appointments.

In one integration model, insurance companies have sought to tailor dental benefits and manage care for patients with certain chronic diseases (e.g., diabetes, heart disease) and for pregnant women. Aetna initiated a dental-medical integration program offering free dental care to "at-risk" members (Albert et al. 2006; Aetna 2013). Cigna attempted to improve health and lower costs through extended benefits to expectant mothers, patients with diabetes, and patients with cardiovascular disease (Cigna 2013). United Concordia studied the association between treating gum diseases and savings in terms of reduced annual medical costs for patients with diabetes, stroke, or heart disease (Bramson 2016).

Private integrated health systems such as Kaiser Permanente Northwest (Portland, Oregon), HealthPartners (Bloomington, Minnesota), and Marshfield Clinic (Marshfield, Wisconsin) provide comprehensive health care services, including those related to medical, dental, and behavioral health, to their members. Each has a leadership and organizational commitment to oral health integration and coordinates oral and medical staff to provide the right care, at the right place, at the right time, using professional staff at the peak of their capabilities and scope of practice. Capitated payment for professional services promotes financial risk sharing and a focus on quality. Each organization currently employs fully integrated health records systems. Direct communication through the electronic medical record between dentists, physicians, hygienists, pharmacists, and nurses enables quick and easy coordination of patient care in both medical and dental settings.

Patient Safety and Dental Care Quality

The concept of safety in health care in the United States has evolved, beginning with the establishment of combined federal regulations for employee safety and state licensure and provider scope-of-practice restrictions (U.S. Department of Labor 2014). The Institute of Medicine (IOM), in its report *To Err Is Human: Building a Safer Health System*, defined quality as consisting of three domains. First, the patient is safe from accidental injury. Second, the care provided represents current medical (or dental) knowledge and best practices, as exemplified by the evidence. Third, the care is responsive to the patient's values, expectations, and preferences (Institute of Medicine 2000).

An earlier IOM report on health care quality in the United States proposed six aims for our health care system focusing on safety, effectiveness, patient-centered care, efficiency, timeliness, and equity (Box 2) (Institute of Medicine 2001). The World Health Organization describes quality of care as "the extent to which health care services provided to individuals and patient populations improve desired health outcomes in a safe, effective, timely, efficient, equitable and people-centered way" (World Health Organization 2020, p. 3). The National Academy of Medicine defines it as "the degree to which health services for individuals and populations increase the likelihood of desired outcomes and are consistent with current professional knowledge" (Institute of Medicine 2001, p. 44).

Box 2. The Institute of Medicine's proposed six aims for the U.S. health care system

It must be: (1) *safe* and avoid care that harms patients; (2) *effective* and avoid underuse and misuse; (3) *patient centered* in providing care that is respectful of and responsive to patient preferences, needs, and values; (4) *timely* in reducing harmful waits and delays; (5) *efficient* in avoiding waste of equipment, supplies, ideas, and energy; and (6) *equitable* so that care does not vary in quality because of personal characteristics.

Source: Institute of Medicine, *Crossing the Quality Chasm: A New Health System for the 21st Century* (2001).

In general, the medical community has come to recognize that preventable events that cause harm to patients (adverse outcomes) could be the result of any number of factors. These factors might include medical errors; lack of awareness related to proper communication among team members and patients, families, and caregivers about safe practice; system-wide failure to recognize and deal effectively with professional burnout; and lack of care coordination within the health care system, which can affect patient outcomes (Hakanen and Schaufeli 2012; Chapman et al. 2017). The dental profession's slower embrace of safety as a key element of high-quality patient care may stem from the fact that most dental practices are solo practices rather than health care organizations. External influences, such as malpractice claims and the dental professional organizations' codes of ethics, also play critical roles in shaping the safety and quality of professional practices in dentistry (Yansane et al. 2020). Federal and state agencies provide guidelines for safety in dental practice. However, centralized reporting systems for problematic patient care are not well established or developed.

Patient Safety System

Malpractice claims constitute the most widely used surveillance system in dentistry, although their primary purpose is to help patients receive compensation for injury incurred during dental care. Liability providers are obligated to report payments made at the state level to the National Practitioner Data Bank (Health Resources and Services Administration 2021c), which collects information on adverse events as well as malpractice claims. Unfortunately, these reports and the data collected are isolated, often voluntary, and not integrated consistently within the continuum of education, licensure, and practice.

The problem of safety is larger than these poorly organized efforts suggest (Burger 2019). Growing scientific evidence confirms that patient harm occurs in dental offices (Weiman et al. 1995; Lee et al. 2007; Lee et al. 2013). Dentists, like physicians, routinely perform highly technical procedures in complex environments. Reports, both in medical literature (Obadan et al. 2015) and in the FDA Manufacturer and User Facility Device Experience database (Hebballi et al. 2015), describe deaths associated with dental treatment as well as a range of other adverse events—for example, the swallowing of endodontic files (Weiman et al. 1995) and the swelling of tissue as a result of tooth bleaching (Spencer et al. 2007). Reviews of electronic dental records have confirmed a broad array of harmful events during or following dental surgery, including an adjacent tooth inadvertently being dislodged, a patient found nonresponsive following anesthesia and transferred to the emergency room, and lip numbness lasting weeks as a result of nerve injury (Kalenderian et al. 2018).

Oral health specialty professional organizations, such as the American Academy of Pediatric Dentistry (AAPD) and the American Association of Oral and Maxillofacial Surgeons, exemplify how the dental profession is working to model the safety culture of medical professional organizations. These organizations have undertaken initiatives to raise the awareness of safety issues, emphasize the need for transparency when problems occur, and advocate for standardized protocols for treatment, including clinical practice guidelines (CPGs) and checklists (Wyckoff 2019; American Association of Oral and Maxillofacial Surgeons 2021). For example, AAPD co-developed guidelines with the American Academy of Pediatrics to address the special challenges involved in using sedation techniques with children (Coté and Wilson 2019).

Checklists have been developed to reduce dental errors (Pinsky et al. 2010), minimize wrong-site extractions or procedures (Lee et al. 2007; Perea-Perez et al. 2011; Saksena et al. 2014), and reduce misdiagnoses of temporomandibular joint disorders (Beddis et al. 2014). However, improving safety requires a systems perspective that considers individual variables, technology, organizational factors, processes and procedures, and the environments within and surrounding medical and dental practice (Carayon et al. 2014).

Communication to Promote Patient Safety

The medical community has long recognized health literacy's importance in developing health care providers' and organizations' effective communication with patients in medical environments. Health literacy has an impact on safety, as well as quality, in the dental setting. The Joint Commission, which governs education programs in health care, initiated a public policy initiative in 2007, to improve providers' delivery of safe, high-quality health care. In particular, it highlighted making effective communication—including health literacy—an organizational priority to improve patient safety, pursue policy changes that promote effective practitioner-patient communications, and incorporate strategies to address patients' communication needs across the care continuum (The Joint Commission 2007).

IOM describes a health-literate health care organization as one that "makes it easier for people to navigate, understand, and use information and services to take care of their health" (Institute of Medicine 2012, p. 2). It has called for required provider education on communication and cultural competency to improve effective use of patient communication strategies. The ADA Council on Advocacy for Access and Prevention developed an action plan to create health-literate communication information for dental practices (American Dental Association 2009; Rozier et al. 2011; Bress 2013). A culture of patient safety in oral health involves not only making oral health information clear and accessible, but also contextualizing that information to patients' lives (Horowitz et al. 2012; Maybury et al. 2013).

EHRs are another important resource patients can use to understand their dental problems, treatment plan, and care providers' instructions. Patient portals allow patients to securely log in, view and correct personal information, get test results, and email questions to health care providers. Regulations issued to implement the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 included requirements focused on patients being able to receive a clinical summary after office visits as well as being able to access their health information via internet-based tools, such as patient portals. This after-visit summary is designed to help patients remember the visit's content, support patient engagement in decision-making, and improve the quality of information in EHRs (Hummel and Evans 2012). Opportunities remain for improving the adoption and use of patient portals to ensure these innovative tools are fully integrated into the workflow of the oral health care delivery system (Irizarry et al. 2015).

Clinical Practice Guidelines

IOM defines *quality of care* as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge" (Institute of Medicine 2001, p. 44). Scientific evidence has grown at such a rapid pace that dental providers are on their own to sift through new knowledge and to update their decisions about clinical care. ADA defines *evidence-based dentistry* as the integration of "the dentist's clinical expertise, the patient's needs and preferences, and the most current, clinically relevant evidence" (American Dental Association 2020j). The process of translating scientific evidence into clinical practice has been described as taking place in three phases: synthesis, dissemination, and implementation (Pitts 2004a; 2004b; 2004c). Calls have recently been made advocating evaluation of CPGs as part of this process.

The synthesis phase consists of collecting and summarizing relevant, high-quality clinical research so it can be used to answer a specific question. Such systematic reviews concisely lay out the benefits and harms of treatment or diagnosis. During the dissemination phase, the evidence summary is adapted to promote clinicians' understanding so they can adopt information in routine clinical practice. Common dissemination strategies include webinars, continuing education courses, and journal articles.

A more formal type of evidence adaptation, the CPG, has now found its way into dentistry. High-quality CPGs present clear recommendations regarding the benefits and potential harms that patients could receive from a particular course of treatment. Essentially, a sound CPG should lead to improvement in dental care (Faggion 2013). Although the main goal of CPGs is to ensure that high-quality evidence, known to provide patient benefits, reaches appropriate patients, the general quality of CPGs can vary considerably (Mubeen et al. 2017). Major producers of CPGs include professional organizations, such as ADA, AAPD, and Cochrane; and government agencies including CDC and the U.S. Preventive Services Task Force.

The third phase of translation is implementation. Much research-generated evidence fails to find its way into routine clinical practice in a timely way, a phenomenon referred to as the "know-do gap" (Institute of Medicine 2001). The know-do gap is in play when treatments known to be beneficial and based on high-quality evidence differ from the care patients actually receive. Research shows that evidence-based beneficial treatment often is not adopted in clinical practice unless accompanied by an implementation plan that addresses the barriers for a given clinical setting. Many of the barriers to implementation (e.g., financing, provider training, information technology support, scope of practice, workflow concerns) exist within a clinical care setting, and much of an implementation plan focuses on system-level changes. Effective implementation plans need to be specific to the clinical setting for which they are intended. In the United States, ADA has led efforts to disseminate information on the use of evidence-based decision-making in clinical care (Carrasco-Labra et al. 2015) and to develop and promote a set of clinical guidelines for certain procedures (American Dental Association 2020j). Some are calling for a "fourth phase" that refers to evaluation, but is more aligned with improving rigor in the creation of CPGs (AGREE Next Steps Consortium 2017; Benavidez and Frakt 2019).

Measurement of Quality

Health care performance measurement systems include at least three common uses of quality measures (Institute of Medicine 2006). Accountability includes information to assist patients, health plans, and accrediting organizations in making choices about dental providers or clinics. Responses by patients to questions such as "How often did your regular dentist treat you with courtesy and respect?" and "Did the dental practice offer translators for non-English-speaking patients?" are used by dental administrators and national surveys (Dental Quality Alliance 2012; 2015). Quality improvement measures provide information to improve care in organizations. Examples of quality indicators are the percentage of health center patients aged 18 and older who have had a dental examination in the past year (Health Resources and Services Administration 2014b), the percentage of children 6 to 9 years of age who received at least one sealant on a permanent first molar within 6 months of an oral evaluation or assessment, and the percentage of patients aged 1 to 5 years who received a follow-up oral evaluation within 3 months of a well-child visit. Calls continue for improved development, standardization, and implementation of oral health measures, including patient-reported oral health outcome measures (Dental Quality Alliance 2012).

Population oral health measures assist stakeholders in making decisions about access to services (e.g., public insurance benefits and coverage), support those involved in community-wide programs and efforts to address racial and ethnic disparities and promote healthy behaviors, and are used by public officials responsible for disease surveillance and health protection. Examples of an access-to-care measure is "children 2–11 years of age with untreated decay" or "the percentage who reported they were unable to get needed dental care in the past year." An example at the national level is the Healthy People 2030 objective to "increase the proportion of children, adolescents, and adults who use the oral health care system" (U.S. Department of Health and Human Services 2020b).

Chapter 2: Advances and Challenges

During the past 20 years, a number of innovative strategies have been launched to improve the oral health workforce, education system, and delivery system to provide underserved populations with more equitable access to quality care. New categories of oral health care providers have been developed, including the dental health therapist and the community dental health coordinator (CDHC), and in some states dental hygienists' scope of practice has been expanded. Increased scholarship and loan repayment programs have contributed to offsetting educational costs for many recent graduates, including those from lower socioeconomic backgrounds. The number of dental and allied education programs has grown, as have new programs to recruit a diverse student body. More dentists are working in large group practices and federally qualified health centers (FQHCs) that serve low-income populations. Practices in schools are more focused on patient-centered comprehensive care than ever before, and public clinics and nontraditional dental settings are better addressing the needs of low-income patients, persons with special needs, and other underserved groups. Teledentistry is now helping dental providers to extend services to patients in schools, rural areas, and homes, for those who are unable to go out. Stronger oral health integration has been achieved by involving primary care practitioners and by increasing the use of multidisciplinary dental teams with shared responsibilities for the provision of oral health services.

However, it is clear that the delivery of oral health care still does not meet the needs of tens of millions of Americans. Dentists are distributed unevenly across the country, resulting in an oversupply of providers in some areas and not enough in others. Those who depend on Medicaid for dental coverage face a significant barrier to care, because nearly more than half of dentists do not participate in public insurance (American Dental Association 2020l). The current system delivers predominantly office-based care that is convenient for providers but not for many underserved patients, especially older adults, persons with disabilities, and others who cannot travel for care or who work in jobs without leave during general working hours. Ongoing challenges for the oral health profession include the distribution of dentists to areas of need, restrictive state practice acts, barriers to workforce models, the lack of demand-based modeling that could help providers better respond to patient needs, and the impact of public health crises.

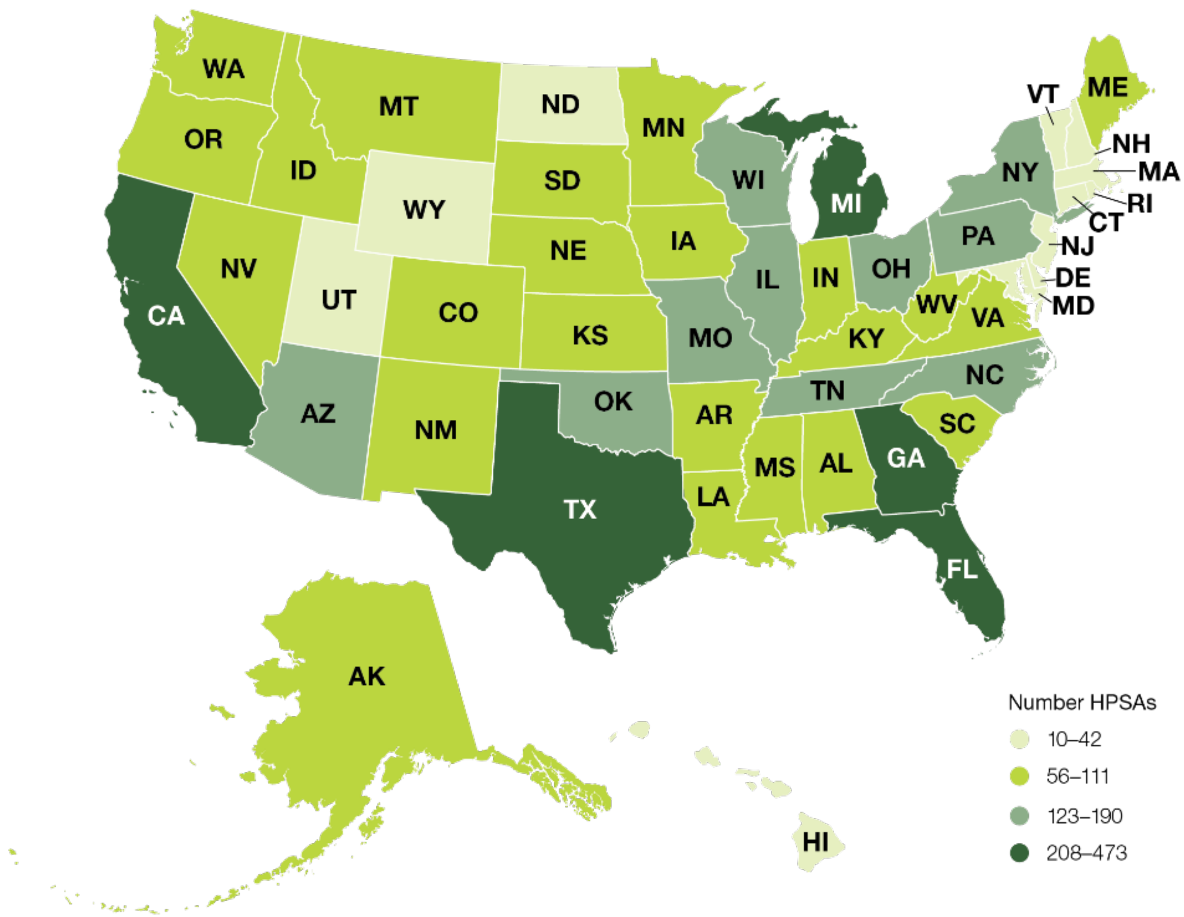
Workforce

Lack of Dentists in Underserved Areas

Multiple barriers exist to improving access to oral health services for underserved patient populations. In 2018, there were more than 5,800 dental health professional shortages areas (HPSAs) affecting almost 58 million people in the United States. A HPSA is identified by a defined geographic area and must have a population-to-provider ratio meeting a defined threshold, for dental care that ratio is generally 5,000 to 1. Figure 5 depicts dental HPSAs in the United States and it shows that every state has dental shortage areas, from Delaware (10) to states such as California, Texas, Michigan, Georgia, and Florida, which have between 208 and 473 areas (Health Resources and Services Administration 2020c). Population groups, such as some served by the Indian Health Service (IHS), accounted for the majority of the shortage designations, totaling 1,834 designations and serving more than 47 million individuals (Health Resources and Services Administration 2020b). It is estimated that only 50% of the dental needs among underserved population groups were met. Rural areas accounted for more than two-thirds of all shortage areas (National Advisory Committee on Rural Health and Human Services 2018).

In a survey of executive leaders and chief executive officers at health centers, 45% reported having at least one dentist vacancy; of those vacancies, 47% had lasted longer than 6 months (National Network for Oral Health Access 2018). In 2019, IHS reported having more than 100 openings for oral health professionals (Indian Health Service 2021). Only a small percentage of dental students come from rural areas, but increasing their number is important because they are most likely to return to their hometowns or other rural areas to practice (Vujicic et al. 2016b). Job opportunities in local and federal health centers are not widely promoted or advertised, which leaves dentists unaware of these opportunities.

Figure 5. Dental health professional shortage areas (HPSAs): United States, 2018



Note: Number of HPSAs refers to the number of shortage areas within each state.
Source: Health Resources and Services Administration (HRSA), Bureau of Health Workforce (2018).

Redefining the Roles of Oral Health Care Providers

Several strategies have emerged in the last 20 years to address inadequate oral health care in underserved areas. The most notable change in that time has been the introduction of dental therapy into the United States. The profession of dental therapy began with the establishment of New Zealand's School Dental Service in 1921 and has since expanded to more than 50 countries. Dental therapists have been providing dental care in other countries for many years, and that care has been shown to improve population and individual oral health in underserved communities. These allied professionals prepare and fill cavities using a hand drill and perform nonsurgical extractions—procedures reserved for dentists in the United States. This allows oral health services to be delivered to many who might not otherwise receive them.

In 2004, the U.S. version of the dental therapist, the dental health aide therapist (DHAT), was introduced in Alaska when the first Alaska Native students graduated from the University of Otago dental therapist program in New Zealand and returned home to address their villages' and communities' oral health needs. In 2007, the Alaska Native Tribal Health Consortium opened a 2-year DHAT education program in partnership with the University of Washington School of Medicine's physician assistant training program. In 2015, the program transferred its academic affiliation to Iḷisaġvik College, a tribal college based in Utqiaġvik, Alaska, and was renamed the Alaska Dental Therapy Educational Program. Graduates of this tribal college program earn an associate degree in applied science. The program recruits students from the communities where they will return to work. In the nearly 15 years of DHAT practice in Alaska, 74% of those trained are still practicing.

The awarding of an associate degree positioned the program to meet the Accreditation Standards for Dental Therapy Education Programs of the Commission on Dental Accreditation (CODA) (Commission on Dental Accreditation 2015). Therefore, in August 2020, the 3-year Alaska Dental Therapy Educational Program at Iḷisaġvik College became the first CODA-accredited dental therapy program in the United States. Now, culturally appropriate training and student support from a tribal college open a door to higher education that was once closed to many rural Alaskan youth. Students gain the skills and confidence they need to go on to higher education and careers.

After graduation, DHATs must complete a minimum of 3 months or 400 hours of preceptorship under the direct supervision of a licensed dentist. Upon approval by the supervising dentist, DHATs can apply for certification from the Community Health Aide Program Certification Board. DHATs are recertified every 2 years, a process that includes continuing education requirements and competency assessments in all procedures in their scope of practice. Certified DHATs work under indirect and general supervision of a dentist in accordance with established standing orders. As of March 2021, there are 35 certified DHATs in Alaska.

A 2010 study looked at many aspects of DHAT practice and supervision, including blinded evaluations of work by both DHATs and dentists, and found that DHATs in Alaska provide safe, appropriate, and effective care that patients value (Wetterhall et al. 2011). Since then, a number of studies in Alaska's southwestern region have shown that communities receiving more days of coverage by a DHAT had fewer cavities and extractions and that both children and adults in those communities received more preventive services than those in communities without DHAT coverage (Chi et al. 2018). Other studies of DHATs have yielded positive findings regarding quality of care (Wetterhall et al. 2011), access to care (Minnesota Department of Health 2014), and cost-efficiency for practices employing these professionals (Apple Tree Dental 2018).

The success of the DHAT program has prompted other states to revise state practice acts to allow dental therapy practice. The first state to successfully add dental therapy to a practice act was Minnesota in 2009. The resulting legislation allows for dental therapy practice at differing levels and includes a requirement for these therapists to practice under a dentist's supervision and to primarily serve low-income, uninsured, and underserved patients. Dental therapists licensed in Minnesota are required to graduate from a program approved by the Minnesota Board of Dentistry or accredited by CODA with at least a baccalaureate degree. Currently, all Minnesota dental therapy program graduates are eligible to practice both dental therapy and dental hygiene. As of 2019, there were 92 licensed dental therapists with 95% working in their field.

Innovations are expanding the role of dental hygienists through additional functions, alternative programs, and independent practice. Since 2001, there have been important changes in the scope of practice for dental hygienists in many states (Langelier et al. 2016a; Langelier et al. 2016b). A number of states now permit dental hygienists to provide preventive oral health services in public settings, including schools, nursing homes, day care centers, and Head Start programs, which creates a new point of entry for underserved populations to receive preventive oral health services (Langelier et al. 2017b; Keough et al. 2020). Dental hygienists can now also provide new materials and technology, such as silver diamine fluoride and interim or atraumatic restorations, without prior authorization from a dentist (Langelier et al. 2016b). These therapeutic agents are especially helpful in stopping or slowing decay progression so that children, the elderly, and others may be protected from pain and further tooth deterioration.

This provides lower-cost preventive and basic restorative care, especially to those who have not received regular dental care—or any dental care at all. In some states, public health dental hygienists are licensed to practice under a dentist's general supervision after successfully completing at least 10 hours of continuing education (e.g., in infection control, in risk management for practice in a public health setting, involving hands-on experience in a public health setting). The scope of practice for dental hygienists varies by state and is generally expanding (Langelier et al. 2016b). Evidence suggests that in states in which they have a more autonomous scope of practice, dental hygienists have had a more positive impact on population oral health (Langelier et al. 2016b).

Barriers to Development of Workforce Models

Despite payment system reform and other progress, barriers continue to limit the development of new workforce models (Frogner et al. 2020). Health care organizations can limit flexibility by using privileges based on established professional boundaries (Frogner et al. 2020). Restrictive state practice acts, health care, and/or educational requirements limit the expansion of new and existing workforce models. State practice acts vary considerably; many states do not authorize dental therapists, and they may restrict the scope of practice of dental hygienists, preventing them from providing the full range of services for which they are trained. In 2018, a federal report titled *Reforming America's Healthcare System Through Choice and Competition* recommended that states should evaluate emerging health care occupations, such as dental therapy, and consider ways in which their licensure and scope of practice can increase access and drive down consumer costs while still ensuring safe, effective care (U.S. Department of Health and Human Services 2018). Restrictive rules remain, despite a lack of evidence that they are necessary to protect against unsafe care. In short, a better-performing, wider-reaching oral health delivery system cannot be achieved without legislative and regulatory change.

Many professions have raised educational requirements without any increase in scope of practice. Studies in nursing demonstrate that these requirements do not improve patient outcomes or increase wages for practitioners, but they do decrease the satisfaction of practitioners, who cannot use their full scope of knowledge. Professional organizations often encourage "degree creep" or "credential creep," found in many educational programs (Garvin 2013; Fuller and Raman 2017). Minnesota's educational requirements for dental therapists exemplify this kind of overtraining with respect to the state-permitted scope of practice. CODA dental therapy standards require much less education than the bachelor's and master's level of education mandated in Minnesota legislation, yet Minnesota hygienists and therapists are allowed no broader scope of practice than is permitted with the associate degree in Alaska. It should be noted, too, that higher degrees require more time and money to complete, which can discourage lower-income individuals, persons of color, and others from underserved and rural communities from entering the health professions (Ashford 2013).

Effect of Unserved Oral Health Needs on the Health Care System

Examining the risks and benefits of dental care reform provides one perspective on why reform has been slow. For the most part, the outcomes of unaddressed dental disease do not fall to the dental field to deal with. Instead, they are borne by the medical system in the form of emergency department (ED) bills to manage pain and infection resulting from untreated oral disease and by patients who have difficulties chewing associated with loss of their teeth (McDonough 2016; Rowland et al. 2016). An indicator of an underperforming delivery system is the number of persons who seek hospital ED care for preventable dental conditions during regular office hours (Wall et al. 2014). In 2016, there were 2.2 million oral health-related ED visits at a cost of $2.4 billion (American Dental Association 2019e). Likewise, the broad potential benefits of improving dental care access and oral health—such as superior diabetes care, improved management of cardiovascular health, prevention of childhood diseases, and employment of low-income adults—are not tied to tangible incentives within the dental care system (Mertz and O'Neil 2002). The consequences experienced outside the dental care system underpin many calls for system integration by policymakers (Koppelman et al. 2016).

Increasing Programs to Diversify the Workforce

The 2000 Surgeon General's Report on Oral Health in America documented the disparities in oral health among specific populations and emphasized the importance of addressing the lack of racial and ethnic diversity in the dental workforce. By 2050, racial and ethnic minorities will make up half the population of the United States (Colby and Ortman 2015). Yet in 2015, nearly 3 out of every 4 dentists were White, and Hispanic/Latino, Black/African American, and American Indian/Alaska Native (AI/AN) dentists continued to be underrepresented in relation to their proportions in the general U.S. population (Table 7).

The Indian Health Care Improvement Act (Public Law 94-437, as amended)(1976) authorizes the IHS Scholarship Program, Loan Repayment Program, health professions training-related grants, and recruitment and retention activities—all to improve Native Americans' health while attracting them to the dental workforce and to the numerous workforce shortage areas within IHS settings.

These IHS programs work synergistically with tribal organizations and federal authorities to recruit and retain health professionals to provide high-quality primary care and clinical preventive services to AI/AN individuals and to increase the number of sites eligible to participate in the scholarship and loan repayment programs. In fiscal year 2018, the IHS Loan Repayment Program made 100 awards to dentists and dental hygienists, including 39 new awards and 61 contract extensions.

Reaching parity in representation of populations of color among dental practitioners is critically important because concordance between practitioners and patients enhances patient satisfaction and the quality of care. Minority practitioners treat a disproportionate number of low-income and minority patients (Mertz et al. 2016). Yet in the 2018–2019 academic year, six dental schools enrolled no Black/African American students, and another nine each enrolled only one (American Dental Association 2019d).

Burnout, Well-Being, and Resilience

Addressing the potential for professional burnout remains a challenge. A Mayo Clinic study found that more than 50% of physicians reported at least one symptom of burnout, and other health providers are similarly affected (Talbot and Dean 2018). There are two philosophical approaches to dealing with burnout or overwhelming stress, and the differences have sometimes led to contentious national debate.

One approach to burnout addresses individuals, with the goal of increasing resilience and coping skills to make the stressors less overwhelming to the practitioner. Because dental school, residency, and the practice of dentistry are inherently stressful, dentists must develop the ability to manage these stressors without being overwhelmed. Resilience requires that providers be taught specific skills, including conflict management, emotional regulation (how to calm down after being upset), and perspective taking (looking at a situation from both persons' point of view). A perspective-taking intervention was found to increase patient satisfaction with medical students' clinical examinations (Blatt et al. 2010).

The other approach is to consider external stressors a systemic problem so that the goal is to decrease them. This approach starts with the assumption that the structure and practice of dentistry and dental training is unnecessarily stressful and inevitably produces burnout. In other words, no one should have to become resilient to something that they should not have to endure. An example of a systemic approach was the Accreditation Council for Graduate Medical Education's 2003 call to reduce medical resident working hours to no more than 80 hours per week, a change that reduced medical errors as well as stress experienced by residents (Agency for Healthcare Research and Quality 2019). Other proponents of the need for systemic change point out that an increasingly business-like health care environment overwhelms a busy provider with tasks (e.g., maintaining profitability, completing electronic health records) unrelated to actual patient care (Talbot and Dean 2018).

Multiple groups are examining burnout and the fallout associated with burnout within the health professions, including the American Dental Association (ADA), the American Dental Education Association (ADEA), and the National Academy of Medicine. The risk of professional burnout, which has been associated with such negative effects as medical errors and malpractice suits, may be somewhat ameliorated by the practitioner's workplace (Dyrbye et al. 2017). For example, surveys of community health center providers found high levels of professional satisfaction (National Network for Oral Health Access 2014; 2018). Most providers working in such health centers chose these settings out of a desire to provide care for underserved populations. In 2013, 84% of dentists and 94% of hygienists in community health centers planned to remain there (National Network for Oral Health Access 2014). Satisfaction remained high in 2018, with 70% of dentists and 87% of hygienists intending to remain in this setting (National Network for Oral Health Access 2018).

Table 7. Percentage of dentists and new dental graduates by race/ethnicity compared to the overall population: United States, 2016

Race/ethnicity	Existing dentists*	Dental graduates	U.S. population
White	74.8	54.2	61.3
African American	3.0	4.9	13.3
Hispanic	6.1	6.9	17.8
Asian	14.3	23.6	5.7
American Indian/Alaska Native	0.1	0.3	1.3

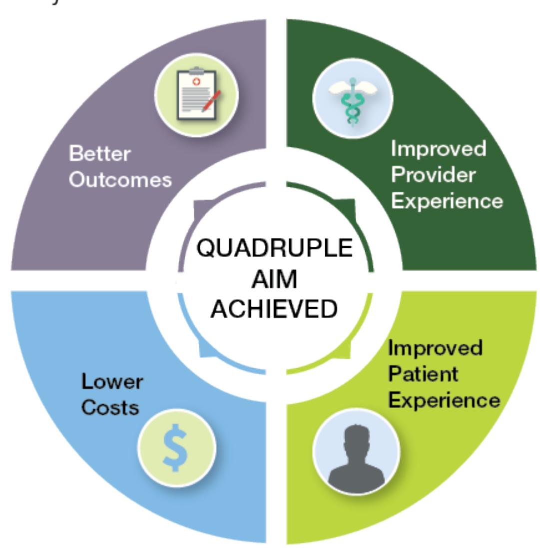
Note: Existing dentists in the U.S. workforce data is for 2011–2015.

Sources: American Dental Association Health Policy Institute. Survey of Dental Education 2016-17, Table 19 (2019b); HRSA, Bureau of Health Workforce (2017); U.S. Census Bureau, Population Division (2017).

However, these levels of satisfaction may not apply across the entire oral health care landscape, and are being addressed by groups who think it is important to examine burnout's impact on professional satisfaction. The National Academy of Medicine, one of the three institutes that make up the National Academies of Science, Engineering, and Medicine, launched the Action Collaborative on Clinician Well-Being and Resilience in 2017 (National Academy of Medicine 2021). The initiative was in response to leaders from professional health care associations, educational institutions, large health care centers, public and private payers, health information technology vendors, government agencies, trainees, and patient and consumer groups expressing the need for an initiative to address "concerns from the clinical community about rising challenges to clinician well-being and resilience." The collaborative is committed to three goals: raising the visibility of clinician stress, burnout, depression, and suicide; improving baseline understanding of challenges to clinician well-being and consequences for clinicians, patients, and the health care system; and advancing evidence-based, multidisciplinary solutions to improve patient care by caring for the caregiver. In addition, as an update to the Triple Aim, addressing burnout has been included in the Quadruple Aim (Bodenheimer and Sinsky 2014). This approach is now being supported by the Agency for Healthcare Research and Quality (AHRQ) to help facilitate a more effective health care delivery system (Figure 6) (Agency for Healthcare Research and Quality 2019).

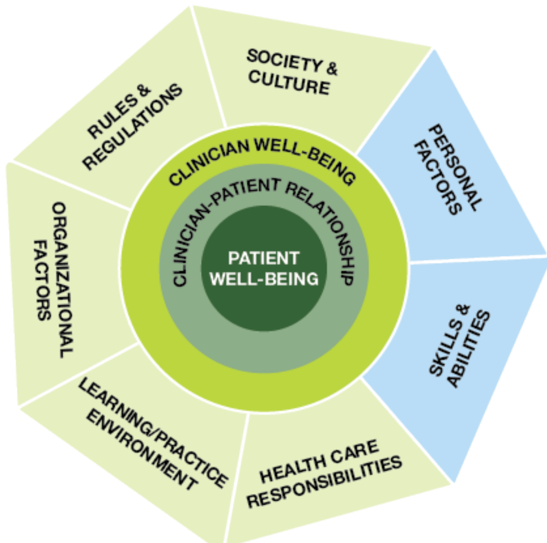
The collaborative's Clinician Well-Being Knowledge Hub emphasizes a systems-centered approach to address burnout and promote well-being that is structured around three key areas: (1) causes of burnout, such as organizational factors, learning and practice environment, society and culture, rules and regulations, personal factors (Figure 7); (2) effects of burnout, including safety and patient outcomes, clinician well-being, turnover and reduction of work effort, and health care costs; and (3) solutions to burnout, such as individual and organizational strategies and measurement of burnout. The collaborative has begun to break the culture of silence around this issue by initiating dialogue across the health care professions about challenges to clinician well-being and identifying resources for understanding the factors affecting clinician well-being and resilience. ADA has developed a Well-Being Initiative, which includes online resources on burnout, stress, and building resilience (ADA Center for Professional Success 2020).

FIGURE 6. The Quadruple Aim and the Optimization of Health Systems



Source: Agency for Healthcare Research and Quality (2019).

Figure 7. Factors affecting clinician well-being and resilience



Source: National Academies of Sciences, Engineering, and Medicine (2019). With permission from the National Academy of Sciences. Courtesy of the National Academies Press, Washington, D.C.

Education and Training

The number of general, advanced, and specialty dental education programs has increased since 2000. Increased enrollments in these programs have produced more dental providers, a broader range of dental and allied providers, and a diversity of enrollees, with growth noted in certain areas, for example, women, Hispanics, and Asians. The major challenges for dental education are managing the increasing knowledge base, incorporating technologies into the curriculum and practice, introducing new interprofessional practice models and corresponding curriculum, ensuring student population diversity, and reducing the cost of education. Examining ways to reduce the cost of a professional education, including that for dentistry, also offers a challenge to educational administrators at a variety of levels. From a population health perspective, educators should envision an educational system that prepares practitioners to solve the inequities in health across the nation. The system should incorporate more focused training on the impacts of policy on health care access and social determinants of health in didactic and clinical training to prepare students to deal with the current and future U.S. population.

Allied Provider Programs

Since 2000, the types of educational programs in operation or under accreditation have expanded to include dental therapists, advanced-standing dental hygienists, and CDHCs to meet the demand for more providers. First-year enrollment in dental hygiene programs grew from 6,486 students in 2000 to 8,370 students in 2016. The new CDHC programs have grown quickly to 39 states as of 2019, with 150 students enrolled, 305 CDHC graduates, and 17 schools offering, or planning to offer, training. On the other hand, first-year enrollment in dental assisting programs decreased from 6,150 to 6,080 during the same time period. Similarly, first-year enrollment in dental laboratory technician programs fell from 444 to 324 (American Dental Education Association 2018a).

Dental Programs

Between 2000 and 2017, the number of U.S. dental schools grew by 20%, from 55 to 66. There were four new public and eight new private dental schools, as well as the closure of one school (American Dental Education Association 2018b). First-year enrollment in Doctor of Dental Surgery or Doctor of Medicine in Dentistry programs grew from 4,327 students in 2000 to 6,317 in 2020, an increase of 46% (American Dental Education Association 2021b), which can be attributed both to new schools and increases in class sizes at existing dental schools.

Specialty and Advanced General Dentistry Programs

The number of accredited specialty programs increased from 416 to 457 between 2000 and 2016. Although some specialties lost programs (dental public health lost three and prosthodontics lost nine), the number of enrollees increased in all specialties. The top three specialty programs in terms of overall enrollee growth during that period were oral and maxillofacial surgery, which grew from 848 to 1,195 enrollees; pediatric dentistry, which grew from 442 to 921 enrollees; and orthodontics, which grew from 714 to 1,043 enrollees (American Dental Association 2016).

The number of advanced dental education enrollees also grew between 2000 and 2018. The number of General Practice Residency enrollees grew slightly, from 1,063 to

1,237. The number of enrollees in advanced education for general dentistry increased from 614 to 924 (American Dental Association 2016; 2020f).

Educational Cost and Debt

Most college students in America take on debt as they seek bachelor's or higher degrees. Average dental school debt has grown greatly, from $87,605 in 2000 to $242,289 in 2019 (American Dental Education Association 2020c). The proportion of dental school graduates reporting debt greater than $150,000 increased from 20.9% in 2000 to 71.4% in 2019 (American Dental Education Association 2020c). Annual tuition and fees also have risen sharply for dental hygiene education programs, from an estimated $26,000 to $41,000 (American Dental Association 2020k). Graduating debt for dental hygiene students is not well known, although the Institute for College Access and Success states that the average college graduate accumulates $28,650 of debt (The Institute for College Access and Success 2018). Although federal and private loans and some scholarships assist some students, significant challenges remain.

Although debt represents a major challenge for many students as they select a career or start their careers, there are no national data that document debt's impact on career or location choice. Studies have found that the strongest "predictors of postgraduate educational plans were mentoring and encouragement from significant others, including family members and dental school faculty" (Scarbecz and Ross 2007). Wanchek and colleagues (2014) found a mild positive correlation between educational debt and intended employment choice, but student characteristics had more impact. Among the foreign-trained dentists, higher levels of debt have been reported associated with International Dentist Programs (IDPs). Black dentist respondents in a workforce survey reported an average total debt of $167,792 compared to an average of $147,871 in 2012 dollars for all students, with those graduating from IDPs having the greatest debt (Mertz et al. 2017b). This suggests that debt may have a greater impact on the numbers of African American and Hispanic dentists given that workforce studies indicate that 49% of Hispanic/Latino dentists and 85% of Black dentists were born in the United States (Raja et al. 2017; Mertz et al. 2017c).

Debt does not appear to have deterred U.S.-born applicants from applying to dental school. The number of applicants to dental school between 2000 and 2018 rose from 7,770 to 11,298, a 45% increase (American Dental Education Association 2018a). A strong concern, however, is whether debt deters underrepresented minorities and lower-income individuals from choosing dentistry as a career. Available data do not answer this question. Moreover, it is not clear whether options for reducing debt—for example, by committing to practice in workforce shortage areas or through loan repayment programs—are understood or convincing for potential minority applicants (California Dental Association 2011; American Dental Education Association 2019a).

Diversity

The 2000 Surgeon General's Report on oral health highlighted the challenges in recruiting and retaining women and underrepresented minorities in the dental workforce. Since that time, efforts have been made to diversify the student bodies in both dental schools and allied professional programs. The Historically Black Colleges and Universities (HBCUs) were early responders to develop supportive programs for underrepresented minority students to enter medicine and dentistry. A workforce study of Black dentists reported that the majority of U.S. trained Black respondents older than 49 years of age had attended an HBCU dental school and only 35% attended a public dental school, but the pattern had reversed for younger black dentists suggesting that pipeline programs have successfully extended to a broader cadre of dental schools (Mertz et al. 2017b). In addition to pipeline programs, schools adopted holistic admission reviews (Price and Grant-Mills 2010), minority recruitment, and community-based dental education programs (Formicola et al. 2010). Enrichment and recruitment programs (Johnson et al. 2013) and combined advanced education programs (Davies et al. 2019) have shown positive results in selected populations and schools (American Dental Association 2021h).

Postbaccalaureate programs were designed to provide additional support, such as Dental Admission Test preparation, academic courses in the sciences, mentoring, and clinical observations, for highly motivated applicants initially denied dental school admission (Alexander and Mitchell 2010). A study of seven such programs showed that four programs accepted students at a rate of 90–95% and the three remaining schools accepted students at a rate of 45–72%. Graduation rates for students in all seven schools were more than 95%. Most of these programs target students who are committed to providing patient care in underserved communities (Wides et al. 2013; Johnson 2017).

Diversification of the dental workforce also is supported through the entry of foreign-trained dentists. Dentists have several pathways by which to acquire a U.S. dental license through further education, as described in Chapter 1 (see *Pathways to U.S. Dental Practice for Foreign-trained Dentists*) (Allareddy et al. 2014). Another method is through an immigrant H-1B visa, supported by a dental school to serve as academic faculty. Vujicic (2017b) reported that the number of foreign-trained dentists in U.S. academic settings increased from 3.3% in 2003 to 13.1% in 2016.

Dental education loan repayment and scholarship programs are important tools for enhancing workforce diversity. As of 2020, numerous federal and state programs were available to reduce the high cost of dental education (American Dental Education Association 2020b). For example, Illinois specifically provides financial support for minority dental education (American Dental Education Association 2020b).

As a result of these initiatives, the racial and ethnic composition of dental students has become more diverse. Between 2000 and 2018, among all dental students, there were decreases in the proportion of non-Hispanic White students (62% to 51%) and increases in that of Asian (22% to 24%) and Hispanic/Latino students (5% to 9%). Enrollments of Black/African American students have remained unchanged since 2000 (5%). The percentage of male dental students decreased from 60% to 49%, and the proportion of female students increased from 40% to 50% (American Dental Association 2019d).

With regard to allied dental programs, the ADA Survey of Allied Dental Education showed similar trends for dental hygiene students between 1998 and 2018. Representation grew for Hispanic/Latino (5% to 15% of total dental hygiene students), Asian (5% to 8%), and Black/African American students (3% to 5%) (American Dental Association 2020d). Racial and ethnic representation in dental assisting programs increased similarly: Hispanic/Latino (9% to 19% of total students in dental assisting programs), Black/African American (12% to 17%) and Native American (1% to 1.7%) (Haden et al. 2001; American Dental Association 2020c).

Dental hygiene schools reported the use of career days, counseling, and representatives at job fairs (Moore 2012) to boost their diversity. Hunter and colleagues (2015) noted that CODA standards did not require a diverse student body, and only 43% of dental hygiene programs had a recruiter. A proposal has been made for consideration to add a statement in 2021 CODA Accreditation Standard 1—Institutional Effectiveness that "the program must have a humanistic culture and learning environment by fostering diversity of faculty, students, and staff" (Commission on Dental Accreditation 2020d, p. 18).

Curriculum

Because of new CODA standards, curriculum changes have resulted in more integration of the behavioral, clinical, and basic sciences as well as interprofessional training (Elangovan et al. 2016). Active, problem-based, or case-based learning (Elangovan et al. 2016), critical thinking, self-assessment, and the use of evidence-based approaches also have been incorporated. Both specialty and advanced graduate education programs and allied provider programs reported more education on integrated systems (Wides et al. 2013), person-centered care, collaborative care, and team-based practice (Elangovan et al. 2016). Requirements were added for dental education to make opportunities available for students to engage in community-based learning experiences. Although this is not a replacement for basic education on the importance of social determinants of health or principles of dental public health, it gives students experiential education on application of cultural competency. Pathways for career advancement (new training programs, continuing education, licensure, and practice models) have changed to allow more options and geographic mobility.

The Association of American Medical Colleges developed oral health competencies for medical students in 2011 with funding from the Health Resources and Services Administration (HRSA). It also created an initiative funded by ADEA to encourage faculty members to develop peer-reviewed training modules to address the oral health competencies as a means of training future physicians (Krisberg 2018).

Students and faculty will be challenged to navigate a future that includes a rapidly changing U.S. population, technological change, increasing emphasis on evidenced-based dentistry and quality control, and growing connections with the rest of the health care system. In addition, person-centered care in both dental school and a broader range of community clinical settings will be stressed, including care provided in long-term care facilities and other areas where the growing older population resides. Major technological changes include use of virtual reality by some dental schools, even for preparing teeth in the laboratory before working on patients.

Given the graying of America, an additional topic for interprofessional education (IPE) is considerations surrounding end-of-life oral health palliative care. Hospitals and long-term care facilities might value an approach that offers oral health care services and provides needed personnel to address these issues. The current challenge to providing these services is that professionals rarely receive any formal education or training in providing palliative oral care in hospitals, hospices, and assisted-living facilities. Dental schools and residency programs have an opportunity with IPE partners to advance knowledge and skills for providing the needed care for this population (Treister et al. 2020). A 2013 study reported that the majority (89%) of dental schools offered didactic training in treatment of older adults, and less than one-quarter offered specific clinical training on older adult care (Levy et al. 2013).

The maintenance of oral health for an aging population suggests attention needs to be paid to incorporating curriculum on age-appropriate prevention and treatment of disease, as well as end-of-life oral health palliative care, into dental and resident training programs. Community-based programs that include long-term care facilities are needed for hands-on training to manage care for functionally declining elders and to train caregiver staff in regard to oral health (Macdonald et al. 2020).

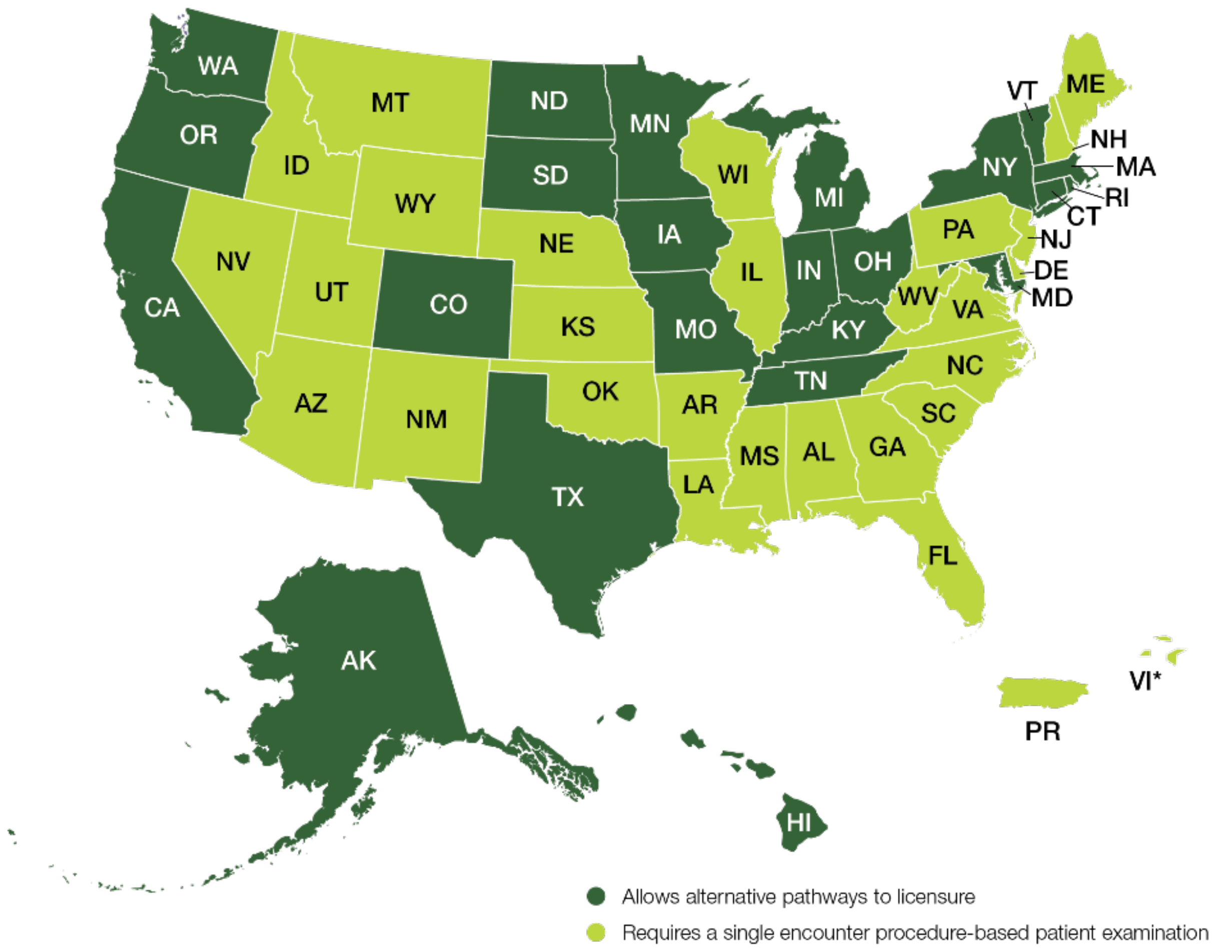
Studies indicate that academic dental clinics, in particular, stand to benefit from an increased focus (in didactic and clinical settings) on quality and patient safety (Ramoni et al. 2014). Administration of the Medical Office Survey on Patient Safety Culture, developed by the Agency for Healthcare Research and Quality, revealed that dentistry scored lower on all patient safety dimensions than did medicine. In addition, many studies chronicle the stresses students face during their dental school experiences (Elani et al. 2014). The negative effects of stress demand an increased emphasis on educational programs within the curriculum that help professionals manage stress throughout their careers (meditation, yoga, and promoting good nutrition and sleep) (Alzahem et al. 2011).

Licensure and Certification

After many years of an extremely restrictive state-based licensure process, change is occurring. For example, nearly half of U.S. states (shown as dark green) now allow alternative pathways to dental licensure (Figure 8). Whereas there were 53 licensure examinations in the United States in 1968 (Catalanotto 2017), there currently are just five testing agencies: the Council of Interstate Testing Agencies, Inc.; Commission on Dental Competency Assessments; Southern Regional Testing Agency; Central Regional Dental Testing Service, Inc.; and Western Regional Examining Board. The first two of these agencies also administer the dental hygiene examination.

Five structural pathways to licensure are available in the United States—the traditional format, curriculum-integrated format (CIF), postgraduate residency (PGY-1), objective structured clinical examination (OSCE), and portfolio-based examination. The five testing agencies offer the traditional examination. Following the 2019–2020 academic year, some states modified their examination processes for licensure because of the COVID-19 pandemic. Organized dentistry, state regulators, and educators have developed clear plans to implement the OSCE, which will replace the single-encounter, patient-based examination, which both the profession and the public have questioned. Four of the agencies offer the CIF, which enables students to take the examination in sections during a period of time. The PGY-1 pathway allows students to gain licensure if they complete 1 year of accredited PGY-1; Delaware and New York mandate this pathway; and it is an option in Minnesota, California, Colorado, and Ohio. The state of Washington will accept completion of a PGY-1 offered in certain state-approved programs. Minnesota accepts the Canadian OSCE, California accepts a portfolio-based examination, and Colorado has announced it will accept all options (American Dental Association 2021i).

Figure 8. Adoption of alternate pathways toward dental licensure in the United States



Source: American Dental Association Council on Dental Education and Licensure (2021).

Interprofessional Education and Practice

Education and training programs in oral health promotion for predoctoral and medical residents as well as medical practitioners have been developed over the past 20 years. Programs for pediatricians have incorporated the provision of oral health services—examinations, oral hygiene instruction, fluoride varnish, education, and anticipatory guidance—and parental education about the need for a dental home with regular dental care for children, including children with special needs and other vulnerable populations (see Section 2 for more information) (Mouradian et al. 2003; Rozier et al. 2003; Hummel et al. 2016). Common risk factors for diseases and social determinants of health in which lack of dental insurance, of a dental home, or of access to community water fluoridation are increasingly seen as issues both medical and dental personnel should address (Petersen 2009; Watt and Sheiham 2012). Moreover, training of dental providers has begun to incorporate chairside medical screening into dental practices (Barasch et al. 2012).

The National Network for Oral Health Access convened national experts in 2008 to discuss caries disease prevention and to update and recommend strategies for health centers and other safety net dental programs that would enable medical providers to deliver preventive oral health services to pregnant women and children (National Network for Oral Health Access 2008). Care options for persons with special health care needs also advanced in areas of community-based and portable dental care, essential care, and general awareness (Havercamp and Scott 2015).

Although important advances have been made in the past 2 decades, challenges persist. The barriers to and facilitators of sustainable IPE (Lawlis et al. 2014) and oral health integration (Savageau et al. 2019) are well documented. In the past 10 years, the opportunities for academic and practice organizations to accept IPE have increased (e.g., the publication and adoption of Smiles for Life, a national curriculum that is said to be the most widely used resource for primary care physicians) (Deutchman et al. 2011). Nonetheless, professional medical and dental education face challenges related to competing demands, coordination of calendars, difficulties in planning meaningful exercises, and lack of appropriate multi-professional assessment modalities.

Although many accrediting bodies require IPE and practice, challenges remain in implementing meaningful, profession-wide exercises that truly gauge students' competency. Currently, students are being taught IPE, but have limited experience with interprofessional practice and how it can be applied after graduation. The coalescence of a diverse set of leaders from across the health professions could provide impetus for a new model of health professions education that mirrors the nation's health care needs.

Dental education must also be integrated within dentistry itself. Despite a call for more productive clinical care, with providers working to the full extent of their licenses, dental education remains largely a solo endeavor for the dentist-in-training, with little involvement of dental hygienists, dental assistants, dental therapists, or behavioral- and mental-health professionals. Functioning as an efficient, productive team requires training.

In addition, the concept of a career ladder—a formal progression from entry-level positions to higher levels of education, responsibility, salary, and skill—is needed. An education and training system that allows individuals to assume some professional responsibilities at an entry level and advance through education and training could be an important strategy for addressing workforce diversity and shortage issues. For example, New York passed a law in 2017 requiring not a baccalaureate degree (Bachelor of Science in Nursing, or BSN) at licensure, but rather that licensed registered nurses obtain a BSN or higher in nursing within 10 years of initial licensure. Similar strategies could construct career ladders in dentistry for individuals who enter the profession as dental assistants, therapists, or dental hygienists.

Changes in Education and Training as a Result of a Public Health Crisis

Following the terrorist attack on the World Trade Center in 2001, calls accelerated for changes in curriculum and policy related to preparation of dentists to assume roles in disaster relief and management. Professional associations and dental schools developed relevant symposia (Guay 2002), curricula, and training (More et al. 2004; Glotzer et al. 2006; Psoter et al. 2006; University of Illinois at Chicago College of Dentistry 2019). A curriculum on bioterrorism (Palmer 2003) and published journal and association magazine articles (Mages 2002; Chmar et al. 2004) aimed at clarifying the role of dentists in these crises.

As the novel coronavirus (COVID-19) pandemic advanced, the U.S. Department of Education quickly finalized new rules that governed distance learning for higher education to ensure a robust capacity for remote teaching. The guidelines emphasized ensuring student competency during the time allotted and simplified the requirements for direct assessment programs (U.S. Department of Education 2020). Schools focused on creating revised assessment of competency for graduating students and residents, in lieu of completion of requirements for graduation. Dental clinics implemented teledentistry to maintain contact with patients who called with problems and to triage those patients who required in-person emergency appointments. Content was delivered online, virtual meetings took place for small group learning, and assessments were completed using self-proctoring technologies.

Because many dental school clinics are set up in large open spaces, adapting new practice models in these settings has presented special challenges. Because students' clinical experiences were truncated in Spring 2020, schools also were confronted with the need to identify new ways of training and managing in-person patient experience despite social distancing in limited space. Moreover, understanding patient COVID-19 status became critical to appropriate treatment and required use of personal protective equipment (PPE). Many dental schools have attempted to incorporate point-of-care testing for COVID-19, but preference for access to testing was most often granted to hospitals, leaving dental schools with limited access to accurate patient status. Some dental schools strengthened their relationships with their academic health centers by sharing spaces, donating PPE, and collaborating on testing services for COVID-19.

External bodies that control the process for licensing of new graduates also adapted to the pandemic. Some licensing bodies substituted simulation-based exercises for the live-patient components of their examinations, and at this time, it's unclear if this change will become permanent after the end of the current public health crisis. In addition, some local boards of registration created new pathways toward licensure, with some issuing temporary licenses.

Oral Health Practice

During the past several decades, solo dental practices and privately-owned practices have decreased in number, and the number of group practices and community clinics has increased. The nature and type of dental procedures provided have changed as well, with a large increase in diagnostic and preventive procedures and a corresponding drop in restorative procedures. A number of innovative programs have been created to divert patients from EDs to dental offices.

Following the changes to medical practice, solo private dental practices have decreased as a percentage of all dental practices, with a concurrent increase in the number of group practices and corporate-owned practices. Specifically, the proportion of dentists in solo practices decreased from 56% in 2010 to 51% in 2017, a trend most evident among dentists aged 35 to 44 years (49% to 40%) and those younger than 35 years of age (27% to 21%). Practice ownership also has declined, with 84% of dentists owning their practices in 2005, compared to 78% in 2017. Again, the change was greatest among dentists under 35 years of age (44% to 28%) (American Dental Association 2018). In contrast, group practice affiliation is rising, with 8.8% of U.S. dentists reporting an affiliation with a dental service organization; among dentists younger than 35 years of age, that share was even higher at 18% (American Dental Association 2019b).

At the start of the 21st century, 22% of dental care involved restoring teeth that were damaged as a result of dental disease. Now, restorative care accounts for only 12% of dental procedures, whereas diagnostic and preventive care make up 76% (Guay 2016). This reduction in restorative and periodontal procedures indicates that dental disease has decreased, at least among patients able to access dental care.

There has been a significant increase in the proportion of persons treated in low-cost public practices. The number of individuals receiving oral health services at FQHCs across the United States increased from 1.4 million in 2001 to nearly 5.2 million in 2020 (Health Resources and Services Administration 2021a). A number of factors have contributed to this increase, including efforts under the Affordable Care Act (ACA) to expand access to oral health services for children and Medicaid-eligible adults, and HRSA's funding of oral health expansion at FQHCs.

HRSA has provided substantial financial support to FQHCs interested in directly providing oral health services, awarding more than $55 million in oral health expansion grants beginning in 2001. In 2019, HRSA awarded more than $85 million to 298 health centers to expand their oral health service capacity (Health Resources and Services Administration 2019a). This funding recognizes that oral health care services are a part of overall health care and that FQHCs generally serve uninsured and government-insured populations. The additional funding has resulted in increased access to dental services for more patients.

Diversion Programs in Emergency Departments

Since the turn of the century, use of EDs to manage orofacial pain and nontraumatic conditions remains a continuing challenge. In addition to efforts that would include integrating dentists into the hospital setting, a number of innovative programs were created to divert patients to primary care locations (Leavitt Partners 2015). Improved care coordination programs were established to create linkages between hospitals or primary care providers and dental offices or community clinics. In some cases, dentists were brought into hospitals to treat emergencies or to screen patients and refer them to local dental clinics to treat the emergency. In others, case managers assessed the patient's need and triaged the problem (Langelier et al. 2015). Increased awareness, coupled with diversion programs and some expansion of adult dental benefits, showed some early results in decreased ED utilization for dental problems.

Although local programs have showed short-term potential in diverting dental emergencies from EDs to primary care settings (Leavitt Partners 2015), long-term efforts are needed to ensure that patients seek urgent care in private and public practices, rather than in hospital EDs. The use of the emergency room to manage or treat dental problems increased from 1.1 million visits in 2000 to 2.2 million visits in 2012 (Allareddy et al. 2014; Okunseri 2015), and research has shown that dental visits in these settings are less likely to be categorized as immediate or urgent compared to non-dental visits (Wall et al. 2014). Almost two-thirds of dental ED visits occur outside of normal business hours, suggesting that the emergency room is the only place for patients to seek care because dental offices rarely have night and weekend hours. Diversion of ED visits to a dental office could save up to $1.7 billion per year (Nasseh et al. 2014).

Dental Practice Technology

During the past 2 decades, several technological advances have impacted the delivery of oral health care in dental practices, including the introduction and near universal use of digital radiography and the incorporation of computer-aided design/computer-aided manufacturing (CAD/CAM). See Section 6 for an in-depth discussion on technological changes in dental practice.

The use of CAD/CAM systems in dental education and practice has become more widespread (Poticny and Klim 2010; Prager and Liss 2020). CAD/CAM systems have evolved to eliminate the need for physical impressions of patient teeth, as well as for construction of the restoration. Even more appealing for dental practice is that newer systems and materials make it possible for dental practices to deliver crowns and prostheses with same-day appointments, saving patients and dental practices time, although not money.

A survey of U.S. and Canadian dental schools reported that 93% of reporting schools utilized CAD/CAM digital scanning, and the majority of schools made some use of digital intraoral impressions (Prager and Liss 2020). Of those schools with digital scanning in the clinic, some also were using the technology to deliver same-day restorations. Because of increased use of this technology in dental schools, more recent graduates are using the technology to support care delivery in their practices.

Many EHR computer systems provide decision support to busy providers, reminding them to provide preventive services or warning them when they consider prescribing medications that may interact with others a patient takes. EHRs also support improvements in safety and quality of care through use of clinical decision support, which “provides clinicians, staff, patients or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care” (Mullins et al. 2016). Clinical decision support currently is being used in dentistry to calculate a patient’s risk for dental caries or periodontal disease and to suggest appropriate management strategies (Mullins et al. 2016).

Although primarily a tool for providers, EHRs also are an important resource for patients. Many EHRs are connected to patient portals, online websites on which patients can securely log in, manage appointments, complete medical intake forms, access after-visit summaries, obtain patient educational resources, and securely email their providers (Irizarry et al. 2015). EHRs have not yet fully lived up to their expected benefits in transforming and improving the state of health care (Howe et al. 2018). A major challenge with the existing generation of EHRs is that they are not interoperable among health care systems. There is no central repository that allows health practitioners to add individual health records to an integrated data collection platform or that allows providers to incorporate data from other providers into their records. Instead, the industry still relies on individual clinics or practices to send patients’ medical or dental records to requesting providers.

A limiting factor for the meaningful use of dental EHR data for quality improvement has been the lack of universal diagnostic criteria. Although academic institutions and some large group practices have adopted standardized diagnostic terminologies (Kalenderian et al. 2011; Tokede et al. 2013), the vast majority of dental practices do not use them, and neither the dental insurance industry nor government funders request the diagnostic codes. Connecting a diagnosis to treatment would improve the measurability of the care provided and, ultimately, the quality of oral health care. More information on the EHRs are provided in Section 6.

Since 2000, important advances in the use of telehealth have occurred in the United States. Telehealth includes the use of technology to deliver health care services at a distance, as well as patient and health professional education and public health and administrative activities (Daniel et al. 2015). Although teledentistry has been slower than telemedicine to be adopted, it is becoming more widespread across the United States and in other parts of the world (Kopycka-Kedzierawski et al. 2008; Irving et al. 2018). To facilitate the addition of teledentistry in oral health, HRSA offered grant support to state oral health workforce programs to develop teledentistry facilities, supporting four such facilities in 2016–2017 and 42 in 2017–2018 (Health Resources and Services Administration 2018b).

Teledentistry was used primarily in rural areas for oral health screenings, specialty consultations, referrals, education, and emergency care (Ojima et al. 2003; Kopycka-Kedzierawski and Billings 2011; Queyroux et al. 2017). For example, the virtual dental home program enables dental hygienists on location to communicate with dentists to provide care to underserved and vulnerable patients in remote locations (Glassman et al. 2012). Both synchronous (real-time) and asynchronous (delayed) teledentistry hold promise for improving access to care, especially among disadvantaged children. Teledentistry may improve satisfaction with oral health care; reduce costs to the oral health care system, such as staff administrative efforts and patients' time to access and utilize oral health care services; and foster treatment completion.

Innovative uses of teledentistry emerged during the COVID-19 pandemic. Teledentistry was utilized to triage and screen patients and to provide remote diagnosis in order to decrease person-to-person contact. In addition, some providers started to explore how teledentistry could reduce patient contacts and save PPE during routine preventive visits for dental cleanings. Ordinarily, a dentist would perform an in-person dental examination after a dental hygienist makes any required radiographs and performs prophylaxis, which requires fresh PPE for each patient the dentist is treating and any time they revisit a patient during the patient's appointment. Instead of in-person examinations, the dentist would utilize teledentistry to conduct the examination from another operatory to save PPE and result in fewer person-to-person contacts within the dental setting, thereby reducing the opportunity to spread the virus. Increased use of teledentistry in the post-COVID-19 pandemic era, especially around consultations and urgent or emergency conditions, is likely to increase. Oral surgeons normally have in-person consultations with patients before their surgical appointments. Many of these consultations may be handled using teledentistry, and this use of teledentistry will likely increase because of consumer demand. Both full consent of patients and transparency in communications are important for these new applications of teledentistry to work.

Teledentistry also needs to become a viable adjunct to mainstream clinical dentistry, but various challenges to widespread use must be addressed. Permanent changes in state and federal rules and regulations are needed to allow reimbursement in these settings and reinforce data quality and security. In addition, with technology's ability to cross state borders, provider licensure transferability is a key issue that states are examining to expand access and improve efficiency in the existing workforce. The U.S. Department of Veterans Affairs (VA) Authority of Health Care Providers to Practice Telehealth in any VA facility, regardless of state licensure, provides an important model for facilitating this mode of care (U.S. Department of Veterans Affairs 2018). Additional information on teledentistry can be found in Section 6.

Financing Dental Care

Dental insurance provides important financial support for patients in seeking regular dental care and often identifies specific dental offices for the patient to consider. Thus, dental insurance is critical to the financial success of America's dental practice. Although most dental insurance supports care in private dental offices, an increasing proportion of private offices also deliver care supported by public programs, such as Medicare Advantage programs for the older adult. During the past 20 years, policy changes have led to an increase in the number of persons who have dental insurance coverage under Medicaid, Medicare Advantage, and the Children's Health Insurance Program (CHIP), resulting in more patients who can afford to seek dental care. However, the number of dentists unwilling to accept patients with public insurance remains high.

Dental Insurance Coverage

Progress has been made since 2000 in providing dental benefits to U.S. children and adults. As shown in Figure 9, the percentage of Americans covered by dental benefits grew from 55% in 2009 to 78% in 2017—an estimated 40% increase (National Association of Dental Plans 2018). Two-thirds of the U.S. population with dental insurance, or 166.2 million Americans, had private or commercial dental coverage in 2017. However, the expansion in dental insurance coverage has mostly benefited children and adolescents.

Dental services are part of pediatric services and, in that context, are one of the ACA's 10 essential health benefits (EHB). However, the rules on dental coverage differ from those governing other EHBs. On health care exchanges, dental insurance often is sold as a stand-alone benefit, and most states do not require that families purchase dental care as part of a health plan (Norris 2020). Large-employer group plans and self-funded plans also are not required to offer pediatric dental coverage as part of their essential benefits (Waltman 2017). Because many of the dental insurance plans fall into the category of "not required to comply" with the pediatric dental EHB, not all children receive the benefit of having dental insurance.

The percentage of uninsured children declined from 22% in 2000 to 10% in 2015 (Nasseh and Vujicic 2016b; American Dental Association 2017c). A smaller percentage of children had private dental benefits in 2015 (51%) compared to 2000 (58%) because more children received dental coverage through Medicaid and CHIP, with the proportion increasing from 21% in 2000 to 39% in 2015. The Children's Health Insurance Program Reauthorization Act of 2009 mandated that states provide dental benefits under CHIPE and extended coverage options under Medicaid for former foster youth up to age 26 (Rudowitz et al. 2014).

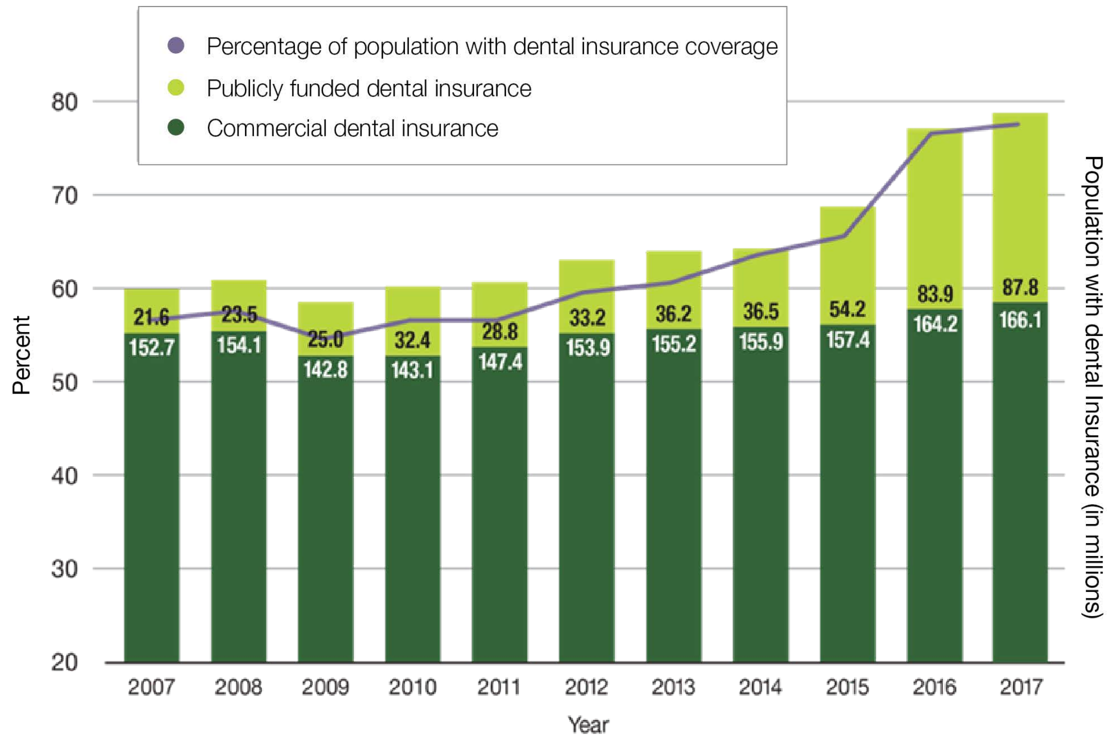
Whereas there is an EHB for children's dental insurance coverage, no such provision exists for adults, even those for whom it would be medically beneficial. This results in challenges for many adults in accessing dental care. In addition, adult dental benefits are optional in many states for low-income adults who rely on Medicaid. Consequently, states may choose to exclude dental benefits from their adult Medicaid programs. As of 2019, most states and the District of Columbia provided some adult dental benefits under Medicaid, with 18 states and the District of Columbia providing extensive benefits, 17 states providing limited benefits, 12 states providing emergency-only benefits, and 2 states offering no benefits (see Figure 8, Section 1). Between 2014 and 2017, enrollment in public programs providing dental benefits increased 140%. This large increase resulted from a combination of factors: state Medicaid expansion, the addition of coverage for adult dental services in many states, the guarantee of funding for state CHIP programs, and an increase in older Americans selecting a Medicare Advantage Plan (MAP) with a dental benefit. Medicare does not currently cover dental care except in very limited circumstances. For example, Part A covers inpatient hospital care for emergency or complicated dental procedures, but not the dental care itself.

In the past 20 years, enrollment in MAPs has increased from about 7% to 22%, with two out of three enrollees in these plans having a dental benefit, which may have helped indirectly by covering the cost of some dental care (Jacobson et al. 2019). MAPs are managed by private health insurers, and dental benefits have normally been limited to dental examinations, cleanings, and imaging. A new trend for 2019 and 2020 plans has emerged, with some insurers expanding dental benefits under these plans to attract consumers. Unfortunately, MAPs typically do not help many lower-income older adults living in assisted-living facilities, hospice, or similar settings to overcome challenges in accessing the oral health services they need. Another concern is that although MAPs are increasing, it is not clear that they have expanded proportionately to rural areas, where adult dental services are less available and dentists may not accept public insurance.

Risk-Based Dental Benefits Coverage

Traditional dental insurance has not been risk based, meaning that all consumers have similar benefits, regardless of their risk for dental disease. As risk assessment becomes more accepted in the dental community, dental benefit plans are emerging that provide additional evidence-based benefits to those at risk. Health through Oral Wellness, a patient-centered program that leverages a dental risk assessment to offer additional evidence-based procedures such as fluoride

Figure 9. The number of people covered by publicly funded and commercial dental insurance relative to the percent of the US population with dental insurance coverage: United States, 2007–2017



Source: National Association of Dental Plans (2018). Reprinted with permission.

applications for those at risk for disease (Northeast Delta Dental 2017), is one example of the personalization of benefits, which may continue to grow.

Impact of Dental Coverage on Medical Costs

The health insurance industry is beginning to look at ways to improve health care effectiveness. Oregon implemented statewide Medicaid reform in 2012, promising to improve health care access and quality at reduced cost by focusing on prevention and primary care across the medical and dental systems (Oregon Health Authority 2018b). One component of the reform was a program to fund pilot projects and programs that local agencies and providers believed would improve performance metrics on care (Atchison and Rozier 2017; Atchison et al. 2019). Projects were selected on the basis of their likelihood of achieving specific quality improvement milestones, such as increasing the numbers of diabetes mellitus patients or pregnant women who saw a dentist. Achieving such milestones would result in performance payments.

Research using claims data from dental services provided through medical financing shows how the provision of dental care can positively affect overall health and its associated medical costs. Medical insurers use dental claims analyses to understand the impact of oral health care services on medical conditions, particularly birth outcomes and chronic conditions such as type 2 diabetes, cardiovascular disease, and cerebrovascular disease. Research shows that dental care can help reduce overall health care costs as measured by savings on medical costs and number of hospitalizations. Jeffcoat and colleagues (2014) reported that providing an insured population with periodontal disease with the appropriate dental treatment saved $2,840 per person annually for persons with diabetes and $5,691 for those with cardiovascular disease. A similar United Healthcare Services study reported that affording certain individuals with chronic health conditions appropriate dental care for gum conditions resulted in an average of $1,037 in savings in health care expenditures (United Healthcare Services 2013).

These findings demonstrating the potential to reduce overall medical costs are having an impact on insurance benefit designs, with insurers placing increased emphasis on improving access to dental services through integrated dental and medical services and the provision of additional dental services supported by medical insurance plans.

Impact of the COVID-19 Crisis on Dental Practice Finances

State-ordered quarantines and closures for elective dental care because of COVID-19 resulted in higher levels of unemployment and many furloughed employees in the oral health care workforce. The Paycheck Protection Program allowed employers to keep their employees on payroll, receiving paychecks, even if the employer's business was closed due to the pandemic restrictions (U.S. Small Business Administration 2020). This also allowed employees to keep their health and dental benefits during this period. Additionally, many dental insurers across the country developed unique and innovative programs offering financial assistance for dental practices. The Delta Dental plans of Washington and Iowa were the first to come out with such programs, offering dentists advances on future claims. These programs were designed to ensure that dental offices could stay in business and the insurers' members could continue to have access to dental services. ADA has a complete list of these programs (Burger 2020).

By November 2020, nearly all dental practices had reopened with 4 out of 5 practices reporting that patient volumes were similar to pre-COVID-19 levels, but the rates varied from 75% in the largest U.S. cities to 83% in nonurban areas, with staffing in dental offices reaching 91% of pre-COVID-19 levels (American Dental Association 2020m). At this time, the long-term impact of this pandemic on dental practice remains unclear, in part because of the large number of U.S. workers who have lost employment, and with it their dental insurance. This could lead to lower utilization of dental services, lower revenue in the dental industry, and ultimately, worse oral health for the nation as a whole.

Access to Dental Care

Since 2000, there have been major advances in policies that incorporate oral health into primary care, in dental insurance expansion for underserved and vulnerable patients, and in efforts to strengthen the community health center safety net to provide primary care and preventive oral health care for vulnerable populations. However, persistent problems in accessing dental care remain for certain vulnerable populations, including older adults and those with special health care needs (SHCNs). Low Medicaid participation rates among dentists exacerbate these challenges.

Policy Advancements

Key policy measures that accelerated improvements in access to oral health care included the Health Center Growth Initiative of 2001, which strengthened and expanded existing health centers' capacity and created new health centers with open positions for graduating dentists interested in group and community practices (Shi et al. 2010). Other policies, including the Children's Health Insurance Program Reauthorization Act of 2009, the Patient Protection and Affordable Care Act of 2010, the growth in MAPs, and the expansion of Medicaid benefits for adults in some states have had a direct impact on expanding the covered dental population to private dental practices (Horner et al. 2009; Farrell et al. 2011; Jacobson et al. 2019). The ACA's recognition of pediatric dental care as an essential health benefit (Centers for Medicare & Medicaid Services 2020b) required states to cover medical benefits for children up to age 26 on their parents' health insurance, resulting in most commercial dental plans voluntarily offering the same age coverage (Nasseh et al. 2015).

The growth in HRSA initiatives in health workforce education and training brought diversity to the workforce and provided clinical training sites accompanied by loan repayment support for selected dental graduates in selected areas, such as pediatric dentistry, as well as the possibility of a career in the federal dental service (Health Resources and Services Administration 2018b; Jacobson et al. 2019).

The multidisciplinary study, Improving Access to Oral Health Care for Vulnerable and Underserved Populations, concluded with a goal that all persons should have "access to quality oral health care across the life cycle" (Institute of Medicine and the National Research Council 2011). The report recommended changes to the proposed dental education, financing, and regulation system; that clinicians should prioritize disease prevention and health promotion; that oral health services should be provided in a variety of settings; that care should rely on a diverse and expanded array of providers who are competent, compensated, and authorized to provide evidence-based care; that services should include collaborative and multidisciplinary teams working across the health care system; and that continuous improvement and innovation should be fostered. Some of these changes are underway, particularly with respect to the competencies and education of dentists, physicians, and other non-dental health care providers to integrate oral health into primary care.

Populations with Challenges in Accessing Care

There are several reasons why many Americans lack regular access to dental care within their communities: because there is a limited number of providers within a geographic area to provide care, as in rural areas; because providers may not accept the patient's form of public insurance; or because distances are large and transportation options are few. Rural areas have many special oral health challenges, including large numbers of persons with loss of all teeth (edentulism), shortages of dental care providers, and higher-than-average rates of chronic and population diseases (Mitchell et al. 2013; Jacobson et al. 2019). In December 2018, there were an estimated 5,833 dental health professional shortage areas (HPSAs), representing almost 58 million persons and an estimated need for 10,635 additional dentists (Health Resources and Services Administration 2020c). Every state has HPSAs, ranging from 10 in Delaware to 446 in California. These designations reflect the poor distribution of dentists across the United States, particularly in rural and inner-city locations.

HRSA's State Oral Health Workforce Program allows states to identify their individual state's oral health workforce gaps and address them through a variety of mechanisms. In addition to the expansion of access through teledentistry, the program supports the integration of loan repayment, the development of community-based prevention service programs for underserved populations, and the expansion of the state dental office to support grant activities such as enhancing capacity to develop and analyze data and policy related to oral health access and workforce needs to identify Dental Health Professional Shortage Areas (HPSAs) (Legal Information Institute 2021).

Patients with Special Health Care Needs

Although awareness and delivery enhancements have improved care for people with SHCNs, numerous barriers persist in the current oral health care provision models, including inadequate workforce training, a dental benefit design that often limits comprehensive care and dental specialty access, and limited early oral health intervention.

The limited availability of dental providers trained to serve special needs populations continues to be a major issue. Despite changes in the CODA education requirement in 2004, multiple studies have shown that dental school curricula remain insufficient for this purpose. Studies show that only 64% of schools offer a course focused on patients with special needs, and only 37% have a clinical area for treating people with SHCNs (Dehaitem et al. 2008; Krause et al. 2010). Most dental students, therefore, do not have clinical contact with this population, nor are they even exposed to information about their needs. There is increased emphasis on care of patients with SHCNs at the postdoctoral level, but these training programs are located primarily in metropolitan areas.

Patients with SHCNs continue to face unacceptable yearlong wait times to access any care. The difficulty finding dentists willing and able to treat them is especially significant as children transition into adult care (Nowak et al. 2010; Clemetson et al. 2012; Licari and Evans 2017). Studies have shown that many dentists are unable to handle special medical needs (Nowak et al. 2010; Williams et al. 2015; Wesman et al. 2017). Adults with disabilities are probably the most disadvantaged of all because priority is given to children and the elderly (Stiefel 2002).

The National Council on Disability reported in 2017 that the CODA accreditation standards did not require dental school graduates to learn to treat people with SHCNs, but instead required them only to know how to "assess" treatment needs. The Council further stated that the ADA Principles of Ethics and Code of Professional Conduct discriminated against people with disabilities because it allowed dentists to refuse to provide care (National

Council on Disability 2017). It recommended more robust training for dental professionals and that dental students be required to demonstrate clinical practice skills in performing designated treatments for this population. ADA responded by strengthening the Principles of Ethics and Code of Professional Conduct to require dentists to refer people with SHCNs to a dentist with appropriate capabilities (Garvin 2019).

People with HIV/AIDS

Advances in the medical management of HIV changed what was once a fatal disease to a manageable chronic condition for individuals who remain actively engaged in health care (Deeks et al. 2013; Centers for Disease Control and Prevention 2018). Today, a federal government initiative, *Ending the HIV Epidemic: A Plan for America,* seeks to reduce new cases by 90% by 2030 (Fauci et al. 2019). However, the initiative relies on expansive testing of people for HIV and immediate linkage to treatment. HIV testing recommendations in *Healthy People 2020* and 2030 and the National HIV/AIDS Strategy (U.S. Department of Health and Human Services 2010; 2015) promote goals and actions to greatly increase the number of individuals with knowledge of their HIV status.

Dental professionals are in a key position to identify people at risk for HIV, including some among the estimated 19.5 million people who do not see a medical provider but visit a dentist each year (Strauss et al. 2012). Pollack and colleagues (2010) found that among 610,000 Americans who reported HIV risk and had never been tested or received any medical care during the preceding year, 61% had visited a dentist within the prior 2 years. Dental patients report a positive attitude about accepting HIV screening from dentists and dental hygienists in private, community health center, and dental school settings (Dietz et al. 2008; Greenberg et al. 2012; VanDevanter et al. 2012; Davide et al. 2017; Abel et al. 2019). Fortunately, oral health care providers also express a willingness to offer chairside HIV screenings (Pollack et al. 2014; Parish et al. 2018; Santella et al. 2019).

Accessing oral health care remains a significant challenge for people with HIV or AIDS (Benjamin 2012; Centers for Disease Control and Prevention 2019b). Guidelines that recommended routine screening for HIV infection for all patients 13 to 64 years of age in health care settings did not include specific guidelines for screening in dental care settings (Branson et al. 2006; U.S. Department of Health and Human Services 2015), despite studies showing the willingness of dental health care workers to perform HIV screening and its acceptance by patients (Strauss et al. 2012). Training programs offered through HRSA's Ryan White HIV/AIDS Program, although they include oral health professionals, are not enough to adequately prepare the dental workforce.

To increase the percentage of people with HIV/AIDS with access to comprehensive dental care, the dental and primary care professions must further strengthen the oral health safety net. Some specific steps can be taken to increase the number of interdisciplinary providers able to provide health promotion, as well as preventive and basic dental care for this population. To advance the national goal of increasing the percentage of this population who know their status to at least 90% (U.S. Department of Health and Human Services 2015), the dental profession can take leadership in developing enhanced professional training, providing counseling guides, examining states' dental practice acts that challenge implementation of HIV screening in the dental practice, and educating state legislative bodies on the public health advantages of screening and early entry into HIV treatment.

Lesbian, Gay, Bisexual, and Transgender Patients

The LGBTQ+ community continues to face health policy issues that prevent many in the community from obtaining oral health services. Perceived fear of discrimination can permeate all aspects of life, including seeking or receiving health care services (Meyer 1995). Patients identifying as LGBTQ+ often report care refusal, harsh and abusive language from providers, and physical abuse in the clinical setting (Lambda Legal 2010; Kates et al. 2018). In 2016, the Office for Civil Rights within the U.S. Department of Health and Human Services (HHS) issued a new rule expanding nondiscrimination protections for LGBTQ+ people in health care facilities, programs, and activities receiving federal funding, reflecting provisions in the ACA prohibiting discrimination against LGBTQ+ people in health insurance coverage and health care. Two years later, the 1964 Civil Rights Act was amended to include sexual orientation.

Older Adults

Older adults face ongoing challenges in accessing regular oral health care, including those related to limited income and limited dental coverage under traditional Medicare (The Gerontological Society of America 2017a; 2017b). Many older adults in long-term care facilities do not have dental providers or transportation to a dental office. They also may have mobility problems or cognitive impairment that interferes with independent daily oral hygiene, and they may rely on caregivers who may not have the necessary training or skill to perform oral hygiene tasks.

According to a 2003 survey, only a subset of dental schools provided predoctoral clinical education to dental students about the geriatric population (Mohammad et al. 2003). Furthermore, non-dental providers who care for older adults often lack training in oral health promotion and disease prevention. Solutions for improving oral health access and oral health promotion in this population include improving the oral health knowledge and skills of non-dental health care providers, caregivers, and long-term care staff, as well as increasing the number of innovative models for delivering oral health services to older adults where they live.

Regulations and Policies that Impede Access to Care

The practice of dentistry is regulated by each state's Dental Practice Act, with authority delegated to the state dental board, which regulates the practice of all dental providers in the state as a way of ensuring public safety. However, some regulations function in ways that actually limit access to care. For example, dental hygienists in some states are prohibited from providing care in community-based settings without a dentist's physical presence, or from sealing teeth in school settings without the child's prior examination by a dentist. These regulations persist, although there is no evidence that they promote safety. Although many states now allow hygienists to work in public health settings, such as schools or long-term care facilities, other states restrict hygienists to providing preventive services in public health settings only when a dentist is present for supervision. In actual practice, then, these regulations prohibit professionals from providing the treatment for which they are trained unless a dentist is present.

Regulations and policies also affect how practitioners are allowed to treat children and adults covered by government programs such as Medicaid, Medicare, and CHIP. Whereas Medicaid and CHIP offer comprehensive care for children, Medicaid's coverage for adult dental care is optional and varies widely by state. Some states support dental care for adults whose incomes are at or below 138% of the federal poverty level, but may restrict that care to specific providers and settings, thereby limiting the value of the benefit for many. In some states, dental hygienists providing services in community-based programs are required to bill Medicaid through a supervising dentist, and dentists may be restricted with respect to employment or supervision of hygienists in such programs (The Pew Charitable Trusts 2018). Before the COVID-19 pandemic crisis of 2020, a number of states would not reimburse for consultations provided through telehealth technology (Seidberg 2017). All of these rules impede care to underserved and vulnerable populations. Similarly, Medicare covers only limited dental care and only in hospital or emergency department settings, or for procedures that are necessary prerequisites to pending medical care (Centers for Medicare & Medicaid Services 2021). Moreover, dental services provided in hospital EDs are costly and unlikely to fully meet oral health needs.

Low Dentist Participation in Medicaid

Although the number of individuals with Medicaid coverage has grown since the ACA took effect, challenges in finding dentists who accept it and are capable of treating vulnerable populations remain. States vary widely, from 15% to 85%, in the percentage of dentists who participate in Medicaid. As of 2016, 39% of dentists participated in pediatric Medicaid or CHIP programs. In comparison, an estimated 70% of physicians accepted Medicaid (Decker 2011). Dentists who are female, are younger, or are in general or pediatric practices are more likely to participate in these public-insurance programs (American Dental Association 2020l). Dentists who are employed by a dental service organization also are more likely to participate in Medicaid (Langelier et al. 2017a).

Researchers have evaluated the impact of various policy levers on the receipt of dental services by Medicaid recipients and the participation of dentists in Medicaid or CHIP programs. Increased Medicaid fee-for-service reimbursement has had an impact on dental care use and dentist participation in public programs (Decker 2011; Beazoglou et al. 2015; Buchmueller et al. 2015). Increasing outreach to boost the number of dentists participating in the Medicaid program and encouraging eligible populations to seek care showed an increase in dental care use as well. Reducing the administrative burden of the Medicaid program also has been successful and has significantly increased dental care use among low-income children (Beazoglou et al. 2015). Using an all-age Medicaid billings data set in Wisconsin, Wagner and colleagues (2019) showed that the difference between dentist billings for preventive services and paid reimbursements grew significantly between 2001 to 2013, with a more pronounced escalation at the high range of dentist billings.

Volunteer Programs

Community-level dental programs that offer care by professionals who volunteer their services have helped address persistent access issues in many underserved and dental health shortage areas in the United States. Dental volunteerism often takes the form of public-private partnerships combining national, state, and local dental professionals; dental education institutions; dental associations; volunteer organizations; and public health programs, along with support from the dental industry to source materials and laboratories. These partnerships augment local dental professionals with a volunteer workforce, equipment, tools, and patient education resources. Public health programs and community-based organizations help identify patients with unmet oral needs and link them to local health programs.

Examples of local, state, and national volunteer programs that feature aspects of public-private partnerships include the following:

- Give Kids A Smile® (GKAS) is a national program involving dental associations and dental equipment and supply companies (American Dental Association 2020n). Since 2003, GKAS has recruited more than 500,000 community and dental volunteers to administer oral care for more than 5.5 million underserved children. GKAS activities include free restorative treatment (44% of services provided), oral health education (23%), and screening and preventive care (33%) (Alexander 2019).
- Mission of Mercy, an initiative of the America's Dentists Care Foundation offers free clinics in 31 states with support in equipment and funds from industry and foundations. Since 2008, the group has provided volunteer dental care worth at least $190 million for more than 275,000 patients (America's Dentists Care Foundation 2021).
- Bright Smiles, Bright Futures® (BSBF) provides a fleet of mobile dental vans for dental and nonprofessional volunteers to use to provide education, dental screening, and treatment referrals annually for more than 10 million children in underserved rural and urban communities. One million children have received $39 million in donated dental care, and 3.5 million children have participated in BSBF's classroom curriculum (Hannan 2019); Colgate-Palmolive 2020).
- Appalachian Miles for Smiles, a regional volunteer program, provides dental services to uninsured residents of primarily rural areas of Tennessee and Virginia (Appalachian Miles for Smiles 2017). Dental volunteers see an estimated 50 patients daily in a mobile dental unit. In 2017, the program provided free dental care to 3,000 individuals.
- Donated Dental Services improves the oral health of people with disabilities, the elderly, the homebound, or the medically fragile by linking a nationwide network of 15,000 dentists and 3,700 volunteer laboratories to patients (Dental Lifeline Network 2019; 2021). Dentists volunteer time and office supplies to create free dental care, and laboratories donate their services. Donated Dental Services has provided $378 million in donated services for 120,550 individuals.
- CDA Cares is a program through which the California Dental Association (CDA) provides access to dental care through clinics that have engaged more than 25,000 volunteer dental professionals and community members, local health plans, hospitals, county health departments, community-based organizations, and social service agencies at 15 clinics throughout the state. CDA Cares has provided in excess of $23 million in dental services to more than 28,000 people who self-identify as Latino or Hispanic, travel less than 50 miles to the clinic, and state they have not previously sought care because they have no dental insurance and are not able to afford care.

Although community-level volunteer dental programs provide valuable care to those with no regular access to care, they cannot be considered an adequate substitute for comprehensive care, and they do not provide a dental home, which would go far to ensure ongoing care. Moreover, volunteer clinics usually are held once per year in any specific area, leaving persons without dental care for unacceptably long periods of time. The existence of these special events, and the value placed on them, demonstrate the level of need for more comprehensive dental care provided at workplace, state, and federal levels. It is common for people without access to dental care to drive long distances and wait in long lines to access free care available in these volunteer programs.

Oral Health Integration

The Surgeon General's 2003 *National Call to Action to Promote Oral Health* (U.S. Department of Health and Human Services 2003) emphasized the need for public-private partnerships to improve all Americans' oral health and called for collaborative efforts to integrate oral health care into overall patient-centered health care. Many initiatives have been implemented during the past 2 decades to promote and support the integration of oral health and medical care, often with substantial investment from HRSA to build the evidence base (Health Resources and Services Administration 2014a; Nguyen et al. 2020). These efforts also were supported by the federal Oral Health Strategic Framework, which provided a road map for public and private partnerships that would enhance oral health integration to address the nation's concerns regarding disparities in oral health (U.S. Public Health Service 2014).

Since then, models have emerged in which multidisciplinary teams of health professionals deliver oral health care in a variety of settings outside the dental office (Institute of Medicine 2011a; Harnagea et al. 2018). The focus of new models has varied depending on the primary goal of integration. Integration aimed at improving access and reducing population disparities led to strategies for public health organizations. Other strategies have focused on improving care to reduce costs among defined health system populations, with government metrics evaluating cost and quality (Harnagea et al. 2017). Although there has been some progress in integrating dental care into the health care system, oral and medical health care delivery remain largely separate endeavors, with a number of barriers preventing the integration of oral, medical, and primary care (Harnagea et al. 2017; Atchison et al. 2018; Damiano et al. 2019).

Population-Focused Integration Strategies

Two integration demonstrations were created specifically to integrate safety net populations (Harnagea et al. 2018). These involved partnerships among private and public health organizations, governments, and academic institutions to create two models: the Integration of Oral Health and Primary Care Practice (IOHPCP) model and the Oral Health Delivery Framework (OHDF) model.

Both models focused on risk assessment; prevention, including fluoride varnish treatment; and patient education and involved interprofessional collaboration. The IOHPCP model was implemented by FQHCs and Ryan White HIV/AIDS Program funded clinics (Health Resources and Services Administration 2019b), with onsite dental services. It also established a medical-dental referral process for further dental care. The OHDF coordinated oral and primary care providers in 19 settings in five states at private practices (hospital-based, independent, and part of a large, integrated delivery system) as well as community health centers (mostly FQHCs) (Hummel et al. 2016; Qualis Health 2016). Most sites reported success in implementing at least three aspects of the OHDF: oral health screenings, fluoride varnish application, and dentist referral.

Both care models used interprofessional practice collaborations to integrate oral health into medical care. They were implemented in school-based settings, federal- or state-affiliated health systems, academic institutions, and safety net programs and within rural communities and nonmetropolitan areas (Crall et al. 2016; Harnagea et al. 2017; Dalal et al. 2019).

Patient-Focused Integration Strategies

Insurance companies and commercial and public health systems have used medical-dental integration strategies to improve patient-level care while controlling care cost. Insurance companies such as Aetna, Cigna, and Delta Dental of Wisconsin have focused on integration strategies that expand dental insurance benefits and manage care for patients with chronic diseases, pregnant women, and children. Studies of medical and dental claims have found savings to health and benefits organizations and lower hospital readmission rates as a result of dental care utilization by patients with chronic diseases such as diabetes, cardiovascular disease, and cerebrovascular disease (Albert et al. 2006; United Healthcare Services 2013; Cigna 2019). One study found that patients with diabetes who received an oral periodontal intervention had lower total and diabetes-related medical costs compared to similar patients without periodontal treatment (Nasseh and Vujicic 2016b).

Commercial health systems such as Kaiser Permanente Northwest, HealthPartners, and the Marshfield Clinic, as well as VA, are taking advantage of clinic co-location to promote medical-dental integration through technology and EHR use. A fully integrated health record promotes transparency, information sharing, and coordination of patient care with other health care departments across the enterprise. The interoperability of EHR has led health systems to pilot new clinic and workflow designs to integrate primary care service delivery within dental office settings (Jones et al. 2017).

In 2017, a national convening of 44 rural interprofessional oral health stakeholders, key opinion leaders, and policymakers stated that oral health interprofessional practice could help achieve the goals of the Institute for Healthcare Improvement's Triple Aim initiative (to improve care delivery, patient outcomes, and cost of care) in rural environments if dependable and bidirectional interprofessional care coordination, telehealth, and a value-based financial structure were implemented (Boynes et al. 2018).

Whether in rural or urban settings, children tend to be a focus for initial forays into interprofessional practice or medical-dental integration (Achembong et al. 2014), possibly as a result of pediatric dental care becoming a mandatory covered service as part of the ACA. The ACA model incorporated earlier medical team intervention in regard to oral disease development, an important aspect because many dentists are uncomfortable seeing children younger than 2 years of age, and the well-child medical visit structure can provide an easier integration pathway (Bernstein et al. 2016; Phillips and Hummel 2016; Boynes et al. 2017). Components of well-child oral health visits encountered most often include oral health risk assessment, health coaching or guidance, fluoride application, closed-loop referral and specialty consultation, and financial and policy support (Deutchman et al. 2011; Douglass and Clark 2015; Phillips and Hummel 2016).

Interprofessional Care at the VA

A cornerstone of VA-provided care is the integration of VA dentistry with all aspects of medicine, pharmacy, laboratory, and administration to provide comprehensive care for the nation's veterans. VA's EHR system accelerates care coordination and has been a mechanism through which data-driven operational improvements and dental quality measures have been implemented, resulting in systemwide improvements. One dental quality measure—fluoride treatment for patients at high risk for dental caries—implemented during fiscal year 2009, increased the appropriate use of fluoride in high-risk patients. Collection of national data about the quality measure from EHR allowed VA to conduct a clinical-effectiveness study, which showed the benefits of professionally applied or prescription self-applied fluoride in preventing future dental restorations (Gibson et al. 2014; Jurasic et al. 2014). VA also integrated dental care into rehabilitation programs for homeless veterans. VA studies show that not only does dental care improve veterans' quality of life (Gibson et al. 2008), but it also is associated with improvements in homeless rehabilitation program completion, employment, and housing after program completion (Nunez et al. 2013).

System-Level Barriers

Barriers to integration at the system level include the decades-long separation between medical and dental practices (Valentijn et al. 2015). This barrier is perpetuated by a lack of interest in merging the professions among dentists and primary care physicians and their professional organizations. Other obstacles include poor understanding of the population's oral health status, the low prioritization of oral health on political agendas, and a dearth of appropriate oral health policies (Harnagea et al. 2017). Moreover, federal policies perpetuate the separation of oral and medical insurance through provisions that limit public dental insurance for adults, permit inconsistent insurance coverage across states, and exclude oral health services from quality metrics as part of the ACA (Donoff et al. 2014; McDonough 2016; Damiano et al. 2019).

The lack of insurance coverage across oral health and medical professions creates a barrier to interprofessional practice. Payments to medical providers for oral health services vary by state and payer. Payment reform often lags clinical innovations, failing to keep pace with increases in evidence and public support for change (Hernandez et al. 2015). In short, to advance health integration, federal and state policy reforms are needed, along with private and public health insurance coverage, regardless of provider type, for appropriate oral and medical care services for children and adults (Donoff et al. 2014).

Organizational Barriers

Organizational barriers to integration include the lack of agreements among professional organizations that promote integration, shared governance over scope of practice and guidelines for care, and lack of the accountability mechanisms needed to deliver comprehensive care to a defined population by a group of providers (Valentijn et al. 2015). In 2019, 14 states reported serving at least some of their Medicaid beneficiaries through an ACO model, up from 7 states in 2015 (Kaiser Family Foundation 2019). Most ACOs do not include dental services (Shortell et al. 2015), and others lack the physical and organizational integration of dental and medical providers (Damiano et al. 2019). Harnagea and colleagues (2017) found that the most commonly reported barriers were limited organizational resources (e.g., time, staff) to support integration activities.

Organizational culture and climate for change are important factors for integration (Cunha-Cruz et al. 2017). Some integrated health systems have adopted the use of quality measures in dental as well as medical care, but most stand-alone dental providers and insurers have been slower to implement quality-based performance and compensation measures that are common for medical providers (Institute of Medicine and the National Research Council 2011; Glassman 2014). This lack of integration of the clinical workflow into the care process is associated with poor referral systems and connections between provider organizations.

Professional Barriers

A common understanding of each provider's competencies and roles, within the context of delivering comprehensive health care, is key to professional integration (Valentijn et al. 2015) because scope-of-practice laws govern the range of services that different health care providers can perform. These limits define the interprofessional practice relationships that allow the coordination of oral and medical care services. The lack of clinical guidelines for treating oral health problems, limitations on primary care providers' knowledge of oral health, and time to support integration activities are all challenges to professional integration (Harnagea et al. 2017). Medical providers also report difficulty in referring uninsured and Medicaid patients to dental professionals when additional care is needed (Lewis et al. 2000). The lack of knowledge about medical health promotion and preventive services is a similar barrier for dental professionals (Naleway et al. 2018).

The absence of interoperability among EHR systems creates a substantial barrier to interprofessional integration (Damiano et al. 2019). The lack of integrated health records leads to poor interprofessional communication, information duplication, and inconsistencies between systems, as well as a lack of adherence to treatment guidelines used by coordinating providers (Rudman et al. 2010). A survey of physicians and dentists at four academic health centers found that nearly 70% of dentists reported experiencing instances in which access to an EHR would have improved patient care (Simon et al. 2019).

Even in organizations with interoperable EHR systems, care coordination is challenging because most dental providers do not utilize diagnostic codes (Kalenderian et al. 2016). EHR software vendors increasingly support records integration, but they face barriers in the requirements for standardized diagnostic and billing systems (Rudman et al. 2010). Lack of common diagnostic codes, unless changed, will continue to be an obstacle to future integration, thereby limiting interprofessional communication and care coordination (Kalenderian et al. 2016; Damiano et al. 2019).

Clinical Barriers

Harnagea and colleagues (2017) found that clinical-level barriers to integration were the most commonly reported.

A survey conducted by Lewis and colleagues (2000) showed that most pediatricians (85%) reported they were very likely to visually screen children under 5 years of age for dental caries and provide preventive counseling at well-child visits, and 90% agreed that assessment for dental problems and providing oral health counseling should be a routine part of well-child visits. However, fewer than 15% agreed with the American Academy of Pediatric Dentistry (AAPD) recommendation at the time to refer children to a dentist by 12 months of age (Lewis et al. 2000).

When considering how receptive providers are to expanding their scope of practice, the issue of developing efficient clinical workflows arises, along with the question of whether insurance, government programs, or patients will pay for the extra services. Expanding the scope of practice for both dental and medical providers means more services (e.g., health screenings, fluoride varnish, education) must be provided during an office visit, which affects clinic workflow and time. An early review by Close and colleagues (2010) found that most pediatricians were concerned about whether they could adjust schedules to plan new workflow processes incorporating the extra time for oral health screening and services. Experienced providers may view scope-of-practice changes very differently from younger graduates with more integrated training experiences. Change is more likely to occur with appropriate financial and other performance incentives.

Challenges to Rural Health Integration

Rural communities face multiple challenges, including long distances from health care providers, low incomes, poor insurance coverage, and aging populations with complex care needs (Skillman et al. 2010). Increasing access to oral health care for rural populations requires a multipronged approach that is flexible across communities with different care needs, resources, and cultural and political environments. Financial resources and the flexibility to develop and implement innovative strategies are critical for increasing the availability of high-quality oral and overall health care. Interprofessional care, shared goals, health informatics, and telehealth and other technologies can be used in conjunction with community-wide public health programs and new workforce models to improve access to care for underserved patients while improving the quality of care.

Patient Safety and Dental Care Quality

Dentistry has accepted risk management in some areas of dental practice, most notably in hospital settings, FQHCs, and ACOs. Unfortunately, the impetus for measuring and improving quality in the solo dental practice community exists largely in the form of malpractice claims. Other than professional organization membership guidelines and annual or biannual licensure or specialty certification renewal, little oversight exists across the dental care system.

Communication to Promote Patient Safety and Quality of Care

The medical community has long recognized the importance of health literacy in developing providers' skills for communicating effectively with patients. The Joint Commission (2007) launched a new component of its safety initiative highlighting health literacy as a way to protect patient safety, on the basis of three components: (1) making effective communications an organizational priority to protect the safety of patients, (2) incorporating strategies to address patients' communication needs across the care continuum, and (3) pursuing policy changes that promote improved practitioner-patient communications.

Federal legislation also has promoted appropriate communication by all health care providers. The Plain Writing Act of 2010 (Plain Language Action and Information Network 2011) requires federal agencies to offer health information in clear communication that the public can understand and use. ACA Section 1557, the Act's nondiscrimination provision, states that individuals with limited English proficiency are entitled to language assistance services, including a qualified interpreter when seen in publicly supported health care settings, including dental clinics (U.S. Department of Health and Human Services 2021).

Health providers are increasingly communicating with patients using digital technology, which helps bridge language gaps between providers and patients. For example, websites and applications for tablets and smartphones, some designed for medical and dental purposes, can instantly translate spoken or written words (Chen et al. 2017; Tine Health 2017). Info buttons are now being used to link to context-sensitive information contained in the EHR and to provide digital support to clinicians (Dragan et al. 2015). For example, clicking on a small icon next to a patient's diagnosis or prescribed medication displays a patient-friendly explanation of the diagnosis or medication from an external source or an expanded explanation for a clinician. This information can be used to support shared decision-making at the point of care (Cook et al. 2017).

Clinical Practice Guidelines

Evidence-based clinical practice guidelines (CPGs) are slowly being adopted for use in dental practice. Larger dental care organizations and FQHCs have put effort into adopting these guidelines, which can result in fewer treatment variations. During the past 20 years, ADA has taken a leadership role in the production of high-quality evidence in a number of areas of general practice dentistry. Its process involves prioritizing information needs among general dentists, and then developing systematic reviews and associated CPGs. In addition to ADA guidelines, some group practice models, such as Permanente Dental Associates, develop and employ a wider set of CPGs to guide their practitioners. (For examples of CPGs issued by ADA, see Table 8.)

Following a review of pediatric deaths associated with deep sedation or anesthesia, the American Society of Anesthesiologists, the Society for Pediatric Anesthesia, the American Society of Dentist Anesthesiologists, the Society for Pediatric Sedation, AAPD, and the American Academy of Pediatrics issued joint updated guidelines for the monitoring and management of children during deep sedation and general anesthesia at dental facilities (American Society of Anesthesiologists 2019). The guidelines for safe sedation of children emphasize that a systematic approach should be utilized for any sedation procedures taking place outside of a hospital or surgery center, including in a dental office. They include the use of sufficient numbers of appropriately trained staff both to carry out the procedure and to monitor the patient during and after the procedure, utilizing a properly equipped and staffed recovery area, and providing appropriate discharge instructions (American Academy of Pediatric Dentistry 2021). With the increasing number of evidence-based CPGs, many have focused on preventive practices (Slayton et al. 2018). ADA has issued 10 guidelines since 2008, and the U.S. Preventive Services Task Force has published one recommendation, "Dental Caries in Children from Birth through Age 5 Years: Screening" (U.S. Preventive Services Task Force 2014). Although some group practice models employ CPGs, their use is less common in smaller and solo practices, where most patients are served. Linking insurance payments to appropriate use of nationally approved quality measures would represent a major step in ensuring quality of care.

Measurement of Quality

Progress in developing stronger quality measures has occurred on multiple fronts. Efforts have been made to develop performance measures for dental plans (Bader et al. 1999a; 1999b). Measures from national surveys and reports (e.g., National Survey on Children's Health; Form CMS-416, Annual Early and Periodic Screening, Diagnostic and Treatment Participation Report) were used to assess population access and health state. A 2002 report from the Agency for Healthcare Research and Quality noted the lack of standardized quality measures (Dougherty and Simpson 2004). Three environmental scans conducted a decade later, between 2012 and 2015, documented the disparate set of measures used in the oral health sector and the continued lack of standardization (Dental Quality Alliance 2012; 2015); National Quality Forum 2021). In 2008, CMS reached out to include dentistry in the broader health care quality movement. Engaging ADA in a leadership role, CMS triggered the formation of the Dental Quality Alliance (DQA) to identify and develop evidence-based oral health care performance measures and advance their use and improvement (Hunt and Aravamudhan 2014). DQA members include federal agencies and payer, provider, education, and research organizations that provide a strong foundation to support quality measurement in dentistry.

Examples of quality measures DQA currently advocates are a number of measures for children, such as newly diagnosed carious lesions, caries risk, receipt of at least one sealant on a permanent first molar, receipt of fluoride varnish, and receipt of a follow-up oral evaluation within 3 months of a well-child visit.

HRSA has developed and implemented a number of clinical quality measures within its Health Center Quality Improvement initiative. For HRSA's Ryan White HIV/AIDS Program, one example of a performance measure is the percentage of patients, regardless of age,

Table 8. Clinical practice guidelines from the American Dental Association
• Antibiotic Prophylaxis for Preventing Infective Endocarditis (2008)
• Non-fluoride Agents for Caries Prevention (2011)
• Professionally-applied and Prescription-strength, Home-use Topical Fluoride Agents for Caries Prevention (2013)
• Management of Patients with Prosthetic Joints Undergoing Dental Procedures (2014)
• Fluoride Toothpaste in Young Children for Caries Prevention (2014)
• Nonsurgical Treatment of Chronic Periodontitis (2015)
• Evidence-based Clinical Practice Guideline for the use of Pit-and-Fissure Sealants (2016)
• Evaluation of Potentially Malignant Disorders in the Oral Cavity (2017)
• Nonrestorative Treatments for Carious Lesions (2018)
• Antibiotic Use for the Emergency Management of Dental Pain and Swelling (2019)

Source: American Dental Association Center for Evidence-Based Dentistry (2021).

with a diagnosis of HIV and an HIV viral load less than 200 copies/milliliter at the last viral load test during the measurement year (Health Resources and Services Administration 2021d; 2021e). Giving providers the ability to compare their performance against that of peers initiates efforts to improve quality. Practices that serve publicly insured populations (e.g., Medicaid) have been at the forefront of quality measurement and improvement efforts, driven by the need to achieve the Institute for Improving Healthcare's Triple Aim goal of healthier patients, healthier communities, and lower per capita cost. Dental providers who regularly interact with medical providers in FQHCs now measure "dental sealants on permanent molars among children aged 6 to 9 years with moderate to high risk of caries" and "tobacco screening among adults and percent who received cessation counseling" (Health Resources and Services Administration 2020d).

As measurement of quality began in dentistry, so did efforts to improve dental care and outcomes. Several initiatives across the nation that incorporate aspects of the Institute for Healthcare Improvement's learning collaborative model have demonstrated improved outcomes (Institute for Healthcare Improvement 2003). By using quality improvement principles and techniques to improve care, the Early Childhood Caries Collaborative demonstrated a 28% reduction in patients with new cavities, a 27% reduction in pain, and a 36% reduction in referrals to the operating room (Ng et al. 2014). FQHCs participating in the University of California, Los Angeles's 21st Century Community Dental Homes Project demonstrated a 3.3-fold increase in preventive services for children from birth to age 5 years (Ruff et al. 2018).

Information from patients is another important source of information for improving dental care quality and safety. Patient-reported outcomes (PROs) are commonly used during clinic visits, and some dentists now use text messaging or email surveys to solicit information after the office visit and adjust patients' postoperative management. Measuring patients' experiences is an important component of assessing health care quality (Manary et al. 2013). Some PROs have been formalized and are included in surveys to assess patient experiences with dental plans and dental offices (Agency for Healthcare Research and Quality 2019).

Although some dental practices have begun to implement quality measures, their numbers are limited, and many opportunities to introduce quality measures to the broader delivery system have not been acted upon. Student dentists are being trained in the use of diagnostic codes and integration; however, when new dentists enter the workplace, they often are forced to revert to legacy systems that are dependent on procedure codes.

Dental offices use the Code on Dental Procedures and Nomenclature (CDT codes) to document dental care for submission to insurers for reimbursement (American Dental Association 2021j). The CDT code set describes the treatment provided (e.g., a dental filling) but does not describe the patient's problem or diagnosis (the reason a filling was needed). In October 2015, the U.S. adopted ICD-10-CM (International Statistical Classification of Diseases and Related Health Problems [ICD]-10) the World Health Organization set of diagnostic codes that includes dental codes (Centers for Disease Control and Prevention 2014). Although EDs, FQHCs, other larger clinics, and physicians who provide oral health services use ICD-10 dental codes, few dentists in private practice have adopted them. Use of the ICD-10 codes, however, is urgently needed in order to evaluate the quality and effectiveness of dental care; for example, how many patients have procedures (such as crowns and root canals) that fail.

Patient Safety During a Public Health Emergency

COVID-19 resulted in CDC's strong reiteration of standard precautions since their implementation during the HIV/AIDS epidemic. In the 1980s, those infection control procedures had been developed to address bloodborne pathogens, rather than for viruses that can be spread through droplets or airborne routes as is the case for COVID-19. These comprised essential guidance for the practice of dentistry, where the use of highspeed handpieces and air-water syringes can create droplet splatter and aerosols that increase exposure to disease transmission. Concern over transmission of COVID-19 while treating asymptomatic dental patients led ADA to urge HHS to include dentists as federally recognized practitioners permitted to administer point-of-service COVID-19 tests authorized by the U.S. Food and Drug Administration. That request was denied (Garvin 2020c).

As the pandemic evolved, a number of challenges arose. Dental offices struggled to keep the needed PPE in stock. These generally included gloves, gowns, face shields, and tight-fitting N95 respirators that reduce exposure to smaller particle aerosols. CDC has continued to release new PPE guidelines as appropriate, offering tiered level-of-care guidance to match different PPE requirements to various procedures and in consideration of virus transmission in the community. Another major challenge has become the need for coordinated workforce policies to protect the well-being of clinicians involved in treating patients with COVID-19 (Dzau et al. 2020), especially because patients with the virus may be asymptomatic. Although it is too early to predict the need for permanent changes to practice, it may be important to reconsider scope-of-practice regulations to protect dentists, dental assistants, dental therapists, and hygienists.

Chapter 3: Promising New Directions

Despite the challenges facing the dental profession in the delivery of dental care, numerous promising initiatives can improve the professional workforce and practice settings while encouraging the integration of dental and medical care.

Workforce

As noted earlier, states are beginning to recognize the value of expanded functions for certain dental personnel, including community health workers, as well as practices such as the co-location of dental professionals in medical offices, telehealth-enabled public health dental teams, and HIV screening by dental personnel (Feng et al. 2018). For the 613 U.S. counties designated primary care health professional shortage areas (HPSAs) that lack a dental HPSA designation (Health Resources and Services Administration 2020b), training the dental office workforce to take on some tasks medical personnel typically perform, such as serving as access points for preventive health screening and services, immunizations, and health promotion activities such as tobacco cessation, could improve overall community health (Braun and Cusick 2016). In addition, nurses could be co-located in dental offices (Jones et al. 2017). Dental offices could also provide emergency response infrastructure for disasters, provide sterile instruments, or distribute pharmaceuticals (PHS Commissioned Officers Foundation for the Advancement of Public Health 2010). After Hurricane Katrina in 2005, the most commonly needed services for displaced victims and emergency response workers were dental extractions and temporary dental fillings.

At the same time, new initiatives are expanding functions for medical personnel, developing novel collaborations within the community, and proposing that dentistry adopt workforce models used in medical care, such as community health workers to aid in navigation and patient education. Because community health workers live in the communities they serve, they are uniquely positioned to deliver information where the need is greatest. Improving adherence to health recommendations and reducing the need for emergency care are among the many proven outcomes from the services that community health workers can provide (Health Resources and Services Administration 2007). Additional information on community health workers is available elsewhere (Centers for Disease Control and Prevention 2019c).

Oral Health Care Delivery in Nontraditional Settings

A project in North Carolina, Into the Mouths of Babes, demonstrated the value of expanding scope of practice by incorporating preventive oral health services (POHS) into primary care practices. This project trained pediatricians to include POHS, such as oral assessment, fluoride varnish, and referrals to dental professionals. About 43% of Medicaid-eligible children enrolled for at least 10 months had four or more POHS visits during their first 42 months of life (Atchison et al. 2019). Appropriate training of the pediatricians enabled them to efficiently incorporate POHS into their workflow and to improve access to care. In another effort, National Interprofessional Initiative on Oral Health partners developed an online education system to educate non-dental providers and health educators about oral health and provided web-based and interactive educational resources aimed at integrating oral health and primary care (Box 3). This free resource addresses educational objectives based on Accreditation Council for Graduate Medical Education competencies.

Collaboratives with Population-Specific Entities

The U.S. Public Health Service workforce increases access to care for isolated communities through unique collaborations with other entities. By working in tandem with numerous entities—including Head Start; elementary schools; day care centers; the Special Supplemental Nutrition Program for Women, Infants, and Children; and community health representatives—the Indian Health Service increased by 7% the number of children up to 5 years of age with a dental visit between 2010 and 2014. The percentage of children aged 1 to 5 years with decay experience and untreated decay declined by 5% and 14%, respectively (Phipps et al. 2019).

Coordinating the oral health workforce with a changing population's care needs will require new strategies to match the supply of oral health providers with the demand for their services.

Demand Modeling in Workforce Planning Projections

The World Health Organization's Global Strategy on Human Resources for Health aligns investments in health personnel with specific populations' current and future needs (World Health Organization 2016). Limited planning of human resources for (oral) health has been conducted using simplistic targets for the dentist-to-population or constant-services-to-population ratios, which do not reflect levels of, or changes in, population need (Ono et al. 2013). Incorporating need explicitly into oral health workforce planning and program design would decrease the possibility that supply will be influenced by oral health care providers whose professional interests may not accurately reflect population needs (Listl et al. 2019).

Needs-based oral health services and workforce planning must be connected to enable more effective matching of the composition of oral health providers to the population's specific oral health care needs and must go beyond matching providers to the population's size, age, and racial-ethnic profile. More accurate modeling leads to policies that change oral health providers' scope of practice, including increasing the independence of some allied providers. An example is the proposed California bill, prompted by a shortage of primary care physicians, to license nurse practitioners to work without physician supervision (L.A. Times Editorial Board 2020). It is critical to recognize that individuals' need for oral health care, as well as population disease patterns, will vary over time and that the type of services appropriate to address patient need also may change over time as a result of medical-technical innovation or changes in the skill mix of a provider group (Birch et al. 2009; Ahern et al. 2019; Listl et al. 2019).

The National Advisory Committee on Rural Health and Human Services released a policy brief and recommendations for an extensive modeling and workforce planning program (National Advisory Committee on Rural Health and Human Services 2018).

Box 3. How do communities bridge the gap between medical and dental care?

Since 2009, the National Interprofessional Initiative on Oral Health (NIIOH) has used innovative strategies, tools, and resources to integrate oral health into primary care education and practice, preparing an interprofessional oral health workforce to address dental disease in new roles. NIIOH supports an interprofessional network of partners, organizations, and tools, including *Smiles for Life*, a comprehensive and widely used oral health curriculum. Produced by the Society of Teachers of Family Medicine, *Smiles for Life* is a free, online resource that offers instruction in the knowledge and skills needed to incorporate oral health into interprofessional practice. Endorsed by 8 health professional groups and more than 20 national organizations, by 2020, *Smiles for Life* had registered more than 150,000 users and documented completion of more than 450,000 courses.

More than 550 direct care providers who registered to use the *Smiles for Life* curriculum completed a survey about the impact of their training; of these, 85% reported improvements in conducting annual oral examinations, caries risk assessments, and oral cancer screening, providing fluoride varnish applications, and educating patients. Most educators reported that the curriculum led them to incorporate or enhance their oral health teaching.

To address barriers in practice transformation, NIIOH commissioned development of the Qualis Health *Oral Health Implementation Guide and Toolkit*. Training activities include an annual interprofessional Oral Health and Primary Care Symposium. NIIOH core partners include Oral Health Nursing Education and Practice and the PA Leadership Initiative on Oral Health, as well as legacy funders including the CareQuest Institute for Oral Health and the Arcora Foundation.

The NIIOH has received The George E. Thibault, MD Nexus Award for exemplary interprofessional collaboration in the United States addressing healthcare education and healthcare delivery simultaneously to be better integrated and more interprofessional while demonstrating outcomes. In addition, the NIIOH has been selected as the ADEA Foundation's 2020 William J. Gies Award Winner for Innovation for facilitating the creation, exchange, evolution, and application of new ideas that are bringing value to the dental profession by enhancing strategies that promote oral health across interprofessional education and practice.

The committee noted that challenges of oral health were one of the greatest unmet needs in rural America, affecting 34 million Americans. Although improvements in care had been made, such as use of silver diamine fluoride, expanded telehealth, and implementation of dental therapists, the committee made recommendations to study a variety of options for improving the oral health of young children in Head Start programs. Their recommendations included comparing opioid-prescribing patterns in rural and urban centers, assessing differences in Medicare Advantage insurance options to better serve rural adults, and developing an overall action plan to improve oral health. The report suggests an excellent opportunity to develop stronger modeling programs that can improve a variety of oral health programs in America, using the needs of rural sites as a first test.

Needs-based planning could create a framework to identify changes in the oral health workforce that would better match providers' skills and capabilities to patient care needs and help set priorities for dental curricula and future research. For example, implementing a model that would employ the least expensive type of provider—that is, the one who is able to provide safe and effective care at the least cost to produce—would effectively match skills to need. A dental student requires 8–9 years of education, resulting in an estimated debt of $300,000. In contrast, a bachelor's-level dental hygienist requires 4 years of education and accumulates under $30,000 in debt (The Institute for College Access and Success 2018). Thus, the United States can produce at least nine dental hygienists for the cost of producing one dentist. More important, this reflects the change in the mix of services typically provided in dental practice, which are now more commonly diagnostic and preventive, rather than restorative. State public health departments have excellent opportunities to work with their boards of licensing and dental provider schools to design and test needs-based workforce models to help their communities.

Education and Training

Promising avenues in education and training that respond to demographic shifts and changes in the U.S. health care industry will better prepare graduates to join the workforce. These avenues include a didactic and clinical curriculum that enables students to graduate with a public health or population health perspective, as well as training in patient-centered care that is integrated more fully with other health care professionals in community settings, including long-term care facilities. Full implementation of new licensure paths, such as the postgraduate year initiative and increased use of licensure compacts, which are multistate health care provider license agreements, are expected during the next 10 years.

Patient-/Person-Centered Care

Patient- or person-centered care has been proposed as a way to help a diverse patient population access and navigate medical and oral health care with the assistance of professionals and technology. Health integration models embrace this approach to achieve the Institute for Health Care Improvement's Triple Aim initiative to improve care delivery and patient outcomes and reduce the cost of care. Such models also offer opportunities for training allied, predoctoral, and postdoctoral students. Although much work will be needed to achieve patient-centered care within dental education, the Commission on Dental Accreditation has laid the groundwork with standards calling for a "commitment to patient-focused care" and a "formal system of continuous quality improvement" at dental schools (Commission on Dental Accreditation 2020c, p. 9, 27).

Although dental school based clinics have not fully embraced the tenets of patient-centered care, medical education has explored including it as part of student training (Philibert et al. 2011). Barriers to implementation include school culture, the physical environment, and time and other constraints. There have been early successes, such as teaching medical students to offer patients informed choice, rather than informed consent, and instituting patient advisory councils to improve clinic performance.

Adoption of a patient-centered care approach in dental education institutions, along with a strong emphasis on evidence-based practice and effective communication strategies with team members and patients, will prepare graduates for successful entry into residency and practice. It also will help dental school clinics become more successful safety net institutions. There is ample opportunity for research on curricular approaches to education that identify best practices for clinic based oral health education.

More recently, the concept of person-centered care has been supported by the idea of technology that captures data from individuals and customizes care, which could revolutionize the diagnosis, management, and prevention of many chronic diseases, including oral conditions (Walji et al. 2017). In addition, dental schools should be encouraged to implement teledentistry and integrated models of clinical care in shared sites with allied and predoctoral students from all health care professions in their community-based programs.

Interprofessional Practice

Whenever possible, dental education learning experiences should be integrated with those of other health professional students to lay the groundwork for implementing interprofessional education and interprofessional practice. Following publication of the Core Competencies for Interprofessional Collaborative Practices (IPEC Interprofessional Education Collaborative 2016), recommended models were tested, resulting in the current accreditation requirements for interprofessional education in all health professions. However, interprofessional practice models are not yet as well developed as didactic courses, and opportunities need to be created so that all dental professional students work with other professional groups during their training.

The overall effectiveness of interprofessional practice across geographic and socioeconomic models is still being evaluated, and consensus on national guidelines has not yet been reached (McKernan et al. 2018). When successful, interprofessional practice involves data-driven integration and coordination of care implemented holistically by a diverse health care team (Harnagea et al. 2017; McKernan et al. 2018). By bringing together fragmented care teams and different points of care delivery, interprofessional practice can facilitate the integration of medical and dental systems and positively affect disparities in oral health access and care (Institute of Medicine and the National Research Council 2011; Harnagea et al. 2017).

Curriculum and Licensure

Community-based dental education has grown steadily during the past 10 years, giving dental students the experience of treating disadvantaged patients in a variety of community settings and integrated health centers (Andersen and Davidson 2009). The Advancing Dental Education in the 21st Century project recognized the need to bolster didactic education with a population-focused curriculum to prepare students for the demands of future practice. The focus is on understanding changes in population characteristics, such as demographics, health disparities, and the prevalence of disease; cultural diversity and sensitivity; health literacy; and communication skills (Weintraub 2017). Because the majority of oral health providers live and work in urban areas, access to oral health care is often a challenge for rural America. To address this issue, several organizations and dental schools are working to expose future health care providers to rural health issues and to connect rural residents to an integrated medical-dental care model. For example, the Family Health Center of Marshfield (Wisconsin) has embraced the need for early training of dental students and developed a program to offer students a population-based clinical rotation that exposes them to rural health needs (Box 4).

Licensure changes that have streamlined the pathways to licensing and licensure by credential (holding a license in another state) for dentists are now well accepted and can serve as models for licensing procedures for allied providers. The challenges facing better integration of dental hygienists and dental therapists mirror the problems that faced the nursing profession (Institute of Medicine 2011b). Like dental hygienists, nurses provide care both in homes and in public health settings. Allied dental providers would benefit from the four key messages that were developed with regard to nurses: (1) practice to the full extent of their education and training; (2) achieve higher levels of education and training through seamless academic progress; (3) enable nurses (or hygienists) to be full partners with physicians and other health professionals in redesigning health care in the United States; and (4) encourage the country to develop better workforce planning and policymaking to create an improved information infrastructure.

To achieve these goals, standardized scopes of practice based on professional competence would ensure that dental hygienists and dental therapists practice to the full extent of their education and training. Interstate licensure compacts, such as those used in nursing, medicine, and physical therapy, could expand and expedite licensure for oral health professionals such as hygienists. The ability to move forward in training, through dental-specific programs structurally modeled on Advanced Practice Nursing programs, would guarantee that allied oral health providers could help meet the country's oral health needs. Such training also would facilitate the use of telehealth, which currently is challenged by state rules that restrict dental providers from working across state lines in virtual practice settings. Interstate licensing compacts could support more effective and efficient oral health care delivery.

Oral Health Practice

The dental service organization (DSO) model continues to grow, and DSOs are serving significant numbers of patients eligible for Medicaid and the Children's Health Insurance Program, according to survey findings. Reimbursement from public dental benefits is below average commercial fees. DSOs leverage size and market penetration to the advantage of both their organizational affiliates and the public, making dental services more affordable and readily accessible (Langelier et al. 2017a). However, an American Dental Association (ADA) study (Starkel et al. 2015) found that dentists working in dentist-owned practices generally reported more satisfaction with their role and felt that dentistry better aligned with their expectations, compared to dentists working in management-owned practices. In contrast, researchers within the U.S. Department of Veterans Affairs were the first to demonstrate that characteristics of the patient-centered medical home, such as team functioning, working at the top of one's professional competency, participatory decision-making, and full staffing, were associated with lower burnout among a variety of health care team members (Helfrich et al. 2014). This finding has implications for dentistry, as group practice and the number of allied providers increases.

Box 4. How does an independent health system bring dentistry and medicine together to improve the health of rural populations?

The Family Health Center of Marshfield is part of a private, independent health system that has operated in Wisconsin for over 100 years. Inspired by the 2000 Surgeon General's Report on Oral Health, the health center began opening dental centers in northern Wisconsin almost 20 years ago. Ten dental clinics were established, and since then more than 190,000 dental patients have received services. Recognizing that medical and dental services often are disconnected, the health center developed and implemented several innovative programs. Because more than 70% of the total health system population receive both medical and dental treatment within the system, integrating the electronic medical and dental health records gave physicians and dentists the opportunity to view both medical and oral health information, facilitating cross-referrals. A pediatrician would be trained, for example, to notice if a child was missing a dental visit, and a dentist would be trained to notice that a child was missing a vaccination.

The Health Center modified the *Smiles for Life* curriculum, which is a computer-based educational tool for cross-disciplinary training, and, over a 4-year period, more than 330 medical providers completed the training. The health center also partnered with the Arizona School of Dentistry & Oral Health to place fourth-year dental students into clinical rotations in its rural communities so that they practice in integrated health care environments; a workforce pipeline to rural settings also was established. Finally, the Center for Oral and Systemic Health was established and is devoted to research, education, and identification of best practices. Their Oral Health Integrated Care Model Initiative, introduced in two primary care clinics, resulted in nearly 5,000 new oral examinations for patients with diabetes and more than 600 referrals of patients with diabetes to see a dentist. The Center for Oral and Systemic Health also pioneered implementation of a dental quality dashboard and adoption of dental diagnostic codes in the dental clinical setting. Quality metrics support dentists in tracking progress on achieving benchmarks, such as sealant placement in eligible children.

Local, state, and federal funds have supported the Family Health Center, as well as the Marshfield Clinic Health System Foundation, Delta Dental of Wisconsin, and CareQuest Institute for Oral Health.

Research is indicated to assess job satisfaction and elements associated with oral health care providers' satisfaction in different settings. Burnout is an important issue for the oral health workforce. ADA provides online wellness resources for dental practitioners to help them manage stress (American Dental Association 2020o). Researchers also have begun to investigate wellness issues for students in predoctoral dental education programs (Colley et al. 2018).

Expanded use of technology can help improve access to oral health care. The next generation of electronic health records (EHRs) will support person-centered care through the incorporation of anticipatory guidance and the recognition of social determinants of health, as well as patient data generated outside the dental clinic (Walji et al. 2017). Teledentistry offers strong potential to facilitate care for underserved populations, particularly in rural areas. It is useful for both didactic and clinical training of dental residents (Langelier et al. 2016c). Applications of teledentistry empower licensed professionals to supervise the care provided by dental students, residents, or allied providers at distant sites. Remote supervision also may help educational institutions reporting faculty shortages. State laws and practice norms can be updated to stay current with this technological potential. A systematic review concluded that teledentistry provides a feasible choice for remote screening, diagnosis, consultation, treatment planning, and education in dentistry (Irving et al. 2018).

Provision of Dental Services During a Public Health Emergency

The response to the novel coronavirus (COVID-19) crisis by the Kaiser Permanente dental program (KP Dental) provides insight into how interprofessional delivery systems could mobilize coordinated care during a disaster. Kaiser Permanente developed a regional control center (RCC) to create a centralized decision-making, policymaking, and communication body during the crisis. The RCC consisted of all medical directors and senior leaders from the health plan's ambulatory care, hospital care, and other departments, including dental services. In concert with the Kaiser Permanente Northwest health plan, KP Dental limited delivery of dental services to urgent and emergent medical and dental conditions, using a triage model adapted from the Military Health System, to conserve personal protective equipment (PPE) so that it could be redirected to medical operations. This reduced the risk of exposure and community spread to patients and providers in health care settings. It also maintained the capability of providing emergency dental care to prevent diversion to EDs.

A workforce model was designed to support four dental offices located strategically in terms of geography. Each dental office consisted of a general dentist who performed telephone triage, a general dentist with a broad scope of practice, and 1 of 3 dental specialists (oral maxillofacial surgeon, pediatric dentist, or endodontist). Guidelines were updated to include management of dental emergencies while limiting splash, splatter, and aerosols. Dentists were assigned to patient-facing pools, virtual pools, and on-call and quarantine pools. The University of Puerto Rico School of Dental Medicine used a similar model for integrating dental students teamed with the Medical Sciences campus to conduct assessments of vulnerable areas, execute triage and crowd control, and prepare communication groups at all levels (Lopez-Fuentes 2019). Dental educators could expand on existing disaster curricula for working more closely with public health emergency responders to better equip the United States for dealing with future disasters.

Oregon lifted its pandemic-prompted suspension of dental practices on May 1, 2020. Before resuming full operations, KP Dental developed a plan for a phased opening of dental offices structured on prioritizing care on the basis of patient need, types of care, and location characteristics. It developed a guideline to standardize priority levels for dental care that covered emergency dental services, urgent dental care, routine care, and hygiene services. All patients who had appointments cancelled or who called for an appointment were classified on the basis of the priority level of their dental needs. Dental services were categorized from higher- to lower-priority services. Types of procedures were classified either as aerosol-generating procedures (AGPs) or non-AGPs; these two procedure types require different levels of PPE. Protocols to modify procedures to prevent aerosols were developed and distributed to care teams. KP Dental directed different priority levels and procedure types (e.g., AGPs) to different locations, depending on the amount of PPE in those offices. Hours of operation were expanded, with fewer providers assigned per shift to allow for increased infection control processes and social or physical distancing.

Teledentistry also was used to triage patients with urgent dental needs into appropriate in-office dental visits. Expansion of teledentistry into routine care (e.g., dental examinations, consultations) will be designed to reduce the number of in-person interactions with each patient. With the establishment of a robust COVID-19 testing protocol, patients requiring procedures that produce aerosols can be tested 48 hours before care and treated with standard PPE, assuming a negative test result.

The dental community’s ability to respond to the COVID-19 pandemic quickly, efficiently, and in a carefully targeted manner provides a model of how dental expertise, infrastructure, and flexibility can be utilized to respond to other national disasters, such as hurricanes, fires, and earthquakes, and other natural or human-caused catastrophes.

Financing Dental Care

The increase in dental insurance coverage during the past 20 years brings the potential for improved oral health to millions of Americans. However, administrative and policy barriers in government insurance programs often preclude timely and effective care. The national safety net, although growing, is insufficient to ensure that all provider vacancies are filled and to serve all patients who need care. Although it is clear that too few dentists accept public insurance, government billing requirements appear to overload the capabilities of smaller solo practices, thus discouraging dentists from participating. Only 18 states allow dental hygienists to independently bill Medicaid for dental services (American Dental Hygienists' Association 2021). As licensed providers by their state, hygienists offer a valuable safety net workforce. Regulations vary by state government and include some that impede, rather than support, the ability of a licensed workforce to perform and bill for their services.

Although insufficient numbers of dentists are participating in government-funded programs, many dental providers are willing to staff volunteer clinics serving these same populations. Given the challenges of participating in public programs, dental professional associations can jointly explore the possibility of statewide mechanisms to handle billing and administration for Medicaid, much like a DSO. They also can mobilize dental providers to serve as volunteers for community clinics and other safety net clinics, bringing much needed care to people who are served by government programs but experience barriers to accessing dental care.

The medical insurance system has seen an upsurge in new financing models to improve access to care while improving health, such as the approach of "value-based health care," being implemented by the Centers for Medicare & Medicaid Services. A value-based payment structure is designed to improve health by organizing payment around the *outcome of care*, rather than the *services provided*. When payment is tied to achieving better outcomes rather than fees for services, it influences care and care delivery (Vujicic 2018). The benefits of value-based care focus on the following principles in accountable care organizations (ACOs):

- Patients will pay less and have better outcomes because the focus of care is prevention.
- ACOs will screen, coordinate care, and treat early disease before it causes more serious health problems.
- Appropriately managed, quality care will make patients more likely to report greater satisfaction.

ACOs control the overall cost of care, thus reducing their risk. Data are shared across all provider partners to ensure the best care can be made available at the lowest cost. Society benefits because people are healthier and the cost of care has been contained or lowered. Dentistry has been slow to adopt value-based reimbursement because of concerns about payment system changes and government involvement in the financing of oral care. Dentistry's tradition of fee-for-service payment often emphasizes restorative services. However, under value-based care, a dental restoration has a negative impact on the bottom line of an ACO, which measures patients' disease risk and providers' ability to prevent or manage disease progression to reduce treatment costs.

The few early adopters of value-based care in dentistry are tied to medical organizations such as Oregon Transformation, Kaiser Permanente, and HealthPartners, which have shown that a value-based payment structure holds promise for decreasing the cost of care and improving access to oral health care. Accountable, coordinated, or value-based care organizations will likely continue to grow because of pressure to create greater value for patients and the community, increase access, improve patient engagement, prevent adverse events, and allocate appropriate resources for high-risk patients. Academic health centers should be encouraged to work across the health professions, adapting ACO demonstrations in their patient populations, so that the next generation of graduate dentists, nurses, and physicians are experienced in developing integrated health care that is best for the patient.

Access to Dental Care

Health care is experiencing a paradigm shift toward collaborations among a broader range of providers in a more integrated health care delivery system to improve population health. This shift offers potential benefits in the treatment of vulnerable populations that have many medical, behavioral, financial, and physical challenges. New models of care delivery, such as telehealth-enabled dental teams, clinics in public schools and long-term care facilities, and integrated primary care practices, hold great promise for improving access to preventive and restorative oral health care, especially for vulnerable populations.

The increasing diversity of dentists, including more who are women, from rural settings, and from underrepresented minorities, also holds promise to expand access to care for vulnerable and underserved populations. These new professionals are more likely to work for private group practices, in rural settings, for federal agencies, and in integrated and safety net practices such as federally qualified health centers (FQHCs). This shift will increase the workforce in underserved areas where many patients may receive public support. Increased and widely advertised federal support for loan repayment and scholarship programs also promises to accelerate the diversification of dental education programs at all levels.

Oral Health Integration

Integration of oral and general health can reduce emergency department use, save overall health costs by providing preventive dental services to persons with chronic medical diseases, and reduce hospital costs associated with early childhood caries for children younger than 5 years. It is an effective strategy for improving access to oral health care, reducing disparities in health, and achieving the Institute for Healthcare Improvement's Triple Aim initiative of improving care delivery, improving patient outcomes, and reducing the cost of care.

Progress for adults is being made through Medicare Advantage and Medicaid expansion plans that extend preventive, diagnostic, and basic restorative and periodontal coverage so that individuals have enough healthy teeth to function (McDonough 2016). This basic coverage will enable the expansion of successful ACOs and similar models to improve oral health services while maintaining quality and cost. Policymakers and employers will be able to promote dental care coverage as part of core benefit packages and support the transition to pay-for-performance and quality metrics rather than fee-for-service payments.

Increasing integration also will allow ACOs to focus more on overcoming barriers that limit interprofessional practice relationships and referral networks. Integration holds promise for improving providers' oral and medical care competencies and for promoting more effective health information sharing. An important development for establishing bidirectional interprofessional partnerships is the elevation of the dental home to the same status as the medical home. The patient-centered dental home concept, established in 2004 by the American Academy of Pediatric Dentistry, has since been updated with standardized definitions and performance measures to include oral health integration (Damiano et al. 2019). Recently, the Centers for Disease Control and Prevention's (CDC) Division of Oral Health, in partnership with the National Association of Chronic Disease Directors, awarded funding in September 2020 to establish a national framework for medical-dental integration. According to CDC, the framework will support integration activities to improve access to oral health care for populations with associated chronic diseases. CDC also is investing resources in five states (Colorado, Connecticut, North Dakota, South Carolina, and Virginia) to promote medical-dental integration activities (Centers for Disease Control and Prevention 2020). Finally, the expanded use of integrated EHR systems can improve interprofessional communication, reduce information duplication and inconsistencies between oral and medical records systems, and improve adherence to treatment guidelines involving other health domains (Rudman et al. 2010). Integrated health systems and other organizations are increasingly adopting embedded integrated dental and medical records systems. Integrated EHRs also can facilitate the adoption of common diagnostic coding and billing systems, which will further support oral and medical health integration.

Patient Safety and Dental Care Quality

Medicine's pursuit of a culture of safety for patients at all levels and a commitment to reduce medical errors offers dentistry a road map. The challenge of converting the existing dental care system to one in which safety is integral to practice has been noted, and increased interactions between medical and dental providers at FQHCs, at community health centers, and in ACOs, provide models on which dentistry can build.

Dental education can lead this effort by emphasizing safety in curricula and training standards, following models used in oral surgery residencies. Clinical education, a large part of dental professional training, offers the opportunity to incorporate continuous quality improvement and safety monitoring into clinical training systems in dental schools, as well as the opportunity to upgrade existing providers' practice readiness through continuing education courses, publications, and guidelines.

ACOs emphasize the need for measuring process and outcomes data to enable timely intervention or prevention that can result in more appropriate and personalized care. The time is right for a transition from the dental profession's adherence to dental procedure codes (Current Dental Terminology) to diagnosis codes (Kalenderian et al. 2018). Dental education can lead these efforts by implementing diagnostic codes in their clinics. Today, health systems operating in an ACO are under pressure not only to create greater value for patients and communities, but also to prevent adverse events and allocate appropriate resources for high-risk patients with high-burden health issues (Atchison et al. 2019). Dental schools that exist within academic medical centers should integrate the dental EHR with their medical EHR to facilitate interprofessional practice that enables all health profession students to practice safety and quality in preparation for clinical practice.

Oral health practices are beginning to understand and prepare for this emerging environment. Advances in artificial intelligence (AI) and machine-learning technology can power clinical decision support systems to extend provider team capabilities. As an example, practitioners can use AI to complement traditional diagnosis and treatment planning in periodontal procedures such as scaling and root planing. AI tools can help assess bone levels and periodontal support and enable treatment decisions to be data-driven. Dental insurance companies are starting to leverage such technology in claims reviews, and similar adoption by practitioners will lead to greater standardization and quality care. EHRs should have usable and efficient interfaces and can be designed and employed to improve the quality, safety, and value of oral health care by incorporating items such as AI. Laying the groundwork for usability, recent work has investigated systems for categorizing dental adverse events (Kalenderian et al. 2017).

Federal research dollars are beginning to be directed to clinical research on safety and guideline development, including the development and use of quality measures. Industry also plays an important role in fostering safety in product and device development and testing. Evidence-based therapies consider both efficacy and safety. The Dental Anesthesia Incident Reporting System offers a model of a community-based system that can be used for error reporting and analysis (American Association of Oral and Maxillofacial Surgeons 2021). The profession also can capitalize on opportunities to affiliate with initiatives in public health and medical care to develop additional efforts for error reporting and other uses of data for ensuring the safety of care.

Chapter 4: Summary

The U.S. oral health care system has experienced substantial changes in the past 20 years in its workforce, education, practice, and financing. It has launched efforts to improve access to care for underserved populations, to improve patient safety, and to better integrate oral and general health care delivery. The oral health workforce consists of more than 750,000 dental professionals—more than 200,000 dentists, 221,560 dental hygienists, 351,470 dental assistants, and other dental professionals working in private and public practices, academia, and federal, state, and local government settings. Of current practicing dentists, 32% are women, a proportion that is expected to grow. Other dental professions are primarily composed of women, with the exception of laboratory technicians, who are predominantly men.

Racial diversity in the profession continues to be a challenge. In 2018, 75% of active dentists were non-Hispanic White, and only 3% were Black/African American, 6% were Hispanics/Latino, 14% were Asian, and fewer than 1% were American Indian/Alaska Native. Much remains to be done to increase racial and ethnic diversity, beginning with preprofessional and professional education, so that oral health providers better reflect the racial and ethnic composition of the patient population they treat.

Since 2000, a number of forces, which have been described in this monograph, have affected the oral health workforce and have impacted the delivery of care to many Americans and several of these are highlighted in Box 5. The oral health workforce has expanded to include new types of providers such as dental therapists and community dental health coordinators. New and expanded workforce models have demonstrated effective care delivery to a greater number of individuals by enabling dental therapists and public health dental hygienists to practice the full range of skills in which they have been trained. Community dental health coordinators hold promise for providing culturally competent health information and much-needed health care navigation services. Efforts to improve access to care, particularly in rural areas, for children younger than 5 years, and for people with special health care needs, have led to a new workforce model involving medical providers who conduct oral health screening and risk assessment, educate patients, and apply fluoride varnish and dental sealants.

Box 5. Key summary messages for Oral Health Workforce, Education, Practice, and Integration

- Today's oral health workforce includes not only dentists, but other oral health professionals, such as dental therapists, public health dental hygienists, and community dental health coordinators and medical colleagues who provide oral health assessment and prevention.
- Although there are more oral health providers in the U.S. than in 2000, today about 60 million Americans live in areas (mostly rural) where there are too few oral health professionals to meet local needs.
- Enrollment in dental and allied education programs is at an all-time high. Racial and ethnic diversity within these professions is increasing modestly, and about half of recent dental graduates are women.
- The high student debt resulting from the cost of dental education may inappropriately drive the shape of the oral health workforce increasing the likelihood that graduates will choose to practice in affluent areas, rather than seek faculty, research, or public health opportunities in underserved areas.
- More people have public or private dental insurance than 20 years ago, yet accessibility and services remain limited, and the majority of dentists do not accept Medicaid dental insurance. Oral health professionals must be willing to accept all types of dental insurance.
- Most oral health care occurs in private practices, yet people increasingly receive care where they live, work, and learn—including in community health centers, government-run clinics, dental schools, or in schools, long-term care facilities, mobile practices, and other settings.
- Strategies for the integration of oral and general health care delivery are emerging. Improving adults' access to dental care will require a multipronged approach and coordinated efforts among policymakers, insurers, and dental professionals.
- State practice acts regulating the services that oral health professionals provide often reduce access to dental care by limiting geographic mobility and make it difficult to recruit oral health professionals to work in different settings.
- The development of safety measures, quality measures, and dental diagnostic codes (rather than procedure codes) are necessary to improve and advance the quality of outcomes for oral health care.

Call to Action:

- Improving access to oral health care can be achieved by recognizing dental care as an essential health benefit for all Americans, expanding dental coverage for the uninsured, encouraging new professional models, and by providing educational opportunities that encourage interprofessional learning and the delivery of care in new settings.

Enrollment in most dental education schools and programs has grown, including a 29% increase in enrollment in allied programs and a 45% increase in enrollment in dental programs, plus new advanced dental and specialty programs. Efforts to recruit a more diverse student population have been initiated in dental schools, with modest success in the recruitment of more underrepresented minority students. In addition, curricular changes have resulted in better integration of behavioral, clinical, and basic sciences. Practices in dental schools are more focused on comprehensive care and serving as safety net clinics for underserved patients. The ongoing challenge is to develop an affordable dental education system that prepares practitioners to address health inequities.

Although more dental graduates have created a larger oral health workforce, there are still many areas of unmet oral health care needs. It is difficult to attract providers to designated health professional shortage areas, and the oral health care opportunities of persons living in those areas remain limited. Pathways to licensure for dentists are beginning to allow more geographic mobility, which would enable dentists to work across state borders in underserved areas. More effort is needed to improve geographic mobility and pathways for career advancement for allied professionals. Although some progress has been made, state practice acts need to continue changing in ways that allow a greater variety of health care providers to serve patients in need.

The delivery of dental care by dentists in private dental practices is declining as patients increasingly receive care through integrated and public group practices and in nontraditional dental settings that treat individuals where they live, work, and learn. This type of treatment is especially appropriate for those who face barriers to access, including older adults, young children, people with serious illnesses, those who cannot leave work to get to a dental office, and people with special health care needs. A major development since 2000 has been the growth of dental services within federally qualified health centers, which cared for 4.8 million patients in 2014. These integrated health practices treat underserved populations using a fee schedule that calculates the cost of care on the basis of federal poverty limits and the patient's ability to pay. Growth also has occurred in moving toward group practice, with 18% of dentists younger than 35 reporting affiliation with a dental service organization.

A number of public health crises at the local, state, regional, and national levels have disrupted dental practices over the past 20 years. Crises such as the novel coronavirus pandemic cause disruption by temporarily or permanently closing dental practices and create challenges relating to infection control procedures that call for new and different protocols, new technologies, and safeguards for mitigating the spread of disease through aerosol generation. Various other public health crises have resulted in the implementation of new curricula within specific dental schools. A public health crisis summons a largely volunteer dental professional workforce who are called from their existing capacity in private and federal dental positions to temporarily serve needy patients in locations where dental services have been disrupted. The frequency of these disruptions and a reliance on volunteers to serve persons in need generate uncertainty that all people affected by such crises will have their oral health care needs met. The repeated nature of public health crises calls for a more focused, integrated approach to training current and future dental professionals about disaster management and to strengthening the electronic systems that safeguard the insurance data leading to covered care for persons in need and to financial reimbursement for dental practices.

Insurance coverage is critical to financing and expanding care delivery. Persons with insurance were 1.5 times as likely to access the dental system within a given year and to receive both preventive and restorative care (Meyerhoefer et al. 2014) than were persons without insurance. Such coverage improves the patient's health overall while providing support for dental practitioners. Twenty years ago, 45% of adults had no dental insurance; now only 23% go without this insurance.

In 2018, nearly $136 billion was spent on dental care. Of this amount, 46% came from private dental insurance, 40% was paid out of pocket by the individual, 10% was supported by the government through Medicaid and Medicare, and 3% was paid by other sources (e.g., military) (Figure 3). Thus, although the proportion of adults and children covered by dental insurance has grown and a larger proportion is now covered by public insurance programs that include at least emergency or limited dental benefits, the total expense supported by public programs continues to represent only 10% of the total cost of dental care. Further, dental expenses make up more than a quarter of all out-of-pocket health care spending, exceeding even prescription drug costs. The high percentage of out-of-pocket dental spending continues to make dental care an expensive health benefit for many people.

Whereas increased dental insurance and interprofessional care have helped children gain access to oral health care (Nasseh and Vujicic 2016b), adults still face many barriers to obtaining such care. A chief obstacle is the difficulty of obtaining and using dental insurance. For low-income adults who receive Medicaid, Medicare, or both, limited coverage and low dentist participation in Medicaid make it difficult in some areas to find providers, which in turn makes access to dental care difficult. Further, even when policies are affordable, they often limit dental benefits and require large out-of-pocket payments. Equally problematic is that dental coverage is not as widespread as medical insurance because it is treated as an add-on to health insurance, rather than an essential part of it. Finally, with or without dental insurance, some individuals simply cannot afford the large out-of-pocket costs associated with dental care, resulting in deferral of care among many working-age adults.

The result is that many adults in the United States cannot get dental care, and an expansion of public and private dental insurance alone may not be enough to increase access to dental services. Oral health professionals must be willing to accept all types of dental insurance, and mechanisms must be found to encourage even more provision of oral health care outside of dental offices. Improving adults' access to dental care requires a multipronged approach and coordinated efforts among policymakers, insurers, and dental professionals.

Dentistry has been slow to embrace the medical system's emphasis on safety as integral to quality care and continuous quality improvement to enhance patient outcomes. Some dental programs in hospitals, dental schools, and federally qualified health centers are required to meet certain quality control standards, and clinical practice guidelines have been developed in a few areas. New quality measures have been developed, tested, and launched by insurance groups nationwide. Dental offices and insurers continue to use a reimbursement system that does not include diagnostic codes and does not allow measurement of care effectiveness. In addition, the lack of an integrated patient health record prevents dentists from communicating and sharing important clinical information with other providers treating the same patient.

Finally, the nascent movement toward oral health integration is an important strategy to increase access to care for underserved patients and to provide better, more coordinated care for all patients. Dental-medical health integration can be an effective way to improve patient care delivery and outcomes while reducing costs (Harnagea et al. 2018). Public and private organizations have expanded interprofessional practice models to serve underserved populations. Commercial health systems and insurers have tested new models of integrated care delivery, with the purpose of improving patient outcomes while reducing cost. Although full-scale integration of oral health and medical and behavioral health has not yet occurred, some innovative strategies to address this goal have been launched. An important goal of integration and workforce expansion is to encourage members of the dental team to work at the top of their collective scope of licensing capabilities in order to maximize access to dental care.

Encouraging oral health integration with primary care medicine expands the scope of practice for the existing medical workforce, including pediatricians, nurse practitioners, and physician assistants, to conduct oral health assessments and provide preventive oral health care. Such an approach can reach new patients and expand oral health capacity in areas where there is a shortage of dental professionals. Some medical providers employ dental hygienists to deliver oral health screenings and services in medical offices for high-risk patients in some states under physician supervision. Barriers to practice integration remain, and changes are needed in federal and state licensing laws, along with payment reform, provider education, and information sharing to achieve optimal success.

The oral health care profession has made tremendous progress in the past 20 years in both clinical practice and research. Changes through the years in dentistry and the overall health care system have led to problem-solving innovations, but serious challenges remain. It falls to dental professionals, working with their peers in medicine, academia, insurance, and government, to face these challenges and to advance the accessibility and quality of oral health care in the United States for the next 20 years.

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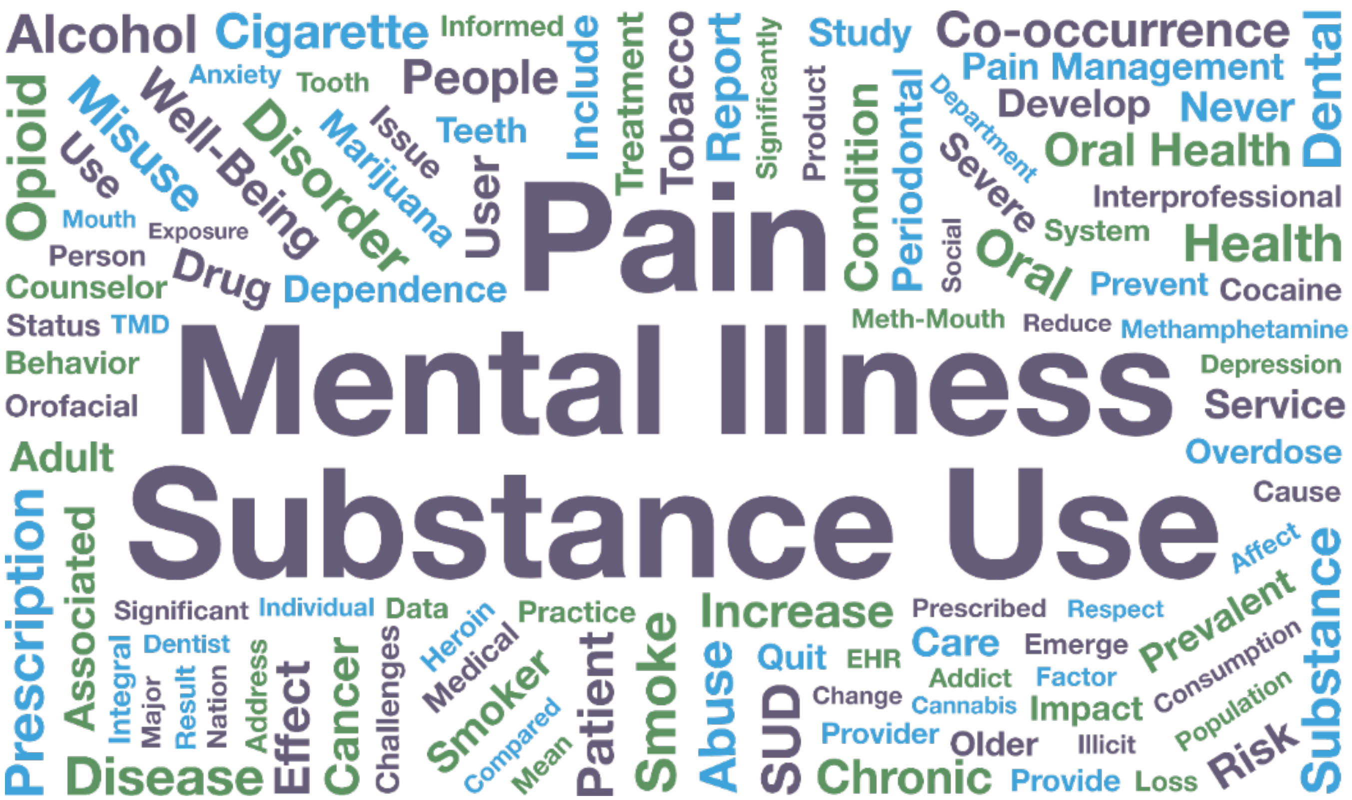
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Oral Health in America: Advances and Challenges
Section 5: Pain, Mental Illness, Substance Use, and Oral Health

Chapter 1: Status of Knowledge, Practice, and Perspectives

The publication of the landmark 2000 Surgeon General's report on oral health provided information that changed perceptions of the importance of oral health and its relationship to general health and well-being (U.S. Department of Health and Human Services 2000). That report described how the mouth and face, while important in their own right, also can provide insights into general health and well-being by revealing signs of disease, drug use, physical abuse, and harmful habits or addictions, as well as general health status. Managing orofacial pain is a common event for oral health providers, and understanding and managing pain is essential for addressing both mental illness and substance use disorders.

Acute and Chronic Orofacial Pain

In both its acute and chronic forms, dental and orofacial pain play important roles in overall health. Pain can signal the presence of mental or physical (including dental) problems, or a combination of these, and it also may be a consequence of correcting or treating those problems. In spite of its important functional role in alerting us to issues of injury and disease, pain also has come to be seen by many individuals as synonymous with dental treatment, often creating an unfortunate cycle of avoidance of care that can lead to still more problems and, in turn, more pain. The management of orofacial pain by dentists remains a challenge.

The complex relationship of physical pain to mental health has been documented, albeit indirectly, in terms of the use of nonmedically prescribed analgesics (Novak et al. 2009). Moreover, it is commonly observed that depression, anxiety, and stress can be experienced as every bit as painful as physical pain, and that misuse of controlled or illegal substances often begins with the need to find relief from any of these conditions (U.S. National Library of Medicine 2021).

Etiology and Prevalence

An estimated 20% of U.S. adults reported the experience of chronic pain, and 8% had high-impact chronic pain in 2016 (Dahlhamer et al. 2016). Chronic pain in general, without focusing on a specific anatomical domain, has been linked to opioid dependency, anxiety, depression, and reduced quality of life. An estimated $560 billion annually in direct medical costs, lost productivity, and disability programs are attributed to it in the United States (Dahlhamer et al. 2018). The prevalence of orofacial pain is not well documented. A review conducted 20 years ago estimated a global median prevalence of orofacial pain to be 13% (Macfarlane et al. 2001). A prospective cohort study conducted in the United States reported an annual incidence of nearly 4% with about half of incident cases resolving after 6 months (Slade et al. 2016).

With the high prevalence of pain in the population, it must be understood as a major societal burden, as well as a significant driver of the opioid crisis. This significance is further compounded by the frequent association of pain with depression and anxiety (Institute of Medicine 2011a; National Academies of Sciences 2017a; 2019a). Concerns regarding the administration of opioids or other analgesics for persistent pain conditions, as well as their admittedly limited effectiveness, have triggered a renewed interest in nonpharmacological approaches to pain management, especially for chronic pain (National Academies of Sciences 2019b).

A key consideration is the need to redefine how pain is understood, the different biological mechanisms of acute and chronic pain, and how these relate to craniofacial conditions that put people at risk for experiencing pain. All these factors influence the prescription patterns of dentists—particularly those of the predominantly surgical disciplines such as oral surgeons, endodontists, and periodontists—as well as other medical practitioners. Eighty percent of the world's supply of prescription opioid analgesics are consumed in the United States, underscoring the need for increased professional understanding and accountability (Institute of Medicine 2011a). In dentistry, one example where this increased awareness has been implemented is with the recently updated predoctoral accreditation standards of the Commission on Dental Accreditation (CODA) regarding the management of oral and craniofacial pain, which also include language requiring "consideration of the impact of prescribing practices and substance use disorder" (Commission on Dental Accreditation 2019).

Oral health professionals treat a variety of problems that cause pain in the mouth, jaw, and face. Causes are linked to dental and non-dental origins. Pain is associated with dental procedures or disease processes involving the dental pulp (Figure 8 – Section 2A), cracked teeth (Figure 7 – Section 3A), and periodontal pathologies (Figure 2 – Section 3A) pathologies. Pain of non-dental origins may stem from musculoskeletal conditions (e.g., temporomandibular joint and muscle disorders [TMD]), neuralgias and neuropathies, persistent idiopathic facial pain, and pain related to mucosal diseases. From infancy to adulthood, craniofacial pain can become a challenge for the affected individual, family, care provider, and society. Standardized and validated, patient-reported pain assessment tools are further developed for adults than for youth or even younger children. Consequently, pain in younger persons may be subject to undertreatment (Eccleston et al. 2021).

Acute pain, including postoperative pain, serves a vital protective function. It lets us know that something is wrong in the body that needs immediate attention: for example, the acute pain of a hot piece of pizza burning the roof of the mouth or the piercing pain of an infected tooth root. When acute pain transitions into chronic or persistent pain, it ceases to serve a protective role and may be associated with the development of depression, anxiety, and other comorbid health conditions.

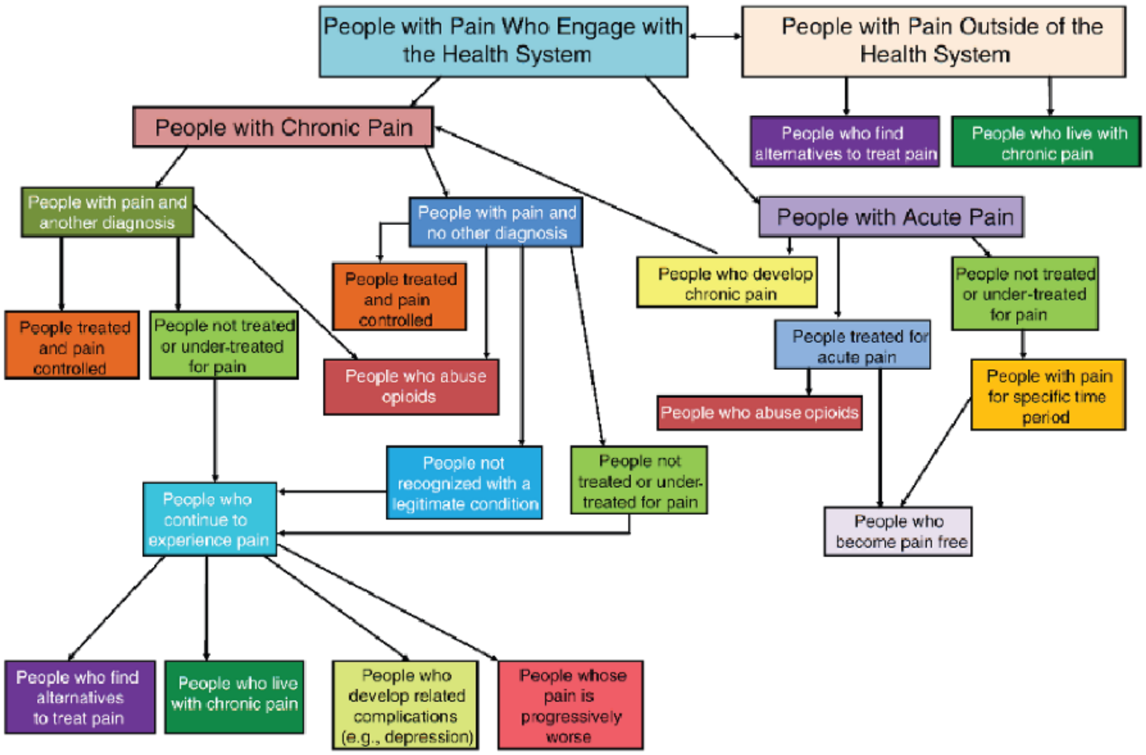
Chronic or persistent pain is complicated and is often referred to as an illness in its own right. It has persistent physical, emotional, and cognitive attributes, even in the absence of clinically apparent pathologic findings. Figure 1 captures the landscape of pain presentations for both acute and chronic pain for persons within or outside the health system, including those who may present for dental care (Institute of Medicine 2011a).

Temporomandibular joint and muscle disorders (TMD) are a group of conditions that cause chronic pain and dysfunction in the jaw joint and muscles that control jaw movement (Figure 6 – Section 3A). Aside from toothache, TMD is the most prevalent cause of orofacial pain. Unlike injuries to the face and jaw that result in pain for a limited period of time, TMD-related pain can persist for months to years. The causes of TMD-related pain are multiple and include both genetic and nongenetic risk factors (National Academies of Sciences 2020a). The craniofacial pain condition that has been most negatively impacted by not observing the distinction between acute and chronic presentations is TMD (National Academies of Sciences 2020a). For additional information about TMD, please see Section 3 of this monograph.

Craniofacial pain may be associated with restrictions in mobility, such as limitation in the range of jaw motion, that can interfere with eating and speaking. Chronic pain, including craniofacial pain, may cause mood changes, depression or anxiety, as well as feelings of poor health or reduced quality of life. Consequently, the potential for exposure to prescription opioids and dependence on opioids increases. Chronic pain can become debilitating to the degree that it affects functions of life, impacts the ability to maintain family relationships and friendships, or limits engagement in pleasurable aspects of life (National Academies of Sciences 2020a). Furthermore, individuals suffering chronic pain are twice as likely as others to report suicidal behaviors (Racine 2018).

Current practice designates high-impact chronic pain as persistent pain that creates limitations in major life domains, such as work, social, recreational, and self-care activities. It differentiates those who can maintain normal life activities despite having chronic pain from those who cannot. This differentiation helps to estimate the population seriously impacted by pain and in need of advanced pain management services.

Figure 1. Pain presentations encountered both within and outside the health care system



Source: Institute of Medicine (2011b). With permission from the National Academies Press.

Based on the 2016 National Health Interview Survey, 50 million U.S. adults (20.4%) have chronic pain, and 19.6 million (8%) live with high-impact chronic pain. Prevalence is higher for chronic pain, as well as for high-impact chronic pain, among women, older adults, currently unemployed people, adults living in poverty, adults with public health insurance, and residents of rural communities (Dahlhamer et al. 2018). Clearly, this is a major public health issue that calls for action.

Current Understanding of CNS Changes in Persistent Orofacial Pain

Research in the past 20 years has significantly enriched our knowledge base about the role the central nervous system (CNS) plays in the development of chronic pain, although additional work is needed to develop more effective approaches to treatment (Volkow and Collins 2017). Neurobiological phenomena such as central sensitization, alterations in pain modulation, and neuroplastic changes appear to be essential drivers in the persistence of pain. Chronic pain can sensitize the CNS to the point where it develops an over-response to pain signals transmitted from peripheral locations of the body and then transmits that information to the brain. This can cause an exaggerated response to the perception of normal stimuli such as touch or temperature, or create a perception of pain after the stimulus is gone, or a perceived spread of pain (Ji et al. 2003; Latremoliere and Woolf 2009).

Central sensitization has been shown by preclinical and clinical studies to be involved in multiple chronic craniofacial pains including migraine, TMD, and such trigeminal neuropathies as trigeminal neuralgia caused by a damaged or irritated trigeminal nerve, which carries sensations from the head, face, and oral cavity to the brain (Furquim et al. 2015; Chichorro et al. 2017). See Figure 1 in Section 3A for the location of the trigeminal nerve and surrounding tissues. TMD patients include those whose pain is primarily related to movement of the temporomandibular joint as well as those whose pain appears to manifest further away from the temporomandibular joint, such as otologic (ear) origin or generalized temporal (headache-like) pain that is more affiliated with CNS mechanisms (Chaves et al. 2013; Slade et al. 2014; Harper et al. 2016; Chichorro et al. 2017; Costa et al. 2017).

A generalized increased sensitivity to pain is a prominent feature in both trigeminal and extra-trigeminal regions in patients, including those affected by chronic migraine and TMD (Chaves et al. 2016; Campi et al. 2017; Garrigos-Pedron et al. 2019). Meta-analyses support the presence of widespread pressure pain sensitivity in patients with fibromyalgia and myofascial pain, including TMD patients. This is indicative of CNS hyperexcitability and suggests patterns of brain stem and spinal cord hyperexcitability specific for mechanically evoked pain (La Touche et al. 2018). For example, sensitization in the central and peripheral nervous systems is responsible for TMD-associated headache, with significant correlations between facial pain intensity and headache intensity (Hara et al. 2016). Peripheral mechanisms may play a role in the onset of chronic pain conditions, including TMD, although clinical data suggest the persistence of pain involves central factors, such as sensitization of neurons in the spinal dorsal horn/trigeminal nucleus of the brain (List and Jensen 2017).

Current Understanding of the Genetics and Epigenetics of Orofacial Pain

Our current knowledge also has increased during the past 20 years in regard to the genetic and epigenetic underpinning of conditions in the craniofacial domain. A Dutch twin study attributed 44% of variation in the occurrence of TMD to genetic inheritance (Visscher et al. 2012), and a female twin study from the University of Washington Twin Registry identified genetic effects contributing about 25–30% to the variance in TMD pain (Plesh et al. 2012).

High comorbidity among pain conditions suggests common underlying mechanisms, including genetic factors (Diatchenko et al. 2006a; Diatchenko et al. 2006b; Diatchenko et al. 2013). An estimated 85% of TMD patients report other chronic pain conditions. It has been estimated that nearly all the risk of developing musculoskeletal pain at different body sites can be explained by a common factor that has a heritability of 46% (Williams et al. 2010). The University of Washington Twin Registry has determined that 12% of the genetic component of TMD pain is shared with migraine headache. TMD has multiple biopsychosocial risk factors that may share common etiological mechanisms with other chronic pain conditions, with genetic variations accounting for a large proportion of the risk (Diatchenko et al. 2006a; Diatchenko et al. 2006b; Kato et al. 2009; Chen et al. 2012; Diatchenko et al. 2013; Smith et al. 2013; Maixner et al. 2016).

A useful tool to summarize available genetic information related to TMD is the Human Pain Genetics Database (HPGDB) (Meloto et al. 2019), a comprehensive variant-focused inventory of genetic contributors to human pain. Analysis of the most recent update in PubMed of all genetic information for all pain-related phenotypes demonstrates that reports on the genetics of TMD are the second most common, next to migraine. Moreover, they are the third most common considering all pain-related phenotypes, after migraine and analgesia. These data demonstrate the prominent role of the orofacial region in the pain genetics field.

Analysis of the HPGDB at the level of single nucleotide polymorphisms (SNPs), which are the most common type of genetic variation among people, identifies 94 SNPs reporting an association with TMD. The variants for which a significant association with a TMD-related phenotype have been most reported are within the catechol-O-methyltransferase (COMT) gene that controls levels of catecholamines. Nine independent reports implicate COMT in experimental jaw muscle pain and TMD (Zubieta et al. 2003; Diatchenko et al. 2005; Smith et al. 2011; Schwahn et al. 2012; Michelotti et al. 2014; Smith et al. 2014; Meloto et al. 2015; Slade et al. 2015; Mladenovic et al. 2016).

Other candidate gene association studies implicate the serotonergic system, including the serotonin 2A receptor (Herken et al. 2001; Mutlu et al. 2004; Ojima et al. 2007; Smith et al. 2011; Slade et al. 2013), and the serotonin 2C receptor (Slade et al. 2013). The high proportion of women with chronic TMD has prompted investigation of variants of the estrogen receptor gene *ESR1*; however, results are inconclusive in terms of attributing variants to TMD cases (Kang et al. 2007; Ribeiro-Dasilva et al. 2009; Smith et al. 2014; Nicot et al. 2016; Quinelato et al. 2018).

Understanding the Social Modulation of Craniofacial Pain

Pain and stress share significant CNS regulatory overlaps. Both phenomena challenge the body's self-regulating mechanisms and call for action to adapt to a disturbed environment. Both pain and stress are modulated to varying degrees by the same social factors, including socioeconomic position (Abdallah and Geha 2017). In this respect, besides the gene variants discussed above, the psychosocial context within which stress and pain are experienced may further contribute to variations in clinical presentation.

The currently accepted biopsychosocial model proposes that a full understanding of health or disease requires the explication of biological, psychological, and social contributors, known as social determinants of health (SDoH) (Gatchel et al. 2007). There are growing data on the biological underpinnings of pain and stress and their psychological modifiers but little that specifically relates to orofacial pain. Regarding SDoH, the past 2 decades have further solidified that medical care is not the only influence on health, and its impact may be more limited than commonly assumed, particularly in determining who becomes sick or injured (Braveman and Gottlieb 2014).

The social context within which patients deal with pain—craniofacial pain included—has significant bearing on their experience of and vulnerability to that pain. Although taking a social history has not been an integral part of the standard assessment in dental practice, understanding of the social environment within which patients deal with chronic pain can be especially useful in case management, particularly for decisions leading to the prescription of opioids.

Orofacial Pain Management

The distinction between acute and chronic pain, with regard to management, extends to craniofacial pain. Acute pain refers to pain of recent onset. Therapeutic regimens for pain generally consider safety as well as efficacy, but the longer treatment times for chronic conditions accentuate the critical need for safety. Interventions administered over a longer period can produce significant harm that may be greater than living with the disease in the absence of such care. Chronic conditions often do not respond to treatments that are highly efficacious in acute situations. In general, management strategies for chronic orofacial pain remain unclear. However, irreversible treatments or those that may cause adverse effects, including dependencies, should be avoided. Opioids should be avoided as first-line therapy and, if used, should be combined with nonpharmacologic therapy and nonopioid pharmacologic therapy, as appropriate.

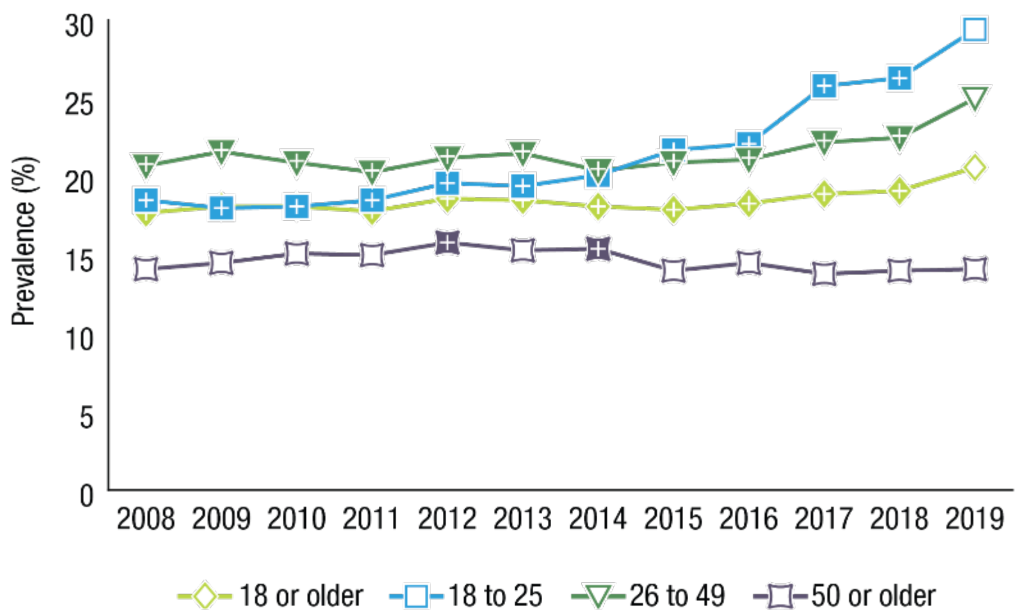
Although state boards mandate the education of licensed dentists regarding opioids, the role and responsibilities of the dental workforce should reflect current science in the broad subject of pain. Given that persistent craniofacial pain often is associated with health issues in other parts of the body, the current scope of practice and the fragmentation of care are not working in favor of patients.

Mental Illness

Etiology and Prevalence

The American Psychiatric Association defines mental illnesses as "conditions that involve a variety of characteristics that include changes in emotion, thinking, behavior, or a combination of these (American Psychiatric Association 2018). The most common mental illnesses are anxiety disorders; mood disorders, including depression and bipolar disorder; dementia; and schizophrenia. According to the Substance Abuse and Mental Health Services Administration (SAMHSA) (2020a), 51.5 million adults aged 18 years and older had any type of mental illness (AMI) in the past year (2019), representing about 1 in 4 of all U.S. adults. Mental illness varies by age, ranging from 29.4% among those aged 18 to 25 years to 14.1% among those aged 50 years and older (Figure 2). With respect to severe mental illness (SMI), 1 in 25 Americans (13 million persons) lived with a serious mental health issue such as schizophrenia, bipolar disorder, debilitating anxiety, or major depression in 2019 (Substance Abuse and Mental Health Services Administration 2020a). The prevalence of SMI among adults aged 18 years and older is higher among women (6.5%) than men (3.9%). The highest prevalence of SMI was found in those aged 18 to 25 years (8.6%), followed by adults 26 to 49 (6.8%,) and those aged 50 and older (2.9%).

Figure 2. Change in any mental illness (AMI) in the past year among adults ages 18 and older: United States, 2008–2019



Notes: +Difference between this estimate and the 2019 estimate is statistically significant at the .05 level. Any mental illness (AMI) is defined as having a diagnosable mental, behavioral, or emotional disorder, other than a developmental or substance use disorder. AMI includes persons who have mild mental illness, moderate mental illness, and serious mental illness.

Source: Substance Abuse and Mental Health Services Administration (2020a).

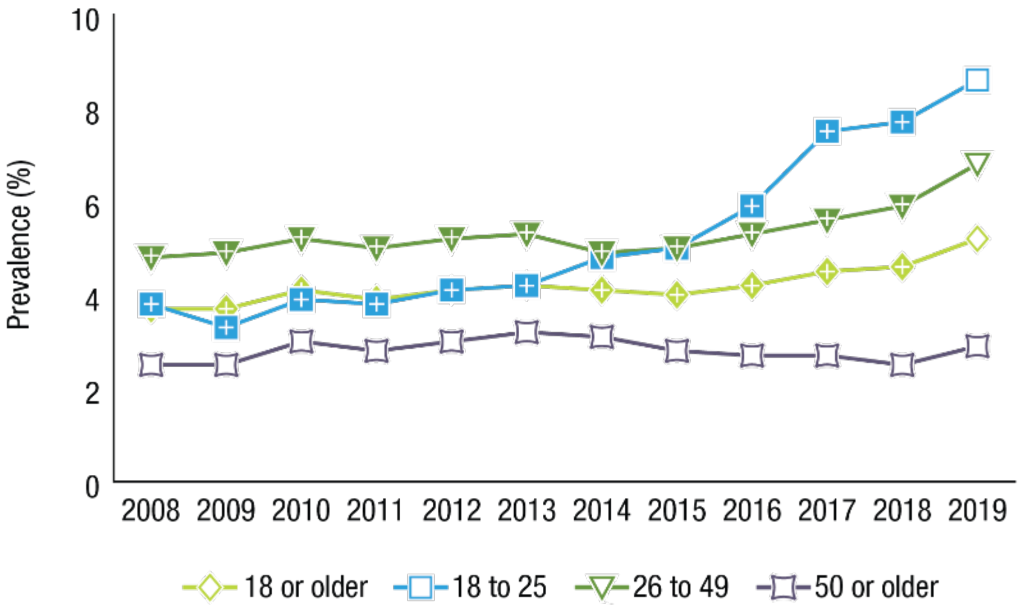
These data come from the 2019 National Survey on Drug Use and Health conducted by SAMHSA (Substance Abuse and Mental Health Services Administration 2019a) using criteria from the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association 1994).

Globally, in low-income and middle-income countries, 76–85% of those with severe mental illness receive no treatment for their disorders. The corresponding range for high-income countries is lower, at 35–50% (Bhardwaj and Bhadwarj 2015). In the United States, people with untreated mental health disorders in economically disadvantaged populations often find their conditions exacerbated by poverty-related health patterns such as multimorbidity, substance abuse, and poor nutritional status (Vick et al. 2012).

Figure 2 shows that the prevalence of AMI was relatively stable up to 2015, followed by an increase in prevalence for adults aged 18 to 49 years. Prevalence remained unchanged for adults aged 50 years and older. A similar trend exists for adults experiencing SMI (Figure 3). Any increase in mental illness in the U.S. population is worrisome because of the potential of co-occurrence between AMI and substance use disorder (SUD). In 2019, 9.5 million Americans aged 18 years and older reported having AMI and SUD concurrently (Figure 4), and since 2016, an increase in AMI and SUD co-occurrence has been observed for adults aged 18 to 25 years (Figure 5) (Substance Abuse and Mental Health Services Administration 2020a).

Adolescents who have had a major depressive episode (MDE) are more likely to use alcohol, to smoke, and to have made a suicide attempt (Boyd et al. 2018). In the United States, 3.8 million youths had an MDE in the past year, nearly 400,000 of those with a co-occurrence with SUD in 2019 (Figure 6). Youths reporting an MDE in the past year used cigarettes, alcohol, marijuana, and opioids at higher levels than those youths not reporting an MDE (Figure 7).

Figure 3. Change in serious mental illness (SMI) in the past year among adults ages 18 and older: United States, 2008–2019



Note: +Difference between this estimate and the 2019 estimate is statistically significant at the .05 level.
Source: Substance Abuse and Mental Health Services Administration (2020a).

AMI and SUD co-occurrence is an important issue for adolescent health and oral health because many of the substances used have known deleterious effects on oral health. Despite the prevalence of mental health issues in the population at large, these comorbid conditions receive little consideration in clinical decision-making in the context of dental care for either adolescents or adults.

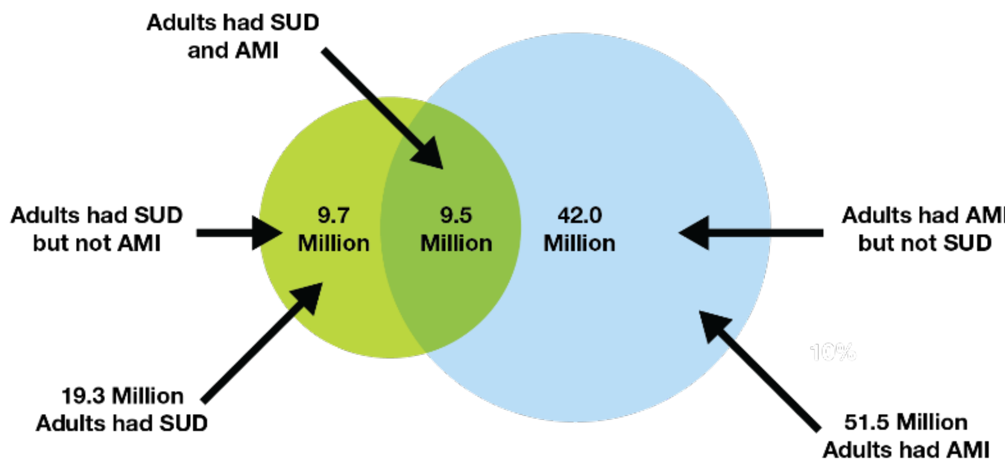
Influence of Mental Illness on Oral Health

The increasing prevalence of mental health issues among those aged 18 to 25 years has implications for the prescription practices of the dental workforce. Not only do many medications prescribed for these disorders compromise oral health, such as medications that cause dry mouth or jaw clenching, but people coping with mental health issues may have a limited capacity to perform more than the basic oral hygiene procedures to maintain good oral health. Further complicating the impact of mental health on oral health is the potential for self-medicating with alcohol, opioids, or stimulants, all of which can affect oral health. It is well established that people with mental illnesses often have comorbidities such as diabetes, cardiovascular disease, chronic lung disease, or cancer (Kisely et al. 2013). It has been suggested that health care professionals provide insufficient attention to the oral health of individuals with mental illness even though oral health plays an important role in overall health and well-being (Kisely et al. 2018).

Mental illnesses relevant to oral health include schizophrenia and other forms of psychoses, anxiety disorders (including dental phobia), eating disorders, mood disorders (e.g., depression and bipolar affective disorder), and post-traumatic stress and personality disorders (Clark 2016). Substance use disorders, including alcohol, benzodiazepines, psychostimulants, and cannabis, are also relevant to oral health. Some substances, notably methamphetamine, directly impact oral health. People with co-occurring SUD and mental illness face further challenges in accessing specialty care for their conditions (National Institute on Drug Abuse 2021a). Moreover, those with co-occurring disorders, often referred to as dual diagnoses, may be disconnected from health and social services.

Of the 19.3 million Americans with substance use disorders, about half also have a distinct mental illness (Figure 4). Individuals diagnosed with co-occurring SUD and AMI are much more common than generally assumed.

Figure 4. Co-occurring mental illness and substance use disorder (SUD) in the past year among adults ages 18 and older: United States, 2019



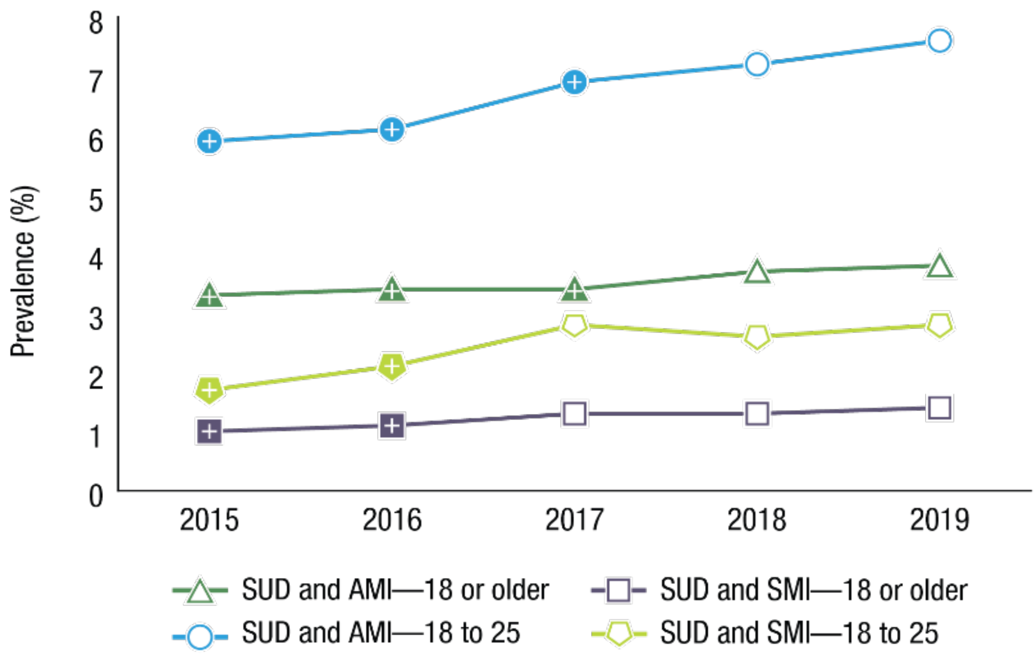
Notes: Any mental illness (AMI) and substance use disorder (SUD) previously defined; 61.2 million adults had either SUD or AMI.
Source: Substance Abuse and Mental Health Services Administration (2020).

For example, 41% of persons with schizophrenia, a severe mental illness, also have unhealthy substance use behaviors (Hunt et al. 2018), and one-third of persons with bipolar mood disorders are diagnosed with SUD (Hunt et al. 2016). According to the National Bureau of Economic Research, individuals who have been diagnosed with a lifetime mental health disorder account for 68% of cigarette use, 69% of alcohol use, and 84% of cocaine use (Saffer and Dave 2005).

There is extensive evidence of a strong association between psychiatric disorders and poor oral health, although the pattern and severity of dental disease varies. For instance, people with SMI, such as schizophrenia, other psychoses, and bipolar affective disorder, have particularly high rates of periodontal disease and decay (Kisely et al. 2011; Wey et al. 2016). These individuals are three times more likely than those in the general population to have lost all their teeth. Rates of both tooth decay and tooth loss are less severe among persons with AMI. However, given the high prevalence of common mental disorders, the resultant societal oral health burden has to be recognized as significant (Kisely et al. 2016). People with psychiatric disorders also have higher rates of tooth loss and tooth wear or erosion. The excessive wear can be due to mechanical forces, such as bruxism (teeth grinding), or loss of tooth structure resulting from the chemical activity of acidic drinks, gastric reflux, or frequent vomiting (Kisely et al. 2015). This is particularly relevant for people with certain eating disorders who, despite having typically good oral hygiene, drink large amounts of soft drinks and purge in an effort to lose weight. As a result, persons with eating disorders have five times the risk of dental erosion in the presence of self-induced vomiting (Kisely et al. 2015). Similarly, both periodontal disease and caries are linked to the use of a wide range of psychoactive substances, including alcohol, amphetamine, cocaine, inhalants, marijuana, opioids, and opiates (Baghaie et al. 2017).

Findings for post-traumatic stress disorder (PTSD) and its impact on oral health are more equivocal. In one study of veterans with PTSD, there was no statistically significant difference between veterans and civilian controls of a similar age in the index of decayed, missing, and filled teeth (DMFT) scores; the PTSD group had significantly more decayed and missing teeth, but significantly fewer restorations (Muhvic-Urek et al. 2007). Another study reported that refugees with PTSD had more dental anxiety than refugees who did not report such symptoms (Hoyvik et al. 2019).

Figure 5. Change in co-occurrence of any mental illness (AMI) or serious mental illness (SMI) with substance use disorder (SUD) in the past year among adults ages 18 and older: United States, 2015–2019



Notes: Any mental illness (AMI), serious mental illness (SMI), and substance use disorder (SUD) previously defined. +Difference between this estimate and the 2019 estimate is statistically significant at the .05 level.
Source: Substance Abuse and Mental Health Services Administration (2020a).

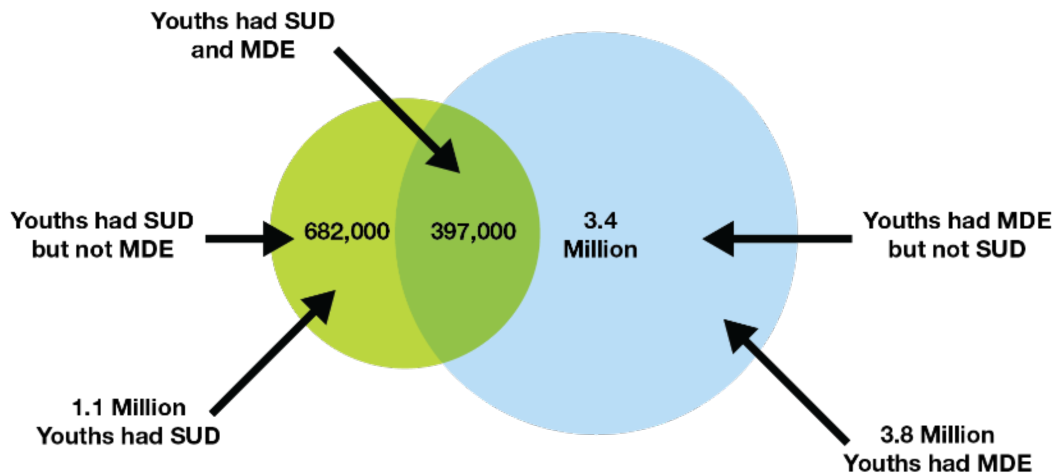
An outpatient sample of persons with mixed psychiatric disorders that included PTSD had more untreated decay and xerostomia (dry mouth) than those who were psychiatrically less severely ill (Cooper-Kazaz et al. 2015).

There is less information on oral health in people with personality disorders compared to the general population. In those diagnosed with a personality disorder, individuals with the Cluster A ("odd, eccentric") and Cluster B ("dramatic, emotional, erratic") types had worse oral hygiene (higher plaque scores); those categorized as Cluster B also had more deep periodontal pockets (Bertoldi et al. 2018). In contrast, oral health was better in individuals with the Cluster C type ("anxious, fearful"). There also is evidence that extroversion and anxious personality traits are associated with bruxism in both adults and children (Montero and Gomez-Polo 2017).

Psychotropic medications may contribute to oral health issues, largely through the common side effect of xerostomia. These include antipsychotics, antidepressants, and mood stabilizers, with the most pronounced effects associated with tricyclic or first-generation agents (Cockburn et al. 2017). This effect may be further exacerbated by the xerostomic effects of the common comorbidities of tobacco and psychostimulant use. Eating disorders are linked to greater susceptibility to tooth erosion and decay, and medications such as mood stabilizers, antidepressants, and antipsychotics can cause xerostomia. Inadequate or poor oral health behaviors also can affect mental health and may manifest in appearance, social acceptance, self-esteem, and self-image.

The evidence shows that mental and oral health are closely associated. For example, people with mental illness or who are being treated for mental illness are 80% more likely to have an acute dental need (Nguyen et al. 2018). Those with severe mental illness are at greatest risk of periodontal disease, caries, and tooth loss, and dental erosion is more common in those with bulimia.

Figure 6. Co-occurring substance use disorder (SUD) and major depressive episode (MDE) in the past year among youths ages 12–17: United States, 2019



Notes: Major depressive episode (MDE) is characterized by depressed mood and long-term loss of pleasure or interest in life, often with other symptoms such as disturbed sleep, feelings of guilt or inadequacy, and suicidal thoughts. 4.5 million youths had either SUD or MDE. Youth respondents with unknown MDE data were excluded.

Source: Substance Abuse and Mental Health Services Administration (2020a).

The increased risk of dental disease in people with AMI is less than in those with SMI, but still contributes overall to a greater likelihood of poorer oral health. The call by SAMHSA and the Health Resources and Services Administration (HRSA) for the integration of primary care (including oral health care) with behavioral health services reflects a long-recognized concern that providers are not connecting their patients to the full range of services necessary to ensure health and well-being (Substance Abuse and Mental Health Services Administration 2021a). Integrated care through the use of electronic health records and centralization of services could ensure that patients pass seamlessly between specialty and primary care.

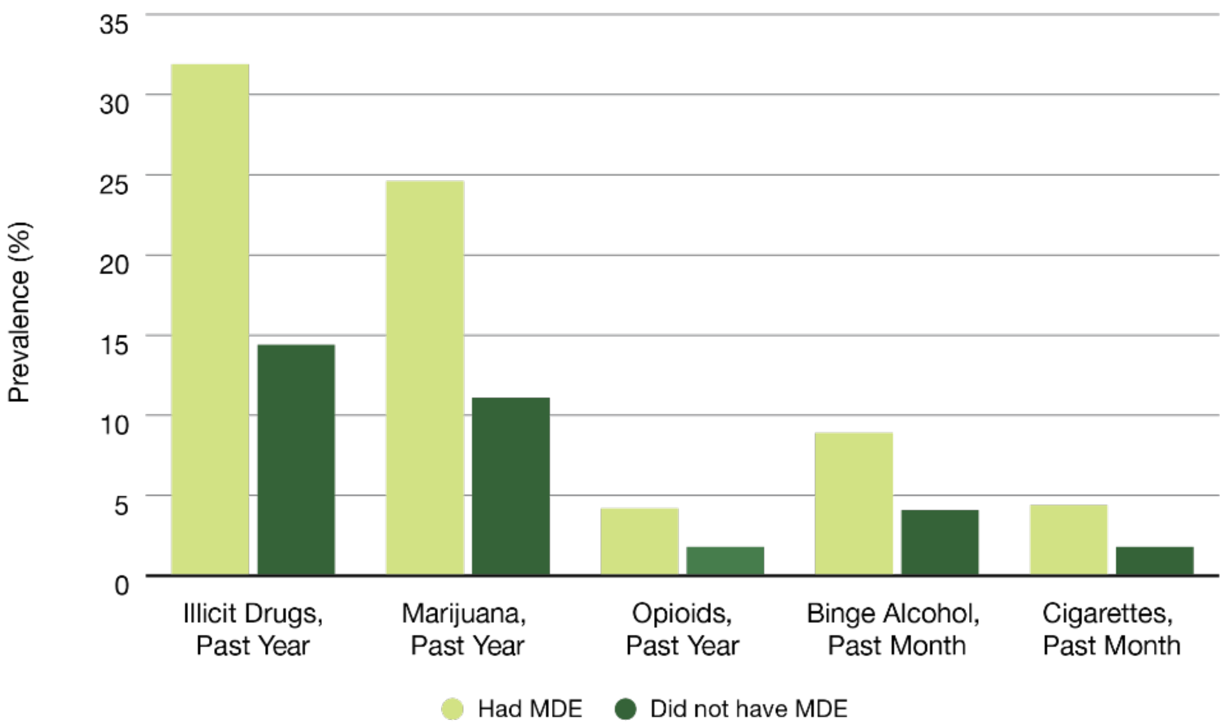
Substance Use Disorders

Etiology and Prevalence

Substances may be legal (licit), illegal (illicit), or controlled for a specific medical use (U.S. Department of Health and Human Services 2016). In 2019, more than 20 million people aged 12 and older (7.4%) reported having a substance use disorder in the past year; 8.3 million reported illicit drug use disorder and 14.5 million reported an alcohol use disorder (Figure 8). About 2.4 million reported both an alcohol use disorder and an illicit drug use disorder (Substance Abuse and Mental Health Services Administration 2020a).

The health effects of the consumption of multiple licit and illicit substances are poorly understood. The harms from substance use extend beyond the primary user for certain exposures. For example, involuntary exposure to secondhand smoke is known to cause lung cancer (U.S. Department of Health and Human Services 2020b). Tobacco, one of the most commonly used substances known to endanger health, kills more than 8 million people a year worldwide, from either direct use or involuntary exposure to secondhand smoke (World Health Organization 2021). Alcohol use results in 3.3 million deaths each year (World Health Organization 2018). Both alcohol and tobacco have direct consequences for oral health that complicate other health problems and their treatment. Substance use disorders continue to increase, remaining a major public health problem, resulting in millions of deaths globally every year. However, the most pressing substance use disorders continue to be associated with the ongoing opioid epidemic.

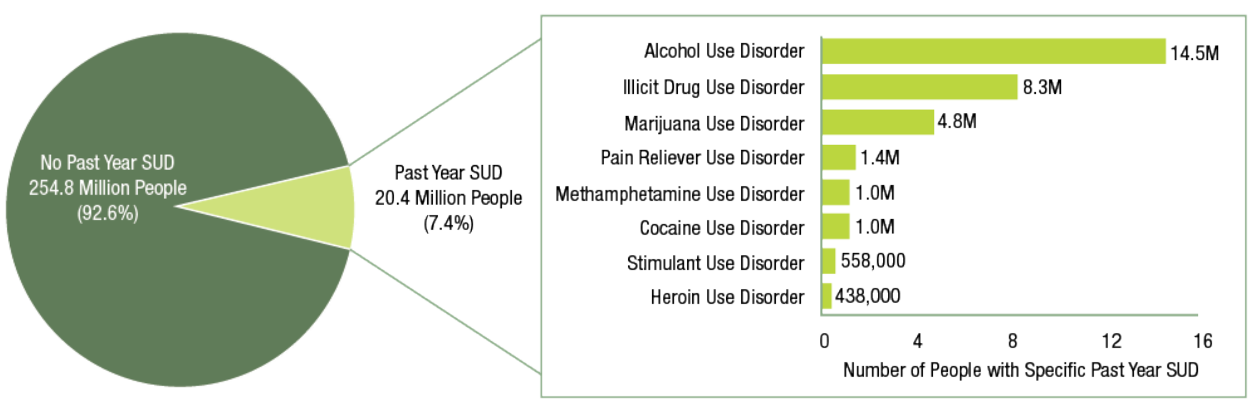
Figure 7. Percentage of substance use among youths ages 12–17 reporting a past year major depressive episode (MDE): United States, 2019



Notes: Major depressive episode (MDE) previously defined. Difference between this estimate and the estimate for youths without MDE is statistically significant at the .05 level. Youth respondents with unknown MDE data were excluded.

Source: Substance Abuse and Mental Health Services Administration (2020a).

Figure 8. Number of people age 12 and older reporting a substance use disorder (SUD) in the past year; United States, 2019



Note: The estimated number of people with substance use disorders is not mutually exclusive because people could have disorders for more than one substance.

Source: Substance Abuse and Mental Health Services Administration (2020a).

Currently, annual drug-related deaths exceed the number of casualties linked to either automobile or handgun deaths (American Society of Addiction Medicine 2016). In 2015, according to the Centers for Disease Control and Prevention (CDC), more than 33,000 people died from an opioid overdose (Centers for Disease Control and Prevention 2017). Four years later, in 2019, the death toll from opioid overdose had risen even higher, to 49,860, representing over 70% of all drug overdose deaths (Mattson et al. 2021). Illicit drugs are substances for which extra-medical use has been prohibited. They include, but are not limited to, prescription opioids, such as oxycodone and fentanyl; illegal opioids, such as heroine; amphetamines; and cocaine. Although cannabis remains illegal at the federal level, as of this writing there are 35 states, the District of Columbia, and four territories that have legalized cannabis for medicinal purposes, and 15 states have legalized recreational use for adults aged 21 years and older through either a legislative process or ballot measure (DISA Global Solutions 2020). Descriptions of the current use of licit (e.g., alcohol) and illicit drugs, including the misuse of prescription drugs, are presented in Box 1.

Regarding substance use disorders in general, it is important to note changes in the diagnostic algorithm between *DSM-IV* and *DSM-5* (American Psychiatric Association 1994; 2013). Some case definitions and case assignments changed between these two editions, and epidemiological data need to be understood accordingly, including those that report on matters referring to comorbid oral health issues. In *DSM-5*, each specific substance is addressed as a separate use disorder (e.g., alcohol use disorder, stimulant use disorder), but nearly all substance use disorders are diagnosed based on the same overarching criteria.

The Influence of Substance Use on Oral Health

Several observational studies have linked negative oral health outcomes such as dental caries, enamel erosion, chronic periodontitis, and tooth loss to the use of alcohol, amphetamines, opioids, marijuana, and cocaine (Araujo et al. 2004; Brand et al. 2008; Versteeg et al. 2008; Hamamoto and Rhodus 2009; Khocht et al. 2009; Martin et al. 2010).

Box 1. Classification of licit and illicit substances

Classification of drugs:

- **Alcohol** — including all forms of beer, wine, and distilled liquors.
- **Caffeine**
- **Cannabis/Cannabinoids** — including marijuana, hashish, hash oil, and edible cannabinoids.
- **Opioids** — including heroin, morphine, methadone, buprenorphine, oxycodone and fentanyl.
- **Depressants** — including benzodiazepines and barbiturates.
- **Stimulants** — including cocaine, amphetamine, methamphetamine, methylphenidate, and atomoxetine.
- **Hallucinogens** — LSD, mescaline, and MDMA.
- **Inhalants**
- **Sedatives, hypnotics, and anxiolytics**
- **Tobacco products** — cigarettes, hand-rolled cigarettes ("roll-your-own"), cigars, pipes, water pipes, cigars, smokeless tobacco products (chewing tobacco, snuff, dip, dissolvable tobacco products), and electronic cigarettes.
- **Other (or unknown) substances**
  Note: In 2016, FDA's deeming regulation brought e-cigarettes under FDA's tobacco regulatory authorities, and U.S. federal reports from the U.S. have consistently classified e-cigarettes as tobacco products.

Source: American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)* (2013).

Use of illicit psychoactive substances adversely affects oral health through two pathways: directly, through pharmacological effects of the drug on oral physiology and, indirectly, by effects associated with the poor nutrition and oral hygiene of people who use illicit substances. The end result of both pathways is increased dental caries, tooth loss, and periodontal disease. Adverse effects on oral health from psychoactive treatments for SUD, such as methadone and buprenorphine used to treat opioid use disorder, may also occur (Nathwani and Gallagher 2008; Suzuki and Park 2012; Suzuki et al. 2013; Raymond and Maloney 2015).

The two major physiological consequences of illicit psychoactive drugs that adversely affect oral health are xerostomia (dry mouth) and bruxism (teeth grinding). Several types of illicit psychoactive substances, including opioids, stimulants, and cannabis, reduce salivary flow, resulting in xerostomia and a decrease in the protective effects of saliva in relation to dental disease (Shekarchizadeh et al. 2013). Stimulants also are associated with bruxism, which may result in tenderness and soreness of the masticatory muscles, as well as tooth wear (Riemer and Holmes 2014).

Loss of control over substance-seeking and substance-taking behavior to the detriment of other goals and behaviors is a characteristic of SUDs (Hasin et al. 2013). The relationship between SUDs and other lifestyle risk factors could be bidirectional—that is, the substance may serve both cause and effect. For example, an unhealthy lifestyle could be a consequence of SUDs through the loss of financial, emotional, and psychosocial support systems. Conversely, the loss of these support systems could contribute to SUDs as a coping mechanism.

Oral health consequences of these behavioral issues have been suggested, including poor oral hygiene, neglect of oral health, poor nutrition (such as high sugar intake), and failure to access dental services (Saini et al. 2013; Shekarchizadeh et al. 2013). A survey of 563 adults with SUD (primarily mixed opioids, stimulants, and cannabis, with 78% heavy alcohol use) who enrolled in a study of addiction and health found that 52% had last seen a dentist more than 1 year earlier. This same study showed that 29% had lost at least six teeth to tooth decay and/or gum disease, and 37% had experienced at least some tooth and/or gum pain over the prior 3 months (D'Amore et al. 2011). A systematic search of the literature published between January 1981 and October 2016 identified 28 studies (all cross-sectional or cohort) of oral health in patients with SUDs and concluded that, "Patients with substance use disorders have greater and more severe dental caries and periodontal disease than the general population, but are less likely to have received dental care" (Baghaie et al. 2017, p. 765).

It has frequently been observed that individuals using illicit substances often neglect their oral health, presumably because of loss of interest and motivation or because they cannot afford it (Baghaie et al. 2017). Moreover, some substances have analgesic properties, which can mask the pain of dental diseases, thereby exacerbating the problem. The use of multiple substances may accelerate the initiation or progression of dental diseases through additive or multiplicative mechanisms, resulting in advanced disease even if care is eventually sought. For example, individuals who use both cocaine and tobacco may experience dental caries through mechanisms that include erosion of the dental hard tissue due to cocaine use, as well as adsorption of tobacco smoke on tooth surfaces, thus encouraging plaque accumulation. At this time, the evidence is suggestive but not sufficient to infer a causal relationship between active cigarette smoking and dental caries (U.S. Department of Health and Human Services 2014). In addition, pain from oral health conditions, such as tooth decay, may promote inappropriate self-medication with illicit opioid analgesics (Shekarchizadeh et al. 2013), especially given that many individuals with SUDs have little or no access to oral health care. Integration of oral health care into the overall treatment program of individuals with SUDs could minimize this problem.

Misuse of Licit Substances

Alcohol (Ethanol)

Overview

Alcohol, a psychoactive substance with dependence-producing properties, can be a contributing factor in more than 200 diseases; of these, there are 25 noncommunicable diseases directly attributed to alcohol (Shield et al. 2013). Its consumption negatively affects oral health, usually through its effects on overall health (Grocock 2018). The World Health Organization (2018) estimates that close to 3 million deaths can be attributed every year to the consumption of alcohol, which in terms of all types of deaths amounts to 5.3% worldwide. Besides negative health effects associated with excessive consumption, its social and economic burden in societies is substantial. Alcohol also can cause health issues related to intoxication behaviors and withdrawal.

In 2017, the proportion of all U.S. adults who engaged in binge drinking (defined as five or more drinks for males or four or more drinks for females on the same occasion for 1 or more days in the past month) was 26.6%. Prevalence of binge drinking was significantly higher for males than females (31.8% vs. 21.8%). By age, prevalence was highest among persons aged 18 to 25 years (38.1%) and lowest among those aged 65 years and older (10.6%).

Heavy drinking (binge drinking on 5 or more days within the past month) was reported by 6.8% of all U.S. adults. Prevalence of heavy drinking was significantly higher among males than females (9.3% vs. 4.4%). Prevalence was lower for older persons, ranging from 10.3% among those aged 18 to 25 years, to 2.5% among those aged 65 years and older (Substance Abuse and Mental Health Services Administration 2019a).

Alcohol changes the oral microbiome—the community of helpful and harmful microbes in the mouth (Fan et al. 2018). Excessive alcohol consumption increases the risk of serious health conditions, such as heart disease, hypertension, and brain and liver damage. Heavy drinking also is associated with alterations in the sense of smell, sino-nasal problems, craniofacial trauma, xerostomia, and dental extractions (Hoffman et al. 2016). Alcohol intake is a significant risk factor for cancers of the oral cavity (lips excluded), pharynx (throat), and larynx (voice box). For people who both smoke and drink, the danger of mouth and throat cancer increases dramatically (National Institute on Alcohol Abuse and Alcoholism 2007).

Alcohol and Periodontal Disease

Excessive alcohol consumption is linked to increased risk for periodontitis (Wang et al. 2016). Analyses of a national sample of U.S. adults within the 2009–2014 National Health and Nutrition Examination Survey (NHANES) revealed that chronic excessive alcohol consumption was an important risk factor for periodontal disease. According to the data, episodic heavy drinkers had a burden of periodontal disease that was comparable in several instances to those who drank only occasionally or in moderation, whereas chronic heavy drinkers had significantly worse periodontal disease. For example, the prevalence of severe periodontal disease was 6–7% among occasional and moderate drinkers, but 8% and 16% among episodic heavy and chronic heavy drinkers, respectively. Cigarette smoking also was an effect modifier of the relationship between excessive alcohol consumption and periodontal disease. Additional analyses of NHANES data, analyzed for this report, further showed that peoples who smoked and drank (regardless of duration or intensity of alcohol consumption) had worse periodontal outcomes than those who only drank.

These findings could suggest the involvement of both behavioral and biological mechanisms in the relationship between alcohol consumption and periodontitis. Chronic heavy drinking may well be a behavioral marker for poor health-related behavior, and poor oral health in general, because people with alcohol use disorder reportedly have shown poor oral hygiene when compared to controls. This observation is in line with previous reports (Araujo et al. 2004) confirming that alcohol use disorder represents an independent risk factor for neglected oral hygiene (Sakki et al. 1995). Persons with alcohol use disorder may ignore their health problems and seek care only at advanced stages of disease with severe symptoms (Santolaria-Fernandez et al. 1995). Similarly, oral hygiene may be neglected and only receive attention when symptoms are severe (De Palma and Nordenram 2005).

Studies also suggest a direct biological mechanism for the effect of excessive alcohol consumption on periodontitis. Individuals who use alcohol are more susceptible to certain infectious disorders and are more prone to bacteremia. This may be because alcohol abuse disrupts the normal functioning of the immune surveillance system (Pavia et al. 2004). A study among African American males reported that excessive alcohol use weakens the bacteria-killing activity of neutrophils (a type of white blood cell that helps heal damaged tissues and resolve infections), which could increase the risk of periodontitis (Khocht et al. 2013). The literature suggests that long-term excessive alcohol intake has a direct toxic effect on periodontal tissues by stimulating bone breakdown and inhibiting bone formation (Tezal et al. 2001; de Almeida et al. 2020).

Alcohol and Dental Caries

The topical effects of alcohol consumption on dental caries may be modified by factors including alcohol concentration and the intensity and duration of consumption. Interestingly, the fluoride concentration levels within an alcoholic beverage may offer anti-cariogenic benefits. Alcoholic beverages produced with water containing high fluoride levels may contribute a substantial proportion of the daily allowable intake among heavy drinkers. The U.S. Department of Agriculture (USDA) National Fluoride Database of

Selected Beverages and Foods, Release 2 (U.S. Department of Agriculture 2005) revealed variable mean fluoride concentrations of different alcoholic beverages, some of which contained higher fluoride concentrations than the recommended level in fluoridated water (0.7 parts per million [ppm]). The fluoride concentration levels for the reported alcoholic beverages included 0.45 ppm for light and regular beer, 0.08 ppm for distilled alcoholic beverages (gin, rum, vodka, whiskey, 80 proof), 1.05 ppm in red wine, and 2.02 ppm in white wine.

Heavy drinking, however, may have an impact on saliva production that promotes caries development. For example, chronic alcohol abuse leads to diminished secretion of saliva that could encourage caries development (Slomiany et al. 1997). Chronic alcoholism also leads to changes in the tissue of the parotid and submandibular glands that impair saliva flow and make it thicker. A study reported that unstimulated salivary flow rate as well as the pH values of both unstimulated and stimulated saliva were lower in the alcoholic group compared to nonalcoholic controls (Dukic et al. 2013). The mechanism for decreased salivary flow rate in this study is unclear but may be through inhibitory effects on the natural cannabis-like molecules produced by the body's endocannabinoid system induced by the ethanol in alcohol (Prestifilippo et al. 2009).

Classification of alcohol consumption in the 2011–2016 NHANES based on intensity and chronicity suggests that those who drink heavily and over a long period of time had the worst dental outcomes in terms of decayed, missing, and filled teeth, compared to episodic heavy drinkers or others who drank less frequently. Within these analyses, chronic heavy drinkers had the highest mean number of decayed teeth (1.2), which was significantly higher than the mean number reported by episodic heavy drinkers (0.70), moderate drinkers (0.60), or occasional drinkers (0.70). Considering the entire DMFT index, however, the mean number of decayed, missing, or filled teeth was lower among heavier drinkers. A lower global DMFT score coupled with a higher decay component of the index may indicate poorer health-seeking behavior rather than a higher burden of disease overall.

Alcohol and Oral Cancer

Heavy alcohol and tobacco use (defined as two or more packs a day and four or more drinks per day), in combination, is much more likely to cause cancer in the mouth or throat than smoking or drinking alone. These major risk factors are responsible for approximately 3 in 4 oral and pharyngeal cancers (Hashibe et al. 2009). Drinking alcohol increases the risk of cancers of the mouth, esophagus, pharynx, and larynx (Stornetta et al. 2018; National Cancer Institute 2019), and alcohol abuse increases these risks to still higher levels (Centers for Disease Control and Prevention 2019a). About 7 out of 10 patients with oral cancer are heavy drinkers. However, oral diseases in alcoholics are thought to be primarily due to associated conditions, such as poor oral hygiene, lack of dental care, and impaired infection resistance during acute alcohol intoxication. Nutritional status can be impaired by heavy alcohol use as a result of primary and secondary malnutrition. Primary malnutrition occurs when alcohol replaces other nutrients in the diet, resulting in overall reduced nutrient intake. Secondary malnutrition occurs when the drinker consumes adequate nutrients but alcohol interferes with the absorption of those nutrients in the intestine so they are not available to the body. For example, nutrients such as vitamins A, C, and E act as antioxidants that are protective against damaging effects of carcinogens from products of alcohol and tobacco (Ziegler 1991; Feinman and Lieber 1998).

The relationship between alcohol consumption and oral cancer may be mediated through multiple biological pathways, including cytotoxic effects, disruption of adaptive immune responses, and genetic activity. The cumulative toxic effect of alcohol on cells lining the oral cavity also results in dehydration and cell death, which activates the division and migration of stem cells located in deeper layers of the mucosal tissue to replace the dead cells. When these stem cells divide, they become exposed to DNA- and chromosome-related errors associated with cell division and are highly vulnerable to the activity of DNA-damaging agents (Lopez-Lazaro 2016). Cancer-causing compounds found in alcoholic beverages that can have direct toxic effects on cells include acetaldehyde, acrylamide, aflatoxins, arsenic, benzene, cadmium, ethanol, ethyl carbamate, formaldehyde, furan, glyphosate, lead, 4-methylimidazole, and N-nitrosodimethylamine (Pflaum et al. 2016).

Alcohol is mostly oxidized to acetaldehyde in the liver by alcohol dehydrogenase (ADH). Several sources suggest the possible involvement of the local production of acetaldehyde in alcohol-related cancer development in the upper aerodigestive tract. A study by Muto and colleagues (2000) demonstrated that *Neisseria* genus bacteria counts increased in the oral microflora shortly after ethanol ingestion, had extremely high ADH and low aldehyde dehydrogenase (ALDH) activity, and might function as a modifier for alcohol-related oral cancer. Metabolism of acetaldehyde, independent of *Neisseria*, also has been demonstrated in oral tissues. The activity of ALDH in oral mucosa is less than the activity of acetaldehyde, which could allow the accumulation of acetaldehyde in oral tissues (Dong et al. 1996).

Alcohol modulates certain aspects of innate and adaptive immune systems in a way that favors tumor development and progression. The cells and signaling molecules of the innate immune response quickly identify cancerous or precancerous cells to destroy them. For example, natural killer (NK) cells actively recognize and prevent tumor development (Meadows and Zhang 2015). However, chronic alcohol abuse impairs the activity of NK cell activity and increases the production of pro-inflammatory cytokines (messenger cells of the immune system) in enough abundance to cause chronic inflammation (Zhang and Meadows 2009). Chronic inflammation can lead to cellular reprogramming that initiates cancers (Jankowski et al. 2000).

Several studies indicate an association between genetic variation and alcohol consumption on cancer risk in humans. The gene *ADH1B* has several variations associated with the risk of different cancers. Two studies in Asian populations found a significantly higher risk of cancer of the upper aerodigestive tract, oral cavity, and hypopharynx in moderate or heavy drinkers carrying the *ADH1B*1/*1* genotype than those carrying *ADH1B*1/*2 or ADH1B*2/*2* (Asakage et al. 2007; Hiraki et al. 2007). Alcohol dehydrogenase 3 (*ADH3*) converts ethanol to acetaldehyde, which is an oral carcinogen. A study examining the association among *ADH3* genotypes, alcohol consumption, and oral squamous cell carcinoma (OSCC) risk found similar distribution of *ADH3* genotypes between cases and controls; however, among those with the *ADH3*2* genotype the risk of OSCC increased 5.3% with each additional alcoholic drink per week, compared with 2.5% among persons carrying other genotypes. These data indicate that the *ADH3*2* genotype increases susceptibility to OSCC risk (Schwartz et al. 2001).

Prolonged exposure to alcohol may cause damage to the cerebellum, an area of the brain that controls motor movements, and thus lead to movement disorders. A history of alcohol abuse or dependence is associated with an increased risk of developing tardive orofacial dyskinesias (involuntary repetitive movements of the mouth and face) in patients who take neuroleptic medications. The severity of dyskinesia appears to be correlated with greater alcohol consumption (Lopez and Jeste 1997).

Tobacco

Overview

Tobacco use remains a major public health concern with well-documented oral health consequences, especially with regard to gum diseases and cancer. There are additional concerns about the potential adverse consequences of e-cigarette use, especially for youth and young adults.

From 2014 to 2017, 28% of U.S. adults reported using a tobacco product (regular cigarettes, hand-rolled cigarettes, cigars, pipes, or smokeless tobacco products) within the past 30 days (U.S. Department of Health and Human Services 2020a). Use of any tobacco product in the past 30 days was highest among these groups: males aged 26 to 34 years, non-Hispanic blacks, adults with less than high school education, persons residing in non-urban areas, those living in poverty, and the uninsured. Prevalence was significantly higher among those who reported having serious psychological distress compared to those who did not report psychological distress (49.1% vs. 26.8%).

***Combustible Tobacco*:** Between 2014 and 2017, the past 30-day (P30D) prevalence of cigarette smoking and/or cigar smoking was 23% among U.S. adults and 29% for smoking occurring in the past 12 months (*P12M*). The prevalence of cigarette and/or cigar smoking in the past 30 days was highest among those aged 26 to 34 years (32%), while the prevalence of smoking in the past 12 months was highest among those aged 18 to 25 years (41%). The prevalence of cigarette and/or cigar smoking was highest among the following subgroups: those with serious psychological distress (*P30D*-44%; *P12M*-50%), the uninsured (*P30D-38*%; *P12M-44*%), those living in poverty (*P30D-35%; P12M-40%*), single, never married (*P30D-32*%; *P12M-41*%), persons with less than high school education (*P30D-31*%; *P12M-35*%), and those residing in nonmetropolitan areas (*P30D-28*%; *P12M-32*%) (Substance Abuse and Mental Health Services Administration 2018). It is noted that these same data comparisons are not available for combustible products other than cigarettes and cigars (e.g., cigarillos, little cigars, hookah pipes, etc.), although use of these products also may contribute to the burden of oral disease.

Smokeless Tobacco: In 2017, 3.5% of U.S. adults reported use in the past 30 days of smokeless tobacco (chewing tobacco, snuff, or dip), and 4.6% reported use in the past 12 months. The prevalence of smokeless tobacco use was highest among the following subgroups: those residing in nonmetropolitan areas (*P30D*-7.2%; *P12M*-8.6%), males (*P30D*-6.7%; *P12M*-8.6%), aged 18 to 25 years (*P30D*-5.3%; *P12M*-8.5%), non-Hispanic whites (*P30D*-4.6%; *P12M*-5.9%), high school graduates (*P30D*-4.6%; *P12M*-5.9%), single, never married (*P30D*-4.4%; *P12M*-6.7%), uninsured (*P30D*-4.4%; *P12M*-6.1%), and those with serious psychological distress (*P30D*-4.3%; *P12M*-6.4%). Use within the past 12 months did not differ significantly by poverty status; use within the past 30 days, however, was highest among those with incomes less than twice the Federal Poverty Level (Substance Abuse and Mental Health Services Administration 2019a).

Electronic cigarettes: These battery-operated devices referred to as e-cigarettes (e-cigs), e-vaporizers, or electronic nicotine delivery systems (ENDS) are used to inhale an aerosol that typically contains nicotine, flavorings, and other chemicals. E-cigarettes and vaporizers can also be used to inhale other drug substances, including the psychoactive chemical, tetrahydrocannabidiol (THC), which is found in marijuana. These devices are packaged as “cig-a-likes,” or may resemble traditional cigars or pipes or items of common use such as pens or USB flash drives. Devices with refillable tanks may have unique designs. Popular names for these more than 460 different devices include e-cigs, e-hookahs or hookah pens, vapes and vape pens, and mods, which are customizable and powerful vaporizers (National Institute on Drug Abuse 2020a). Evidence to date indicates there are short-term health risks posed by e-cigarettes, particularly to the cardiopulmonary system, although the long-term health risks are unknown (National Academies of Sciences, Engineering, and Medicine 2018; Gotts et al. 2019).

Analyses of data from the 2019 National Health Interview Survey showed that 10.9 million U.S. adults (4.5%) reported current e-cigarette use (every day or some days). Prevalence of current e-cigarette use was highest among the following subgroups: males (5.5%); persons aged 18 to 24 years (9.3%); non-Hispanic multiracial persons (9.3%); those who lived in the South (4.9%); those who were single/never married/not living with a partner (6.9%); those who had an annual household income of less than $35,000 (5.0%); lesbian, gay, or bisexual adults (11.5%); those insured by Medicaid (5.0%); those who had a disability/limitation (4.5%); and those who had severe generalized anxiety disorder (10.1%)(Cornelius et al. 2020). Since 2014, e-cigarettes have been the most commonly used tobacco product among youths (Cornelius et al. 2020). During 2020, current e-cigarette use was reported by 19.6% of high school students (3.02 million) and 4.7% of middle school students (550,000) (Wang et al. 2020).

Nearly 15% of adults reported ever using an e-cigarette in 2018; among former cigarette smokers who quit in the past year, 57% were e-cigarette users (Cornelius et al. 2020).

Tobacco and Periodontal Disease

Cigarette smoking has consistently been reported as the strongest modifiable risk factor for periodontitis in literature reviews (Genco and Borgnakke 2013; Borgnakke 2016), and the evidence is sufficient to infer a causal relationship between smoking and periodontal disease (U.S. Department of Health and Human Services 2004). Recent data from NHANES continue to confirm the strong association between smoking and periodontitis (Eke et al. 2016; Eke et al. 2018). Of all U.S. smokers aged 30 years and older, 62% had some form of periodontitis, whereas only 34% of never smokers had periodontal disease. The prevalence of severe periodontitis was 16.9%, 8.0%, and 4.9% among current, former, or nonsmokers, respectively (Eke et al. 2018). Among older adults (aged 65 years and older), 1 in 4 current smokers had severe periodontitis. It is estimated that tobacco use causes nearly 10 million cases of periodontal disease among active tobacco users and 6 million cases among never or former smokers exposed to environmental tobacco smoke (Vogtmann et al. 2017).

Among never, former, and current cigarette smokers, mean attachment loss (the clinical detachment of gum and other supporting tissues from the tooth root) was 1.43 mm, 1.65 mm, and 2.06 mm, respectively; mean probing depth (measure from top of the gingiva to the base of the pocket formed between the teeth and gums) was 1.34 mm, 1.37 mm, and 1.64 mm, respectively (both $p < 0.001$). After adjusting for several potential confounders, including co-use of other substances and sociodemographic characteristics within a multivariable binary logistic regression model, the odds ratio of severe periodontitis was 1.63 (95% CI = 1.06–2.51) and 2.20 (95% CI = 1.43–3.39) among former and current cigarette smokers, respectively, compared to never smokers. The odds ratio of any periodontitis was 1.45 (95% CI = 1.13–1.85) and 2.67 (95% CI = 2.09–3.42) among former and current cigarette smokers, respectively, compared to never smokers. For both combustible and noncombustible tobacco products within NHANES 2009–2014, the loss of attachment was generally higher for the lower teeth than for the upper teeth, and for the front teeth than for the back teeth, based on analyses of the data (Centers for Disease Control and Prevention 2021a). When comparing the different areas around teeth for periodontal disease progression resulting from smoking as measured by clinical loss of attachment across the life span, the rapid periodontal destruction of interproximal sites of molars begins as early as age 30 and can progress quickly, affecting every site of every tooth by age 50 (Billings et al. 2020).

Data from NHANES 2009–2014, analyzed for this report, further demonstrated that the impact of tobacco use on periodontal disease varied by type of tobacco product and region of the mouth. Among people who currently use any tobacco product, those who used combustible tobacco products (cigarettes, cigars, pipes, or hookahs) exclusively had a significantly higher prevalence of any periodontitis than people who only used noncombustible tobacco products (smokeless tobacco or e-cigarettes), with reported prevalence of 62% (SE: 1.7) versus 47% (SE: 1.4), respectively. Mean attachment loss was similarly higher among people who used combustible tobacco (2.06 mm) than those who used noncombustible products (1.65 mm). Mean pocket depth measurements showed a similar trend, with mean levels of 1.64 mm and 1.49 mm found among people who used combustible and noncombustible tobacco products, respectively (Centers for Disease Control and Prevention 2021a).

In the 2013–2014 Population Assessment of Tobacco and Health (PATH) study, participants with any tobacco use had almost three times greater odds for experiencing gingival disease, namely, 2.9 (95% CI: 1.9–4.5) in people who used e-cigarettes, 2.8 (95% CI: 2.4–3.4) among people who used multiple tobacco products, 2.8 (95% CI: 2.0–3.8) among recent quitters (less than 12 months), and 2.7 (95% CI: 1.3–5.3) in people who smoked pipes compared to lifetime never smokers (Vora and Chaffee 2019).

Several mechanisms appear to account for tobacco products causing periodontal disease. Nicotine contained in tobacco products affects blood flow in gum tissue and impairs the function of immune cells that help in the immune response to periodontal and dental infections (Wagenknecht et al. 2018). Cigarette smoke, nicotine-containing e-cigarette aerosol, and non-nicotine-containing e-cigarette aerosol are toxic to connective cells in soft periodontal tissue (Sundar et al. 2016; Javed et al. 2017). Analyses of longitudinal data from waves 1, 2, and 3 of the PATH Study (2013–2016) found that people who used electronic nicotine products daily or some days had significantly greater odds of being newly diagnosed with gum disease during the study (OR = 1.8; 95% CI: 1.1–2.8), and of bone loss around teeth (OR = 1.7; 95% CI: 1.1–2.63, when compared to never users (Atuegwu et al. 2019).

The effect of tobacco on the cells and signalers of the immune system plays a major role in the development of periodontal disease and in impaired healing after treatment for the disease (Winn 2001). Smokers display suppressed activity of neutrophils (healing white blood cells) and regulators of T cells and NK cells (other cells that regulate immune response) (Petropoulos et al. 2004; Tymkiw et al. 2011). The viability of crevicular neutrophils (cells in the gum tissue that attack bacteria) viability is persistently reduced in smokers (an estimated 75% viable) compared to nonsmokers (an estimated 85% viable). The activity of phagocytes, those cells that ingest and destroy harmful bacteria, was diminished in a potentially dose-dependent manner, reflected as 40% in heavy smokers and 79% in nonsmokers (Guntsch et al. 2006). Lowering of pro-inflammatory cytokines in the gingival crevicular fluid can contribute to abnormal host response. Tobacco smoke exposure is also thought to affect the interior structure of neutrophils, suppressing their movement and ability to destroy harmful bacteria (Ryder et al. 2002).

Cigarette smoke appears to limit the capacity of neutrophils to destroy plaque bacteria in a process known as the respiratory/oxidative burst (Sorensen et al. 2004). However, Jain and Mulay (2014) reported that exposing unstimulated neutrophils in the gingival crevicular fluid to tobacco smoke elevated the oxidative burst and released superoxide and hydrogen peroxide from the neutrophils, leading to direct toxic destruction of periodontal tissue. Tobacco smoke stimulation of neutrophils also interfered with the release of elastase and metalloproteinase-8 and 9, enzymes that could repair inflammatory damage to gum tissue (Xu et al. 2008). Smoking also has a chronic effect on blood flow within gum tissue via cotinine, a component of nicotine that causes blood vessels to constrict (Bagaitkar et al. 2010), so that even with ongoing inflammation, symptoms may be disguised (Bergstrom et al. 2000).

Paradoxically, cigarette smoke can suppress the immune system or stimulate it, depending on the specific component of total particulate matter in the smoke (Sopori 2002). For example, nicotine, benzo(a)anthracene, and benzo(a)pyrene are immunosuppressive (Geng et al. 1996), whereas tobacco glycoprotein and metals present in tobacco smoke are immunostimulatory (Francus et al. 1992). The net effect is dependent on dose and duration of exposure to smoke components (Tollerud et al. 1991). This immunomodulatory effect may influence the constitution of periodontal microflora, components of the oral microbiome, thereby influencing periodontal health.

The modification of periodontal microflora by smoking has been implicated in the development of periodontitis (Socransky et al. 1998; Sharma 2010; Duran-Pinedo et al. 2014; Shaikh et al. 2018). Polymicrobial synergy and dysbiosis are key mechanisms through which smoking can cause periodontitis. Specifically, smoking alters periodontal microbiology by favoring the accumulation of keystone pathogens that orchestrate inflammatory disease for example, *Porphyromonas gingivalis*, *Treponema denticola*, and *Tannerella forsythia*. Leukotoxins, lipopolysaccharides, and other harmful substances produced by these gram-negative bacteria can cause tissue destruction.

Tobacco and Dental Caries

Two earlier studies have shown an association between smoking and dental caries (Vellappally et al. 2007; Benedetti et al. 2013). Analyses for this report of NHANES 2011–2016 data from U.S. adults aged 20 years and older who had at least one permanent tooth showed that the mean number of decayed teeth was significantly higher among current smokers (1.6) than among former or never smokers (0.5 teeth each). The mean numbers of missing teeth were 4.0, 3.8, and 1.9 among current, former, and never smokers, respectively. The proportions of individuals with untreated caries were 27.4%, 10.8%, and 10.5% among current, former, or never cigarette smokers, respectively. The proportions of adults with 20 or more missing teeth (excluding third molars) were 19.4%, 14.3%, and 5.9%, respectively, among current, former, or never cigarette smokers. The odds of having untreated caries were 2.1 (95% CI = 1.7–2.5) and 1.3 (95% CI = 1.0–1.6) among current and former cigarette smokers, respectively, compared to those who had never smoked cigarettes. The odds of having a missing tooth due to oral disease were 2.1 (95% CI = 1.6–2.6) and 1.7 (95% CI = 1.3-2.1) among current and former cigarette smokers, respectively, compared to never cigarette smokers.

Among people who report current tobacco product use, those who used combustible tobacco products exclusively had a significantly higher number of missing teeth than those who used noncombustible tobacco products exclusively (3.8 vs. 1.9). No significant differences existed in the numbers of decayed teeth, however. By type of tobacco product used, the proportion with 20 or more missing teeth was 11.8% among those using noncombustible tobacco products exclusively, 18.6% among exclusive smokers of combustible tobacco products, and 21.5% among those reporting dual use of combustible and noncombustible tobacco products.

There is a strong association between tobacco use and dental caries, most likely explained by its impact on the production of saliva, which is necessary for a healthy mouth and caries prevention. Tobacco use is a well-known cause of xerostomia. Toxins from cigarette smoke are known to target the functioning of the parotid gland, resulting in a decrease in the release of watery saliva. This loss of function is compensated by the submandibular and sublingual glands that secrete mucous saliva, resulting in the thicker saliva seen in smokers. Smoking also negatively affects the quality of saliva by destroying enzymes and proteins that reduce saliva's protective role (Rad et al. 2010). Evidence is mixed regarding the effect of smoking on salivary flow rates. For example, it has been demonstrated that nicotine acts on receptors in the brain to cause activation of acetylcholine and noradrenaline, which increase salivary flow rates (Bouquot 1992). Tobacco use on a long-term basis, however, decreases the sensitivity of taste receptors and leads to decreased salivary reflex and xerostomia (Petrusic et al. 2015). One study reported no significant difference in the salivary flow rate of long-term smokers and nonsmokers (Khan et al. 2010). Overall, smoking may initially increase salivary flow rate because of the stimulant effect of nicotine on the salivary glands but decrease salivary flow rate in the long term, especially among heavy smokers (Rad et al. 2010).

Heavy smokeless tobacco use has been shown to result in degenerative changes in the minor salivary glands located in the site of chronic tobacco placement (Bouquot 1992). The high proportion of fermentable sugars in chewing tobacco further stimulates the growth of cariogenic bacteria (Winn 2001), which can lead to tooth decay.

The e-liquid (commonly called juice) used as in e-cigarettes and other vaping devices typically contains nicotine, propylene glycol, vegetable glycerin, and flavoring chemicals. The content of sugar and acids in these chemicals can have a substantial cariogenic effect on teeth, and the high viscosity of the liquid also may contribute to caries development by prolonging contact with tooth enamel, increased biofilm formation, increased microbial adhesion to enamel surfaces, and altered salivary flow (Kim et al. 2018). A recent study has suggested a possible association between untreated dental caries and e-cigarette use (Vemulapalli et al. 2021). Given the relative novelty of e-cigarettes on the market, and the relatively long latent period for certain oral conditions, more research is needed to ascertain the long-term effects on oral health. Current evidence is limited, although population-level data show that e-cigarette use among adolescents may lead to future cigarette smoking (Chaffee 2019).

Tobacco Use and Oral Cancer

Tobacco smoking is the single most important causative factor in the development of oral cancer and also causes cancer in the mouth, throat, larynx, or lungs (Forastiere et al. 2001; U.S. Department of Health and Human Services 2014; Abadeh et al. 2019; Centers for Disease Control and Prevention 2019b). Some studies suggest that secondhand smoke exposure also may increase the risk for oral cancer (Chen et al. 2018).

Tobacco use is a known risk factor for oral cancers. Cigarette smoking and use of chewing tobacco are associated with increased risk for cancer of the mouth or throat and, to a lesser extent, cancer in the cheeks, gums, and inner surfaces of the lips. Tobacco smokers are more likely than nonsmokers to develop these cancers, and the risk increases by duration and frequency of tobacco use (Centers for Disease Control and Prevention 2019b). The use of smoked or smokeless tobacco increases the risk for oral cancer and other head and neck cancers. Heavy smoking (more than two packs a day for 20 years) increases the risk by more than four times. Research is needed to determine whether e-cigarette use also increases the risk for oral cancer (National Academies of Sciences, Engineering, and Medicine 2018; Hashim et al. 2019). Tobacco smoke from cigarettes, cigars, or pipes also can cause cancer of the larynx, lungs, and esophagus. Pipe smoking is linked to a high risk for cancer of the lips where they contact the hot pipe stem.

The most common oral cancer is oral squamous cell carcinoma (OSCC). In some people, this cancer may be caused by a naturally occurring genetic mutation, but chemicals found in tobacco escalate the mutation rate. Variations in expression of enzymes that influence carcinogen metabolism, DNA repair mechanisms, and other protective mechanisms may account for differing susceptibilities to OSCC (Scully and Bagan 2009).

There are more than 70 carcinogens in cigarette smoke and at least 16 in smokeless tobacco (U.S. Department of Health and Human Services 2006; Hecht 2012). Among these, tobacco-specific nitrosamines, polycyclic aromatic hydrocarbons, and aromatic amines appear to have an important role as causes of cancer (International Agency for Research on Cancer 2004a). Most carcinogens in cigarette smoke require a metabolic activation process mostly catalyzed by cytochrome P-450 enzymes (1A2, 2A6, 2A13, and 2E1) to convert the carcinogens into forms that induce mutations and chromosomal aberrations (U.S. Department of Heath and Human Services 2010).

Nicotine is not a direct chemical carcinogen. However, its addictive quality leads to chronic exposure to tobacco, which increases the risk of cancer for people who use tobacco. Whereas carcinogens, such as nitrosamines, induce cancer by causing gene mutations or pro-cancer changes in proteins, nicotine promotes cancer progression by activating signaling pathways that enable cancer cell growth, migration, and invasion (Xue et al. 2014).

Besides nicotine and tobacco-specific nitrosamine exposures, smoking causes tissue buildup of tar (total aerosol residue)—a harmful, highly toxic, and resinous substance. Tar contains most of the cancer-causing and gene-harming substances in tobacco smoke. In the oral cavity, it causes gum damage and desensitization of taste buds (International Agency for Research on Cancer 2004b). Cigarette tar has high concentrations of stable free radicals (Pryor et al. 1983) and hydroxyl radicals that lead to DNA damage and oral cancer (Valavanidis et al. 2009).

Nitrosamines are by far the most prevalent carcinogens in unburned tobacco products, which include oral snuff, chewing tobacco, and other smokeless tobacco products (Spiegelhalder and Bartsch 1996). Smokeless tobacco also contains 28 carcinogens, with non-volatile alkaloid-derived tobacco-specific N-nitrosamines (TSNA) and N-nitrosamino acids being the primary and most abundant groups of carcinogens. Other smokeless tobacco carcinogens include certain volatile aldehydes and traces of polynuclear aromatic hydrocarbons such as benzo[a]pyrene, certain lactones, urethane, and metals (International Agency for Research on Cancer 2004a).

The risk of oral cancer greatly increases when smoking is combined with the use of smokeless tobacco, alcohol, or both. Hence, the risk for mouth and throat cancers is greater in people who use both alcohol and tobacco. For people who smoke and drink heavily, the risk of oral cancer may be as much as double that for people who neither smoke nor drink (Pitiphat et al. 2003). Alcohol enhances the uptake of carcinogens in the oral mucosa by increasing their solubility and by dissolving the layer of the epithelium that normally acts as a protective barrier (Squier 1991). Ethanol acts as a solvent that may facilitate the uptake of environmental carcinogens, especially from tobacco smoke, by damaging cell membranes. Chronic alcohol consumption leads to an induction of cytochrome P-4502E1 (CYP2E1) that metabolizes ethanol to acetaldehyde. This enzyme also is involved in the metabolism of various pro-carcinogens, such as those from cigarette smoke. An increase (up to threefold) in CYP2E1 concentrations after chronic alcohol ingestion has been reported in the throats and mouths of humans. This may well be the mechanism for the synergistic effect of drinking and smoking on the development of cancer in the aerodigestive tract (Baumgarten 1996).

Individuals who use alcohol often have nutritional deficiencies that compound the carcinogenic effects of smoking. These include folate deficiency, which could contribute to an inhibition of transmethylation, which is important in gene regulation. A study by Galeone and colleagues (2015) found an inverse association between total folate intake and overall oral/pharyngeal cancer risk. Alcohol reduces folate absorption and increases folate excretion whereas tobacco consumption increases folate turnover among smokers. Folate deficiency can activate genes that predispose to cancer and induce malignant changes (Duthie 1999).

Tobacco and Other Oral Conditions

Use of tobacco products is associated with staining of the teeth, bad breath, and possible loss of the senses of taste and smell. Tobacco use also can negatively affect the outcomes of any oral nonsurgical and surgical therapy (Kotsakis et al. 2015; Avino et al. 2018), delay the healing of dental implants, and shorten their longevity (Gurlek et al. 2018).

Betel (Areca) Nuts and Khat (Qat) Chewing

Popular mostly in Southeast Asia, chewing of betel nuts or use of betel quid has been documented in the literature. Although use of betel nuts or betel quid is not common in the United States overall, demographic changes, particularly the growth of the South Asian population in many U.S. communities require more oral health practitioners to be aware of it. For example, nearly 1 in 4 South Asians living in Los Angeles, including

Bangladeshis, Nepalis, Pakistanis, and Sri Lankans, reported current smokeless tobacco use (Glenn et al. 2009). Sufficient evidence was found for the carcinogenicity of betel quid (in humans) and areca nut (in animals) about their potential for causing oral cancer and cancer of the pharynx and esophagus (International Agency for Research on Cancer 2004c) Betel quid is made from the betel (areca) nut, a seed of the fruit from the *Areca catchu*, a type of palm tree, combined with spices, lime, and other ingredients including tobacco. Areca nut and betel quid contain cancer-causing substances, which puts people who chew them at increased risk of cancer of the mouth, usually in the gums and inner lining of the cheeks and lips. Areca induces a condition known as betel chewer's mucosa in chronic chewers of the substance (Figure 9). Areca nut chewing is implicated in oral leukoplakia and submucous fibrosis, both of which are potentially malignant in the oral cavity.

Figure 9. Betel nut chewing effects–dysplastic features of tongue

Source: Dr. A.P. Kavitha. Department of Oral Medicine and Radiology, Coorg Institute of Dental Sciences, Virajpet, Karnataka, India.

The twigs and leaves of the khat or qat (*Catha edulis*) tree, which grows in southern Arabia and East Africa, are chewed for their stimulating amphetamine-like effects. Several million people worldwide chew khat, and its use has migrated to the United States and Europe (Al-Maweri et al. 2018). Mechanical and chemical irritation from long-term khat chewing can potentially develop into oral cancer (Al-Akhali and Al-Moraissi 2017). Khat chewing also increases the risk of gingival and periodontal inflammation, as well as gum attachment loss at the chewing site.

Use of Illicit Substances

Overview

In 2016, 18% of the U.S. population—representing 48.5 million people aged 12 years and older—reported using federally illicit drugs or misusing prescription medication (Substance Abuse and Mental Health Services Administration 2019a). However, only 2.2 million individuals obtained treatment for prescription drug misuse or illicit drug use in the same year. Reported prevalence of illicit drug use was 13.6% for marijuana, 1.9% for cocaine, 0.5% for methamphetamine, and 0.4% for heroin. Misuse of prescription drugs included prescription pain relievers (3.6%), prescription tranquilizers (2.1%), prescription stimulants (1.9%), and prescription sedatives (0.4%) (Centers for Disease Control and Prevention 2019c).

Marijuana

Overview

Although the legal status of marijuana varies by state while still being an illicit substance at the federal level, it is the third most widely used substance after alcohol and tobacco. Consumption focuses on the dried leaves, flowers, stems, and seeds from the *Cannabis sativa* or *Cannabis indica* plant. It is smoked in hand-rolled cigarettes, pipes or water pipes, or hollowed-out cigars that have been filled with marijuana (i.e., blunts). In addition, people use vaporizers that administer the substance by means of a liquid marijuana extract. Marijuana also is mixed in food and served as brownies, cookies, and candies, or brewed as a tea. The immediate effects of marijuana, typically lasting for 2 to4 hours, are presented in Box 2. Some longer-range health-related effects of regular marijuana use, with possible implications for oral health, include brain functions involving learning, memory, executive function, and possible impairment of motor and perception tasks such as driving (Sewell et al. 2009; Batalla et al. 2013; Filbey et al. 2014; Levine et al. 2017; Hurd et al. 2019; U.S. Department of Health and Human Services 2019). A summary of the evidence for adverse effects of marijuana on overall health and well-being, especially when use started in adolescence and persisted through adulthood, is shown in Table 1.

Box 2. Immediate marijuana effects

Overactivation of the body's own cannabinoid system is responsible for the "high" that people feel.

Other effects include:

- Altered senses (for example, seeing brighter colors)
- Altered sense of time
- Changes in mood
- Impaired body movement
- Difficulty with thinking and problem-solving
- Impaired memory, when taken in high doses
- Hallucinations
- Delusions
- Psychosis

Source: National Institute on Drug Abuse, 2019a.

There are more than 400 chemicals in marijuana, including 60 or more that are cannabinoid compounds. Delta-9-tetrahydrocannabinol (THC or d-9-THC) exhibits the main psychoactive effect by binding to the cannabinoid-1 receptor (CB1r) (Atakan 2012). The CB1r is part of the body's endocannabinoid system, which is implicated in the regulation of brain development and aspects of our physiology. In adolescents and young adults, consumption may have negative effects on judgment, short-term memory, and other cognitive abilities (National Institute on Drug Abuse 2018; Burggren et al. 2019) and has been associated with initiating some risky behaviors (Azofeifa et al. 2019; Weinberger et al. 2020).

Of mounting concern is that THC concentrations in cultivated marijuana plants have increased on average from about 4% to 12% between 1995 and 2014, making consumption much riskier (ElSohly et al. 2016). In fact, more recent analyses show that cultivated marijuana preparations vary considerably, with THC concentrations reaching up to 23.2% (Jikomes and Zoorob 2018). Marijuana products with higher levels of THC—because of the conditions under which they are cultivated—also draw in higher amounts of heavy metals (such as cadmium, lead, magnesium, and mercury among others) and pesticides from the environment within which they are grown (National Academies of Sciences 2017b; Montoya et al. 2020).

Marijuana also can be laced with fentanyl, cocaine, ketamine, methamphetamine, LSD, heroin, PCP, and embalming fluid, although marijuana is less likely to be intentionally laced with other psychoactive substances than are other illicit drugs (Peters et al. 2008). Referred to as "wet" or "fry" smoking, marijuana cigarettes are dipped into or laced with other substances, typically formaldehyde, phencyclidine, or both (Gilbert et al. 2013). Lacing occurs for two reasons: (1) drugs sold by weight are bulked up to increase profits; and (2) drugs are combined to enhance their psychoactive effects, although sometimes producing potentially deadly mixtures. The health risks to the consumer are expected to be significantly higher if marijuana is obtained from an illicit source, as opposed to a strictly regulated and controlled market. In light of its known prevalence but uncertain or unknown health risks, marijuana consumption as a factor in dental practice and oral health is insufficiently acknowledged. Quantifying the effect of marijuana use on oral health is complicated by various use patterns (medicinal vs. recreational), routes of exposure (chewing, smoking, vaping), and the formulation (e.g., "pure" vs. laced with other substances) (Cho et al. 2005). In general, health considerations around marijuana use have focused on individual risks of exposure to similar substances found in tobacco smoke, as well as population-level harms from recalibration of social norms. An important consideration for the dental provider during treatment of a marijuana-intoxicated patient involves administration of epinephrine containing local anesthetic because of the possibility of abnormal stress responses (Cho et al. 2005; Rechthand and Bashirelahi 2016; Goyal et al. 2017). This is a major clinical and public health concern given the already high and rising prevalence of marijuana use (Odani et al. 2019). Among all U.S. adults during 2015-2017, 9.1% reported past 30-day (P30D) use of marijuana, while 14.3% reported past 12-month (P12M) use.

Table 1. Summary of evidence for adverse effects of marijuana on overall health and well-being

Effect	Overall Level of Confidence*
Addiction to marijuana and other substances	High
Abnormal brain development	Medium
Progression to use of other drugs	Medium
Schizophrenia	Medium
Depression or anxiety	Medium
Diminished lifetime achievement	High
Motor vehicle accidents	High
Symptoms of chronic bronchitis	High
Lung cancer	Low

*The indicated overall level of confidence in the association between marijuana use and the listed effects represents an attempt to rank the strength of the current evidence, especially with regard to heavy or long-term use and use that starts in adolescence.

Source: Volkow et al. (2014).

Marijuana use was highest among males aged 18 to 25 years (*P30D*, 20.8%; *P12M*, 33.4%), non-Hispanic Blacks (*P30D*, 11.6%; *P12M*, 17.4%), those living in poverty (*P30D*, 12.5%; *P12M*, 19.2%), and the uninsured (*P30D*, 14.4%; *P12M*, 21.3%). In 2019, among persons age 12 and older, 48.2 million (17.5%) reported using marijuana in the past year. The highest level of use was among persons age 18 to 25 years (35.4%) (Substance Abuse and Mental Health Services Administration 2020a).

For the past 3 decades, the prevalence of adult cannabis use has steadily increased (Compton et al. 2016) and perceptions of risk have decreased (Okaneku et al. 2015; Pacek et al. 2015) to the extent that, by the end of 2020, state laws had legalized medical marijuana use in 36 states and recreational use in 15 states. (DISA Global Solutions 2020; National Conference on State Legislators 2021). These widespread changes have spurred concern about the potential impact of cannabis use on physical and mental health. Although numerous oral health conditions, including periodontal disease and oral cancer, have been clearly linked to tobacco smoke (World Health Organization 2017), relatively little is known of their relationship to marijuana smoke. However, it is known that people who use marijuana have poorer oral health than people who do not use marijuana (Cho et al. 2005; Versteeg et al. 2008), and this may be worse among those who also smoke tobacco products. For example, marijuana users have higher rates of decayed, missing, and filled teeth; more plaque deposits; and less healthy gums (Di Cugno et al. 1981; Rees 1992; Cho et al. 2005; Schulz-Katterbach et al. 2009; Ditmyer et al. 2013). This may be attributable to the observation that marijuana use is associated with cannabis stomatitis (changes in the lining of the mouth) and, consequently, xerostomia (dry mouth) (Cho et al. 2005). In addition, cannabis and cigarette smokers brush their teeth less often and visit their dentist less regularly. Only 21% of people who smoke both cannabis and tobacco reported attending annual dentist visits, compared to 74% of those who smoke tobacco only (Schulz-Katterbach et al. 2009).

Overall, the literature on cannabis and oral health is sparse, with many studies published more than 2 decades ago. Existing knowledge suggests a relationship between cannabis use and numerous oral diseases and conditions, but gaps in the literature point to the need for additional investigation. Marijuana smoking is associated during initial use with xerostomia and irritated oral tissue as well as caries, and chronic marijuana use is associated with increased risk of gingivitis and periodontal disease, as well as oral candidiasis (Cho et al. 2005; Versteeg et al. 2008; Joshi and Ashley 2016). A 20-year prospective study of 1,037 individuals born in Dunedin, New Zealand, between 1972 and 1973 found that increased use of cannabis was significantly associated with poorer periodontal health at age 38 (Meier et al. 2016). Overall, a recent review has suggested the association between marijuana use and poor oral health is uncertain except when periodontitis is the oral health outcome considered (Keboa et al. 2020).

Unfortunately, the absence of a strong body of science on marijuana does not permit the development of clear guidelines for safe use at this time. However, from what is now known about the association between oral health and cannabis, in conjunction with the increasing prevalence of cannabis use, care providers should be aware of cannabis-associated oral side effects, including xerostomia, periodontitis, and oral candidiasis, especially among those groups that studies have indicated are the most frequent users (Cho et al. 2005; Thomson et al. 2008; Versteeg et al. 2008).

Marijuana and Periodontal Disease

Research focusing on the effects of marijuana use on poor oral health is more abundant and more clearly established when the outcome is periodontal disease. A recent meta-analysis has shown an increased risk for periodontitis from smoking cannabis (Chisini et al. 2019). Among adults aged 30 years and older, people who use cannabis have significantly more sites with deep probing depth and clinical attachment loss (Thomson et al. 2008; Zeng et al. 2014; Shariff et al. 2017). One nationally representative cross-sectional study found that adjusted odds of severe periodontitis were 40% greater among frequent cannabis users than among people who do not use cannabis. This increase was 90% when the sample was limited to participants who had never used tobacco (Shariff et al. 2017). Overall, findings support a positive association between cannabis and periodontitis in midlife (Meier et al. 2016; Ortiz et al. 2018; Chisini et al. 2019). This association has not been observed among young adults or adolescents (Lopez and Baelum 2009; Jamieson et al. 2010; Zeng et al. 2014; Meier et al. 2016).

In the United States, marijuana use was associated with periodontal disease among adults aged 30 years and older from 2009 to 2014 (Centers for Disease Control and Prevention 2021a). Prevalence of severe periodontitis was 6.3% among people who had never used marijuana, 6.2% among former users, and 12.2% among people who current regular users. Prevalence of any periodontitis was 36.1% among never users, 33.7% among former users, and 46.9% among current regular users. In addition, mean unadjusted attachment loss levels were 1.48 mm, 1.45 mm, and 1.77 mm, respectively, among never, former, and current marijuana users. However, stratified analyses within the levels of cigarette smoking status and marijuana use in three broad categories of never, former, and current users found no significant associations between marijuana use and severe periodontal disease among current and never cigarette smokers.

People at the highest levels of marijuana use were more likely to have periodontitis after controlling for use of tobacco products, alcohol consumption, number of comorbidities, age, sex, race/ethnicity, education, and poverty level. This held true regardless of whether the use was measured in the context of frequency, duration, or cumulative lifetime exposure. For example, analyzing duration of lifetime use within NHANES 2009–2014 data showed that only those who reported duration of 20 or more years of marijuana use had significantly higher adjusted odds of severe periodontitis than did never users (AOR = 1.89; 95% CI = 1.05–3.39) (Centers for Disease Control and Prevention 2021a). For any periodontitis (including mild and moderate forms of the disease), however, durations of marijuana use of 5–9 years, 15–19 years, and 20 or more years were all associated with periodontal disease, suggesting that relatively shorter periods of exposure may be associated with clinically detectable disease even if much longer periods of exposure are required for severe forms of the disease.

Marijuana and Dental Caries

Common side effects of cannabis use include xerostomia, decreased saliva pH, and increased appetite. When combined, these three factors may leave teeth vulnerable to attack from cavity-causing food and drink (Joshi and Ashley 2016). People who use cannabis report consuming significantly greater quantities of sugary beverages than controls (Schulz-Katterbach et al. 2009). However, the effect of cannabis on xerostomia appears to decrease over time, likely due to the development of tolerance (Versteeg et al. 2008). Nevertheless, reduced salivary flow is a risk factor for dental caries. With legalization of recreational marijuana increasing, new forms of marijuana consumption are raising another set of concerns. For example, formulations such as cakes, cookies, and candies have the potential to be cariogenic due to the sugar content.

When exploring NHANES data (National Health and Nutrition Examination Survey 2011–2016), unadjusted analyses indicate that current marijuana users have a higher mean number of carious teeth. In 2011-2016, the mean number of decayed teeth varied significantly by marijuana use status (0.7, 0.8, and 1.1 among never, former, and current marijuana users). However, no significant differences among mean numbers of teeth with cavities were observed within stratified analyses in any of the levels of cigarette smoking status (current, former, or never).

Marijuana and Head and Neck Cancer

Some research has linked cannabis smoking to head and neck cancer (Firth 1997; Zhang et al. 1999; Marks et al. 2014; Huang et al. 2015). As is the case for tobacco, cannabis smoke contains a number of carcinogens that make direct contact with oral tissues. Moreover, cannabis smoke contains a 50% higher concentration of aromatic hydrocarbons than the same amount of tobacco smoke (Tashkin et al. 2002). Some researchers have suggested that the combination of tobacco and marijuana smoke may have synergistic effects on cancer risk (Zhang et al. 1999). Considering that the majority of people who use cannabis daily in the United States also use tobacco products (Goodwin et al. 2018), this hypothesis warrants investigation. Although a number of reviews and studies to date have found no association between cannabis use and head and neck cancers (Hashibe et al. 2006; Aldington et al. 2008; Versteeg et al. 2008; Berthiller et al. 2009; de Carvalho et al. 2015; Huang et al. 2015), the reason for these mixed findings is unclear. It may be related to the use of cannabis among people infected with human papilloma virus (HPV), which is a known risk factor for head and neck cancer (Muller et al. 2015). In two case-control studies of head and neck cancer, only people who use cannabis were found to have elevated risk of tumors positive for HPV Type 16 (Gillison et al. 2008; Xie et al. 2018).

Cannabis smoke is rich in acetaldehyde, and experimental evidence suggests that acetaldehyde can be harmful to the DNA of exposed cells and can play a role in oral cancer development as a result of direct DNA damage (Singh et al. 2009). However, Osazuwa-Peters and colleagues (2016) concluded, on the basis of their meta-analysis, that there is no association between lifetime marijuana use and head and neck cancer.

Marijuana and Other Oral Conditions

A connection exists between smoking cannabis and changes in the oral epithelium (Darling and Arendorf 1993) with leukoedema (a type of oral lesion) found in 57.1% of people who used cannabis compared to 20.2% of nonusers. The authors of this study speculated that leukoedema may develop after a threshold for cannabis smoke exposure has been crossed. However, others have suggested that this condition may not be directly attributable to cannabis, as leukoedema is associated with a number of habits, including cheek sucking (van Wyk and Ambrosio 1983; Versteeg et al. 2008).

People who smoke marijuana also have shown greater prevalence and density of candida (fungal/yeast) species in the mouth than people who do not smoke it, leading to higher risk of oral candidiasis (thrush). The hydrocarbons in marijuana are speculated to act as an energy source for certain candida species, although evidence is limited (Cho et al. 2005; Versteeg et al. 2008).

Opioids

The United States consumes most of the opioids worldwide despite representing only about 4% of the world's population (International Narcotics Control Board 2016). Opioids are a class of natural or synthetic chemicals that interact with opioid receptors in the body and brain. This class of drugs includes the illegal drug heroin, synthetic opioids such as fentanyl, and pain medications available by prescription, such as oxycodone, hydrocodone, codeine, and morphine. Increasing misuse of prescription opioids, addiction to these medications, and related overdose deaths remain a major public health concern.

Advances in pharmacology, while welcome, may also have exacerbated problems of substance use. For example, G protein-coupled receptors play an important role in modulating our sense of smell, taste, vision, and pain. They are also active in cell recognition and communication processes and have emerged as a prominent group for pharmacotherapy targets. As a result, the identification of endogenous G-protein-coupled opioid receptors has led to the proliferation of synthetic opioids such as methadone, fentanyl, and oxycodone (Fields 2011).

Prescription Opioids

Overview

Misuse of prescription opioid pain relievers means taking a medication in a manner or dose other than prescribed; taking someone else's prescription, even if for a legitimate medical complaint such as pain; or taking a medication for pleasure—to get high. In 2018, 10.1 million persons, or 3.7% of those aged 12 years and older, reported misuse of opioids in the past year, including prescription opioids and the illicit substance heroin (Substance Abuse and Mental Health Services Administration 2020a). In the National Survey on Drug Use and Health, a host of prescription drugs are included in the category of prescription pain relievers, including hydrocodone, oxycodone, tramadol, codeine, morphine, fentanyl, buprenorphine, oxymorphone, meperidine hydromorphone, methadone, and other prescription pain relievers. The highest prevalence of misuse of prescription pain relievers occurred among persons aged 18 to 25 years (5.3%) (Substance Abuse and Mental Health Services Administration 2020a). Information reported for a cohort of privately insured patients shows that a substantial number of these young people are initially exposed to opioids through dental care primarily associated with third molar extractions (Schroeder et al. 2019). As a result, Schroeder and coauthors have suggested that receipt of opioid prescriptions for these dental services could provide opportunities for opioid misuse.

In 2018, 10.1 million persons (3.7%) aged 12 years and older had misused prescription pain relievers in the past year. Nearly 97% of people who misused opioids in the past year misused prescription pain relievers. (Substance Abuse and Mental Health Services Administration 2020a). On the basis of medical and pharmacy claims from the multistate Truven MarketScan Medicaid Database from 2013 to 2015, orthopedic pain (34.8%) was the primary reason for an opioid prescription, followed by dental conditions (17.3%), back pain (14.0%), and headache (12.9%) (Janakiram et al. 2019a). More than half of the enrolled Medicaid beneficiaries received an opioid pain reliever for orthopedic or dental-related reasons, with the majority of those prescriptions written as the result of emergency services. People were up to five times more likely to receive an opioid prescription for a dental problem if they were treated in an emergency department (ED) rather than in a dental office.

Although the overall national opioid prescribing rate has declined, there were still about 43.3 opioid prescriptions for every 100 Americans in 2020 (declined from 72.4/100 in 2006) (Centers for Disease Control and Prevention 2021b). More than 17% of Americans had at least one prescription filled, with an average of 3.4 opioid prescriptions per patient. Per prescription, the average amount was more than 45.3 morphine milligram equivalents (MME) (Centers for Disease Control and Prevention 2019d). Studies suggest that ongoing nonmedical use of prescription opioids is highly correlated with medical use of prescription opioids (McCabe et al. 2017).

Until recently, dentists have been among the leading prescribers of opioids in the United States. In 2016, the number of opioid prescriptions by U.S. dentists was 35.4 per 1,000 of the U.S. population (Suda et al. 2019). Although the codeine derivative dihydrocodeine was the only opioid prescribed by English dentists, a recent study of prescribing patterns in the United States and England showed that U.S. dentists prescribed a range of opioids that contain hydrocodone (62.3%), codeine (23.2%), oxycodone (9.1%), and tramadol (4.8%) (Suda et al. 2019). A national survey of dentists enrolled in the National Dental Practice-Based Research Network found a majority of dentists rarely prescribed opioids, and only 11% of dentists prescribed opioids only or opioid-combination products (18%) to less than half of their patients in the preceding 6 months (McCauley et al. 2018). National estimates regarding opioid prescription rates by dentists vary from 3% per visit based on 2013–2015 Medical Expenditure Panel Survey data (Steinmetz et al. 2017) to 6–10% using 2013–2015 Medicaid data (Obadan-Udoh et al. 2019; Janakiram et al. 2019b).

The problem of opioid use has been exacerbated not only by increases in the number of legitimate prescriptions written, but also by inappropriate prescribing practices (Manchikanti et al. 2012). Prescriptions written following oral surgery averaged 28 opioid pills, with 15 pills (54%) left over, on average. Unused prescription pain medications are a reason for concern because they are sometimes diverted, and given or sold to other people (Maughan et al. 2016). When refill prescriptions are issued, they are made within 30 days (21%), 90 days (29%), and 180 days (35%), in cases where at least one concurrent prescription already existed (McCauley et al. 2016). In some cases (40–80%), the source of the repeat prescription also was a dental visit (Gupta et al. 2018a).

Some studies have reported on disparities in opioid prescription practices following dental visits for members of specific demographic populations. For example, women with a dental diagnosis were more likely to receive opioid prescriptions than were men, and African Americans and non-Hispanic whites were twice as likely to receive opioid prescriptions than Hispanics (Janakiram et al. 2018). When dental patients fill an opioid prescription, the likelihood of an opioid overdose may increase for both themselves and their family members. Findings from a recent study reported that the risk of an opioid overdose increases more than twofold when patients filled opioid prescriptions within 3 days (5.8 overdoses per 10,000 dental procedures) compared to when they did not (2.2 per 10,000 procedures) (Chua et al. 2021).

The likelihood of dental patients' receiving opioid prescriptions increased by nearly 36 percentage points if they were undergoing invasive procedures, compared to noninvasive procedures (Obadan-Udoh et al. 2019). Tooth extractions, root canal treatment, and implant procedures are the top three procedures frequently associated with opioid prescriptions in the dental clinic (McCauley et al. 2016; Steinmetz et al. 2017; Obadan-Udoh et al. 2019); and in one study up to 94% of patients received opioid prescriptions following third molar surgical extractions (Maughan et al. 2016). Of note, nonsurgical or noninvasive dental visits (such as diagnostic evaluations) accounted for one-third of all opioid prescriptions. This discrepancy between the probability of pain and the probability of a prescription warrants further research (Gupta et al. 2018b; Obadan-Udoh et al. 2019).

Prescription Opioids and Periodontitis

NHANES 2009–2014 analyses of prescription opioid use, which classify lifetime use into three categories (no use/short-term use, medium-term use, and long-term use) did not find any significant association between these levels of opioid use and periodontitis. Nor did analyses examining use within the past month reveal any relationship between opioid use and periodontitis. Mean levels of periodontal attachment loss (more indicative of past disease), but not pocket depth (more indicative of active disease), were found to vary by opioid use status. Mean attachment loss levels were 1.60 mm, 1.76 mm, and 1.71 mm among those reporting no use/short-term use, medium-term use, and long-term use of opioids, respectively. Mean pocket depth was 1.41 mm, 1.39 mm, and 1.36 mm among those reporting no use/short-term use, medium-term use, and long-term use of opioids, respectively.

Prescription Opioids and Dental Caries

Because opioids suppress pain, it may be easier for people who use opioids to ignore early signs of tooth decay, which can progress to more substantial tooth destruction, possible abscess, and tooth loss. In 2011–2016, opioid use was associated with a higher mean number of missing teeth. Among those reporting no use or only short-term use of opioids, the mean number of missing teeth was three. The number of missing teeth increased to five and to nearly seven for those reporting medium-term and long-term use of opioids, respectively (Centers for Disease Control and Prevention 2021c). The proportion of persons missing 20 or more teeth was 9.7%, 23.1%, and 26.3% among those reporting no use/short-term use, medium-term use, and long-term use of opioids, respectively. Among those with at least one missing tooth, there was no differential in missing the upper back teeth by opioid use status; however, long-term opioid users had a significantly higher proportion than those with no use/short-term opioid use missing at least one upper front tooth (54.6% vs. 35.3%), a lower front tooth (39.5% vs. 22.6%), or a lower back tooth (91.5% vs. 82.4%). For past 30-day use status, opioid users in 2011–2016 had a significantly higher mean number of decayed teeth than nonusers overall (1.1 vs. 0.7). Similarly, persons reporting past 30-day use of opioids had a significantly higher prevalence of decayed teeth than nonusers overall (35.0% vs. 23.4%).

Prescription Opioids and Other Oral Conditions

Opioids directly affect oral health by reducing salivary flow, resulting in xerostomia and increasing risk of dental caries (Riemer and Holmes 2014). Opioid use also is associated with bruxism and abnormal changes in oral tissues (Shekarchizadeh et al. 2013).

A 2019 study indicated that most people who misuse prescription opioids also binge drink, which in turn may have oral health consequences. One in five opioid overdose deaths and ED visits are estimated to involve alcohol as well (Esser et al. 2019).

Drugs used to treat opioid use disorder also can impact oral health. Methadone, a drug used to treat opioid addiction, can suppress salivary secretion (Gotrick et al. 2004). Methadone is typically administered in a concentrated sucrose-syrup preparation (Krantz and Mehler 2004), which provides an oral environment ripe for the development of tooth decay. Methadone use (and sometimes abuse) seems to favor a high intake of sugars and low intake of fiber, which could increase plaque accumulation and dental decay (Brondani and Park 2011).

Heroin

Overview

Heroin is an opioid drug that is highly addictive with several immediate health effects, including dry mouth (Box 3). Substance use disorders involving heroin affected 0.3% of persons, or 745,000 individuals aged 12 years and older in 2019. Substance use disorders involving heroin affected 0.3% of persons, or 745,000 individuals aged 12 years and older in 2019. Among these people, about 400,000 also reported pain reliever misuse (Substance Abuse and Mental Health Services Administration 2020a). Notably, as a result of efforts to limit access to prescription drugs, people misusing prescription opioids have turned increasingly to illicitly cultivated and manufactured heroin. In 2018 more than 14,000 people died from a drug overdose involving heroin, which is a rate of more than four deaths for every 100,000 Americans. Overdose death rates by states can vary substantially (Centers for Disease Control and Prevention 2021d).

Heroin and Periodontal Disease

Based on unadjusted analyses using data from the 2009–2014 NHANES, heroin use was significantly associated with periodontitis, regardless of severity, among a national sample of U.S. adults (Centers for Disease Control and Prevention 2021a). A prevalence of 39.3% was found among those who had never used heroin, compared with 43.4% among those who reported ever having used the substance.

Box 3. Heroin

Heroin is an opioid drug made from morphine, a natural substance taken from the seed pod of the various opium poppy plants grown in Southeast and Southwest Asia, Mexico, and Colombia. Heroin can be a white or brown powder, or a black sticky substance known as black tar heroin. People inject, sniff, snort, or smoke heroin. Heroin enters the brain rapidly and binds to opioid receptors on cells located in many areas, especially those involved in feelings of pain and pleasure and in controlling heart rate, sleeping, and breathing.

Note: Prescription opioid pain medicines such as OxyContin® and Vicodin® have effects similar to heroin.

Short-term effects

- Feeling a “rush”
- Dry mouth
- Warm flushing of the skin
- Heavy feeling in the arms and legs
- Nausea and vomiting
- Severe itching
- Clouded mental functioning
- Going back-and-forth state of being
- Conscious or semiconscious

Long-term effects

- Insomnia
- Collapsed veins for people who inject the drug
- Damaged tissue inside the nose for people who sniff or snort it
- Infection of the heart lining and valves
- Abscesses (swollen tissue filled with pus)
- Constipation and stomach cramping
- Liver and kidney disease
- Lung complications, including pneumonia
- Mental disorders (e.g., depression)
- Antisocial behavior
- Personality disorder
- Sexual dysfunction for men
- Irregular menstrual cycles for women

Source: National Institute on Drug Abuse (2021b).

The prevalence of severe periodontitis was 7.4% among people who never used heroin and 19.2% among people who had ever used heroin. When respondents were stratified on the basis of levels of cigarette smoking, however, the difference in periodontitis by heroin use status disappeared, thereby casting doubt on the relationship between heroin use and periodontal disease.

Consistent with the above results, mean levels of gum attachment loss and pocket depth varied by heroin use status within unadjusted analyses, but disappeared completely when stratified within the levels of current and former cigarette smoking status. Among never cigarette smokers, however, there was significant variation of pocket depth by heroin use status (1.33 mm, 1.55 mm, and 2.23 mm, respectively, among never, former, and current heroin users).

Heroin and Dental Caries

Analyses of NHANES 2011–2016 data for U.S. adults indicated that the mean number of carious teeth was 0.7, 1.3, and 3.2 among never, former, and current heroin users, respectively. The percentage with at least one carious tooth was 24.4%, 36.5%, and 67.0% among never, former, and current heroin users, respectively, within unadjusted analyses. In stratified analyses considering use of tobacco, this relationship remained significant only among current cigarette smokers, with prevalence of any carious tooth being 42.1%, 43.3%, and 70.3% among never, former, and current heroin users, respectively. Among all heroin users, the percentage with 20 or more teeth missing was 6.7%, 9.7%, and 15.7% among never, former, and current heroin users, respectively. Status of heroin use, moreover, did not appear to be related to patterns of tooth loss.

Methamphetamine and Other Stimulants

Overview

Although most methamphetamine available in the United States is synthesized illegally, the substance is classified by the U.S. Food and Drug Administration as a prescription-only, Class II drug. Licit methamphetamine is marketed in the form of methamphetamine hydrochloride under the brand name Desoxyn® and is still prescribed in numbers of significance, primarily for the treatment of attention-deficit/hyperactivity disorder, according to the U.S. Drug Enforcement Administration's Diversion Control Division. Adderall is an addictive prescription stimulant with effects similar to methamphetamine that is heavily prescribed and very popular among college students and young adults (Lakhan and Kirchgessner 2012; Vrecko 2015). In 2019, an estimated 2 million persons reported using methamphetamine in the past year (Substance Abuse and Mental Health Services Administration 2020a). The average age of people who were new methamphetamine users in 2016 was about 23 years old (National Institute on Drug Abuse 2019b), and use has been increasing (Substance Abuse and Mental Health Services Administration 2020b). The number of fatal overdoses involving methamphetamine more than tripled between 2011 and 2016 (Hedegaard et al. 2018).

Illicit methamphetamine is swallowed as a pill, smoked, snorted, or injected following dilution in water. Because of its physical appearance, the illegally synthesized crystalline methamphetamine is known under the street name of crystal meth. Methamphetamine is an exceedingly addictive CNS stimulant with established neurotoxicity. Its small molecular size makes it more potent than amphetamine because larger amounts of the drug are able to cross the brain-blood-barrier (Panenka et al. 2013). A well-known oral complication linked to heavy methamphetamine use is colloquially called "meth mouth" and consists of a specific pattern of tooth decay with a characteristic black color that varies in severity and affects primarily anterior teeth (Figure 10). Oral health providers can refer patients with signs suggestive of methamphetamine use for behavioral counseling and treatment. This classic feature, however, may not be present in all people who use methamphetamine; therefore, the absence of this pattern should not rule out methamphetamine use.

Methamphetamine and Periodontal Disease

Although the prevalence of periodontitis is high among people who use methamphetamine, the frequency of methamphetamine use appears to have a minimal impact on the severity of periodontal disease (Spolsky et al. 2018). Between 2009 and 2014 in the United States, the prevalence of any periodontitis among adults aged 30 years or older was 38.5% for never users of methamphetamine, 51.2% for former users, and 64.7% for current users (Centers for Disease Control and Prevention 2021a).

Figure 10. Substantial and distinctive pattern of dental caries resulting from methamphetamine use

Source: Shutterstock.

The prevalence of severe periodontitis was 7.3%, 10.8%, and 17.9% for never, former, and current methamphetamine users, respectively. When analyses were conducted after stratifying for levels of cigarette smoking status, however, no significant association was observed between methamphetamine use and severe periodontitis in any of the groups of current, former, and never cigarette smokers.

Stratified analyses of pocket depth measurements revealed that results were statistically significant only among never cigarette smokers, but not among former or current cigarette smokers. Mean pocket depth among never cigarette smokers was 1.3 mm, 1.4 mm, and 1.8 mm, respectively, among never, former, and current methamphetamine users. That an association was seen for both indexes (pocket depth and attachment loss) only among never cigarette smokers, and not among current or former smokers, may suggest differential immunologic or inflammatory responses to methamphetamine in smoke-naïve versus smoke-exposed tissues, with never smokers likely being more sensitive to exposure.

Methamphetamine and Dental Caries

Within analyses of 2011–2016 NHANES data for U.S. adults aged 20 years and older, the mean numbers of carious teeth were 0.7, 0.9, and 3.5, respectively, among never, former, and current methamphetamine users. Within stratified analyses conducted of the National Health and Nutrition Examination Survey 2011–2016 by cigarette smoking status, the relationship between methamphetamine use and mean number of carious teeth retained statistical significance among current cigarette smokers, but not among never or former cigarette smokers. The mean numbers of carious teeth among current cigarette smokers were 1.5, 1.5, and 3.8 among never, former, and current methamphetamine users, respectively. The proportion of individuals with at least one carious tooth was significantly higher for people who used methamphetamine than among nonusers; prevalence was 23.9%, 32.9%, and 59.6% for never, former, and current methamphetamine users, respectively. This relationship was statistically significant regardless of cigarette smoking status. The proportion of adults with at least one carious tooth among never, former, and current people who used methamphetamine were as follows by cigarette smoking status: current cigarette smokers (41.3%, 46.7%, and 61.7%, respectively); former cigarette smokers (21.9%, 24.9%, and 62.0%, respectively), and never cigarette smokers (19.4%, 22.5%, and 45.3%, respectively). In a previous study that compared demographically similar individuals from NHANES participants found that methamphetamine users are at least twice as likely to have untreated caries and four times more likely to have any dental caries (Shetty et al. 2016).

In the specific caries disease pattern recognized in methamphetamine users, surface involvement is greatest for the maxillary central incisors, followed by maxillary posterior premolars and molars (Shetty et al. 2015; Shetty et al. 2016). Shaner (2002) described a pattern of severe tooth decay around the gum lines of the front teeth as a hallmark of chronic methamphetamine use. In 2011–2016 NHANES data, the proportion of adults missing 20 or more teeth was about 7% for never or former users and 11% for current methamphetamine users. Current methamphetamine users had a significantly higher proportion than never methamphetamine users of missing upper front teeth (48% vs. 32%), but did not differ in their pattern of missing teeth for lower front, lower back, or upper back teeth.

Methamphetamine use appears to encourage the development of caries by suppressing salivary flow, increasing its acidity, and reducing the ability of saliva to clear sugars from the oral cavity. It also may alter the composition and volume of dental plaque. Methamphetamine overstimulates the sympathetic nervous system, depletes norepinephrine and dopamine, and alters serotonin, acetylcholine, and glutamate, which increases the demand for adenosine triphosphate. To compensate for this, methamphetamine users consume more carbohydrates, such as carbonated soft drinks (Richards and Brofeldt 2000). Frequent acidic beverage intake, combined with poor oral hygiene and lack of dental treatment, may increase the incidence of dental caries among methamphetamine users (Saini et al. 2005).

Methamphetamine and Other Oral Conditions

Methamphetamine use leads to surplus levels of dopamine, creating excessive neuromuscular activity that can result in lockjaw and intensified bruxism (McGrath and Chan 2005). When smoked or rubbed in the mouth, the caustic ingredients of methamphetamine bathe the oral cavity, irritating and burning oral tissues (McGrath and Chan 2005; De-Carolis et al. 2015). This leads to significant oral ulcerations and infections. The severe dry mouth that accompanies the use of methamphetamine also leads to, or worsens, oral ulceration.

Cocaine

Overview

Cocaine is a highly addictive stimulant drug derived from the leaves of the coca plant native to South America. In the United States, cocaine is a Schedule II drug under the Controlled Substances Act, unlike the majority of countries where cultivation, transport, sale, and possession are illegal. Cocaine is available in a liquid preparation for topical use for local anesthesia in hospitals and surgical centers. However, it is not offered by prescription, and recreational use is illegal. Cocaine is consumed by snorting the fine, white crystal powder through the nose, rubbing it into the gums, dissolving the powder and injecting it into the bloodstream, or smoking heated crystal "rocks" and inhaling the vapors. To increase profits, dealers may stretch cocaine by adding cornstarch, talcum powder, or flour to the powder, and increase its potency by also adding amphetamine or synthetic opioids. The increasing number of overdose deaths among people who use cocaine appears be related to fentanyl-tampered cocaine (Nolan et al. 2019).

Among all U.S. adults, 0.8% used cocaine in the past 30 days, while 2.1% reported use in the past 12 months. According to the 2019 National Survey on Drug Use and Health, about 2.1 million persons aged 12 years and older currently used cocaine, including the 778,000 people who reported currently using crack (Substance Abuse and Mental Health Services Administration 2020a).

Although its effect lasts for about an hour, the nontopical use of cocaine results in complex actions, including blocking the reuptake of dopamine, norepinephrine, epinephrine, and serotonin in the synaptic cleft (Richards and Laurin 2019). Similar to amphetamines, cocaine directly affects oral health by reducing salivary flow (Antoniazzi et al. 2017) and promoting bruxism (Riemer and Holmes 2014).

Cocaine and Periodontal Disease

Analyses of a national sample of U.S. adults 20 or older within NHANES 2009–2014 revealed that the prevalence of periodontitis was significantly higher among ever versus never cocaine users for both any periodontitis (46.4% vs. 38.1%) and severe periodontitis (10.9% vs. 7.0%). Based on lifetime use with individuals classified as never, former, and current cocaine users, the prevalence of severe periodontitis was 7.0%, 9.7%, and 15.8% among the three groups, respectively.

Consistent findings were seen when examining mean gum attachment loss levels and gum pocket depth by cocaine use status. Unadjusted results among a national sample of U.S. adults aged 30 years or older from the 2009–2014 NHANES revealed that mean attachment loss levels were 1.53 mm, 1.65 mm, and 1.92 mm for never, former, and current cocaine users, respectively. Similarly, mean pocket depth levels were 1.40 mm, 1.44 mm, and 1.69 mm for never, former, and current cocaine users, respectively. After controlling for the effect of cigarette smoking within the separate groups of current, former, and never cigarette smokers, however, no difference in severe periodontitis existed by cocaine use status.

Cocaine and Dental Caries

Cocaine is acidic, whether in its powdered or solid form. Mixed with saliva, it coats teeth with an acidic solution that can break down tooth enamel, possibly leading to dental erosion and tooth loss. Data from 2011–2016 NHANES showed that mean numbers of carious teeth were 0.7, 0.9, and 1.1 among never, former, and current cocaine users, respectively. No significant differences for caries experience were seen by cocaine use status in any of the groups of current, former, and never cigarette smokers. There also were no differential patterns of tooth loss by cocaine use status.

Cocaine and Other Oral Conditions

Cocaine blocks dopamine's transporter, which prevents the reuptake of dopamine and other catecholamines at the presynaptic terminal and explains a variety of movement disorders associated with cocaine use (Deik et al. 2012). One of the most visually dramatic movement disorders induced by cocaine is buccolingual dyskinesia (Riday et al. 2012), which can look like tooth grinding or an oral dyskinesia called boca torcida, or twisted mouth (Saini et al. 2013).

Constriction of blood vessels in the mouth can cause ulceration of the gums, gum recession, and loss of underlying bone. Users who snort cocaine risk damaging tissues between the nose and palate because blood flow and nutrients to the area are reduced as nasal blood vessels constrict. Over time, nasal tissue ulcerates, dies, and sloughs off to form a palatal perforation (Younai 2017).

Pain, Mental Illness, and Substance Use in Relation to Oral Health

Today a great deal more is known, compared to 20 years ago, about issues of pain, mental health, and substance use in relation to oral health. Tobacco represents a well-documented major threat to oral health as well as to overall health, and the potential negative impact of alcohol—especially in combination with tobacco—also is now better understood. The misuse of methamphetamines and their negative impact on oral health also have been well characterized. The emergence of e-cigarettes and other nicotine delivery devices, as well as the legalization of recreational marijuana, are creating new concerns regarding potential harm to oral health.

Because pain is a major factor in the development of addiction and sometimes part of the clinical manifestation of mental illness, greater emphasis on responsible and compassionate management of pain is needed in both the teaching and practice of all health professions, including dental medicine. Unfortunately, treatment for dental pain has been a significant gateway to opioid addiction. More than 48 million people have minimal or no access to dental services, and as a result, hospital EDs have become the point of care for many painful dental emergencies, often resulting in the prescribing of antibiotics and potentially addictive pain medications, without addressing the actual cause of pain (Hocker et al. 2012). Further complicating the situation, individuals often return for the same intervention at the next painful flare-up, even though most EDs may not have dentists on staff, and ED staff may not have the training and/or instrumentation to appropriately manage dental emergencies (Wall et al. 2014; Hsia and Niedzwiecki 2017). Recurrent and persistent dental pain promotes the use of addictive prescription pain medications and may drive people to seek illicit street drugs, which now have become easier to obtain than prescription pain medications.

It is notable that first-time exposure to opioids for many occurs in the context of oral surgery for third molar (wisdom tooth) extractions, placing vulnerable adolescents and young adults at risk. Prescription opioids exhibit high rates of conversion to addiction, particularly in individuals younger than aged 25 years. Heroin use among young adults aged 18–25 years has doubled in the past decade, and findings from one large study point indicate that prescription of opioids before high school graduation is independently associated with a 33% increase in future misuse after high school in those with little drug use (Centers for Disease Control and Prevention 2015; Miech et al. 2015; Substance Abuse and Mental Health Services Administration 2018; Gupta et al. 2018b).

Major interventions to curtail the prescription of opioids are ongoing, and early indicators are showing significant changes in prescription practices (Levy et al. 2015). The American Dental Association (ADA) issued stronger recommendations regarding prescribing, and states have introduced Prescription Drug Monitoring Programs (PDMP) requiring that dentists use guidelines to identify patients at high risk for SUD. At the same time, the equivalent, or superior, effectiveness of other pain medications for various procedures is being recognized by the profession (Moore et al. 2018; National Academies of Sciences 2019a).

Given the complex relationships among pain, mental health, substance use, and economic and social status in American society, the fragmentation of health care into silos of care—general medical, mental, and oral health—frequently is counterproductive. Although comorbidities and co-occurring conditions are known to impact health outcomes, disease-oriented practice continues to be the prevailing approach to care (Fortin et al. 2007; Ritchie 2007). This is true in spite of treatment guidelines warning that when patients are treated for multiple conditions with multiple drug regimens, the likelihood increases for adverse drug interactions and even antagonistic treatment effects (Starfield 2006). The extent of this disconnect between what a patient needs and what current health care provides is reflected in the fact that an estimated 80% of Medicare spending is directed toward patients with four or more chronic conditions (Wolff et al. 2002). The interrelationships among mental health, substance use, and oral health reflect mounting evidence that mental illness and substance use disorders will increasingly impact the oral health of millions of Americans.

Chapter 2: Advances and Challenges

Over the past 2 decades, major strides have been made in our scientific understanding of pain, mental health, and substance use disorders. In addition, new initiatives in treatment and practice and an expansion of tobacco control policies have been implemented to improve oral health and overall health outcomes. In 2016, *Facing Addiction in America: The Surgeon General's Report on Alcohol, Drugs, and Health,* highlighted mental illness and substance use disorders as common, recurrent, and treatable conditions (U.S. Department of Health and Human Services 2016). This was followed by other Surgeon General publications to bring awareness to opioids, marijuana use, and suicides (U.S. Department of Health and Human Services 2018a; 2019; U.S. Department of Health and Human Services and National Action Alliance for Suicide Prevention 2021). Along with the recent smoking cessation report from the Surgeon General (U.S. Department of Health and Human Services 2020b), this collection of information and perspectives provides better understanding of these issues and should help to identify actions that can improve oral health and well-being.

Science and Understanding

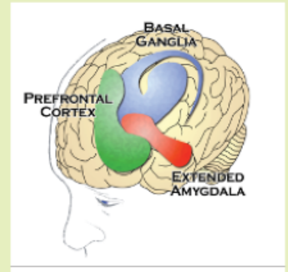
During the past 20 years, notable progress has been made in understanding pain, mental illness, and substance abuse, as well as how many of these conditions are classified. For example, the adoption of the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-5*) (American Psychiatric Association 2013) brought less subjectivity and increased concordance and agreement on the classification of substance use disorders, permitting greater clarity regarding appropriate diagnoses and treatments of mental health conditions. Additional findings provide valuable insight into how and where future efforts can be directed to clarify the complicated and interrelated underpinnings of pain, mental illness, substance use, and oral health. Advances in the science of substance addiction are giving us a much better understanding of individual vulnerability to drugs of abuse and how addiction establishes its hold on the brain and the body (Crews et al. 2007; Sinha 2008).

Because so many instances of addiction—in particular opiate addiction—begin with the experience of pain, researchers have focused their efforts on elucidating the biological underpinnings of chronic pain and distress, including the genetics and epigenetics of persistent pain. Substance use disorder also may be triggered by an underlying mental illness, such as depression or post-traumatic stress disorder. Teasing out the neural circuits and behavioral correlates of these associations has allowed us to create better treatment modalities for those with mental illness and substance use disorders.

Addiction

Addiction is a process involving the initiation of drug use, followed by intermittent to regular consumption, and, frequently, advancement to an entrenched substance use disorder. These disorders can involve compulsive and relapsing behaviors focused on drug seeking and drug use, even in the face of adverse consequences to personal health and social relationships. Consequently, overcoming these physically-based behaviors requires tremendous courage as well as support. Moreover, the changes in the brain that occur with established drug use are long-lasting and persist beyond the time of substance use. Central to the state of addiction is the participation of brain circuits involved in reward/saliency, motivation/drive, conditioning/habits, inhibitory control/executive function, and those circuits that shape mood and control reactions to pain and stress (Box 4) (Volkow and Morales 2015; Volkow et al. 2016; Volkow and Boyle 2018).

Box 4. Brain areas affected by substance use



- **The basal ganglia,** which play an important role in positive forms of motivation, including the pleasurable effects of healthy activities like eating, socializing, and sex, are also involved in the formation of habits and routines. These areas form a key node of what is sometimes called the brain's "reward circuit." Drugs overactivate this circuit, producing the euphoria of the drug high; but with repeated exposure, the circuit adapts to the presence of the drug, diminishing its sensitivity and making it hard to feel pleasure from anything besides the drug. The nucleus accumbens is a component of the basal ganglia.
- **The extended amygdala** plays a role in stressful feelings like anxiety, irritability, and unease, which characterize withdrawal after the drug high fades and thus motivates the person to seek the drug again. This circuit becomes increasingly sensitive with increased drug use. Over time, a person with substance use disorder uses drugs to get temporary relief from this discomfort rather than to get high.
- **The prefrontal cortex** powers the ability to think, plan, solve problems, make decisions, and exert self-control over impulses. This is also the last part of the brain to mature, making teens most vulnerable. Shifting balance between this circuit and the reward and stress circuits of the basal ganglia and extended amygdala make a person with a substance use disorder seek the drug compulsively, with reduced impulse control. Some drugs like opioids also affect other parts of the brain, such as the brain stem, which controls basic functions critical to life, such as heart rate, breathing, and sleeping, explaining why overdoses can cause depressed breathing and death.

Source: National Institute on Drug Abuse (2018b).

Recent scientific research has increased our understanding of the mechanisms that link mental illness and substance use. Substance use disorders (SUDs) now are understood as a form of mental illness. Mental illness may precede substance use, or substance use may aggravate an existing mental health vulnerability. To explain this comorbidity, three major hypotheses have been proposed: (1) drug use serves the purpose of alleviating latent symptoms of mental illness, (2) drug use leads to changes in the brain that promote mental illness, and (3) both mental illness and substance misuse share neurobiological mechanisms that promote vulnerability (Hooten 2016).

People dually diagnosed with a mental illness and an SUD are common, notably among those affected by bipolar or schizophrenic disorder (Kessler et al. 1997). For dually diagnosed individuals, the prognosis for either illness alone is better when the treatment plan addresses both the mental health issue and the SUD (Bradizza et al. 2006). Dually diagnosed patients also may have higher rates of infections, heart and lung disease, stroke, and cancer. Many of these diseases share common risk factors for poor oral health outcomes (see Section 3). Prominent examples of comorbid health issues include tobacco-related cancers, cellulitis, hepatitis C, and endocarditis linked to infections caused by the use of contaminated hypodermic needles, or HIV associated with needle-sharing or engaging in unsafe sex (Moss and Munt 2003; Klevens et al. 2012; El-Bassel et al. 2014).

Although the neurobiological basis of dually diagnosed patients is still not sufficiently understood, it is plausible to assume that shared neurobiological mechanisms and associated biological vulnerabilities, genetic or otherwise, provide the basis for this frequent comorbidity of mental illness and SUDs (Markou et al. 1998; McEwen 2000).

Microbiome

Scientists are beginning to explore the role of the oral microbiome in the interplay of mental health, substance use, and oral health and disease. Use of illicit psychoactive substances directly affects oral physiology, often manifesting as xerostomia (dry mouth) and its sequelae for the teeth and periodontal tissues. Drugs also indirectly affect oral health through poor nutrition and oral hygiene.

The degree to which changes in the composition of microbial communities as well as metagenomic changes mediate the health consequences of smoking or other substances of abuse has emerged as an especially significant area of research.

As covered in greater detail in Section 6, changes in the composition of the oral microbiome, such as those linked to the health conditions covered here, are important because microorganisms do not stay within the confines of the oral cavity, but can translocate to other parts of the body, causing infection and inflammation at extra-oral sites. Oral bacteria have been detected at extra-oral locations associated with atherosclerosis, Alzheimer's disease, pregnancy complications (preterm birth, stillbirth, and neonatal sepsis), respiratory infections, rheumatoid arthritis, gastrointestinal disorders (appendicitis, inflammatory bowel disease, and esophageal and colorectal cancers), and organ inflammation and abscesses (Han and Wang 2013). Multiple oral species can be detected concurrently at such sites, possibly due to coaggregation, enabling them to "travel" as a conglomerate (Han et al. 2009; Warren et al. 2013; Thomas et al. 2019).

Cigarette smoke is one type of exposure that directly influences oral bacteria. These smoke-linked toxicants perturb the ecology through a range of influences, including antibiotic effects, oxygen deprivation, and others (Macgregor 1989). If smoking results in the loss of beneficial oral species, the resultant pathogen colonization can promote disease, for example, periodontitis (Nociti et al. 2015). Recent in vitro studies also suggest the possibility that large amounts of swallowed, dead bacteria from the mouth may stimulate several pathogens in the gut (necrotrophy) and create a new phenotype by upregulation of bacterial virulence genes (necrovirulence) that demonstrate increased cytotoxicity (Rodriguez Herrero et al. 2017).

In a recent study of 1,204 U.S. adults, Wu et al. (2016) assessed the relationship of cigarette smoking with the oral microbiome, using DNA from oral wash samples. The overall oral microbiome composition differed between "current" and "former and never" smokers. Current smokers had significantly lower relative loads of *Proteobacteria* compared to never smokers. Comparing current to never smokers, *Capnocytophaga*, *Peptostreptococcus,* and *Leptotrichia* were depleted, while *Atopobium* and *Streptococcus* were enriched in current as opposed to never smokers, suggesting cigarette smoke to create an environment that favors either strict or facultative anaerobes over strict aerobes. Oral bacteria also are first to come into contact with cigarette smoke as it enters the human body and therefore may play an important role in degrading accompanying toxic compounds (Rodgman and Perfetti 2013; Wade 2013).

Anaerobic, acidic, and/or selectively toxic environments aside, smoking also is known to affect human immunity (Sopori 2002), which in turn can influence the host's ability to resist the colonization by pathogens. It is known that the chemotactic mobility and phagocytic function of oral polymorphonuclear leukocytes is diminished in smokers (Noble and Penny 1975; Kenney et al. 1977; Archana et al. 2015). Because these cells are critical to the host defense against pathogens, smoking inherently promotes a more pathogen-friendly oral ecosystem. Several of Wu and colleagues' (2016) findings are consistent with progression toward a diseased state: *Neisseria* and *Eikenella* are depleted in oral mucosa from periodontitis patients (Mager et al. 2003), and *Streptococcus* species are more abundant in oral sites characterized by progressing periodontal disease than in healthy oral sites (Yost et al. 2015).

This new perspective appears to be applicable to substances of abuse in general. With respect to cocaine, the sensitivity to cocaine also appears to be modulated by the gut microbiota. For example, animals with experimentally reduced gut bacteria show an enhanced sensitivity to cocaine reward (Kiraly et al. 2016). Although more remains to be done, there have been important advances in understanding the relationships of persistent pain, mental health, and substance use to oral health.

Treatment and Practice

Interdisciplinary and Collaborative Care

The commonly practiced separation of both behavioral health services and dental health care from medical health care systems has impeded the advancement of science, health promotion, and patient care (Crowley and Kirschner 2015). Although there has been progress in providing advanced training in interprofessional or collaborative practice between primary medical care and oral health practice, there has been little progress in incorporating behavioral health, specifically activities to address comorbidities of mental health and substance misuse into oral health practice. Dentists entering the workforce today are not always prepared for working collaboratively with behavioral health services, and dental schools may need to enhance the interdisciplinary experiences they provide to ensure this training.

Although interdisciplinary approaches to treating and managing pain, mental illness, substance use disorders, and oral disease are not yet generally regarded as the standard of care, some progress has occurred with respect to interdisciplinary workforce development, as well as improvement in the communication tools for sharing patient information across disciplinary silos (Zorek and Raehl 2013). Accreditation standards for all health profession programs, including dental education, mandate training in interprofessional care teams, although specific competency requirements in interprofessional collaborative practice are not yet in place. Interprofessional care ultimately requires connecting care providers through shared communication platforms and electronic health records (EHRs). The HITECH Act of 2009, which authorized a voluntary program to certify health information technology (IT) and incentives for the use of health-IT, represented an important early and ongoing effort toward system integration (Blumenthal 2009; Adler-Milstein and Jha 2017). Although full-scale integration of oral health and medical and behavioral health has not yet occurred, some innovative strategies to address this goal have been launched. For more information see Section 4 and Section 6.

Prescription Opioids in the Management of Acute Dental Pain

The most common opioid medications prescribed by dentists are immediate-release (IR) opioids, specifically hydrocodone 5 mg, oxycodone 5 mg, and codeine 30 mg (Mutlu et al. 2013; McCauley et al. 2016; Obadan-Udoh et al. 2019). IR opioids are the prescription drugs most likely to be given away or sold (Manchikanti et al. 2012), and dentists are the primary source of leftover prescriptions for nonmedical use (McCabe et al. 2013). A review found that among opioids obtained by patients following a variety of different types of surgical procedures, 42–71% of all tablets went unused (Bicket et al. 2017). In one small study, 54% of opioids prescribed remained unused 3 weeks after dental surgery (Maughan et al. 2016). Obviously, dentists have a significant role to play in curbing the U.S. opioid epidemic (Denisco et al. 2011; National Academies of Sciences 2017a). More than half of dental providers reportedly wrote opioid prescriptions that exceeded the recommended 3 days' supply for acute dental pain (Koppen et al. 2018).

In 1998, U.S. dentists were the most frequent specialty prescribers of all IR opioid prescriptions, accounting for at least 15% of these prescriptions (Rigoni 2003). By 2002, dentists had dropped to the second-ranked specialty prescribers (12%) of IR opioids (Denisco et al. 2011). From 2007 through 2012, there was a steady decline (-5.7%) in opioid prescribing rates by dentists, to 18.5 million prescriptions, 6.4% of all opioid prescriptions written (Levy et al. 2015).

Although this downward trend in dentists' opioid prescribing rates is laudable, the wide variation in the quantity of opioids prescribed (10–40 tablets per patient) is still alarming, given their limited efficacy for acute dental pain management and their well-established risk profiles (Moore and Hersh 2013; Mutlu et al. 2013; Moore et al. 2018; Reynolds and Schwarz 2019; Kiang et al. 2020). The implementation of state electronic prescription drug monitoring programs (e-PDMPs) to track the frequency of prescriptions written for controlled substances and the amounts dispensed represents a major advance in addressing substance use disorders.

Begun in the early 2000s, e-PDMPs have rapidly been introduced throughout the country to facilitate timely ascertainment of prescription record information on controlled substances to deter abuse, doctor shopping, and diversion. They offer a convenient way for doctors, dentists, and nurse practitioners to obtain data regarding prescriptions issued by other health providers, including information of the pharmacy filling the prescription—thereby allowing prescribers to find out whether patients are already receiving controlled substances from other sources. Following the implementation of e-PDMPs, several evaluation studies have reported significant reductions in the prescribing rates for Schedule II opioids, including reductions of more than 30% observed immediately following the launch of the program with the effect maintained in the second and third years following implementation (Green et al. 2012; Sansone and Sansone 2012; Worley 2012; Bao et al. 2016). The past 2 decades also have seen a significant increase in efforts to promote appropriate diversion of unused prescription painkillers through pharmacy-based drug disposal programs, as well as broad community efforts such as the U.S. Drug Enforcement Administration's National Prescription Drug Take Back Day with opioids the majority of controlled drugs collected by such take-back sites (Welham et al. 2015; Maughan et al. 2016; Egan et al. 2017; U.S. Department of Justice 2021).

A persistent challenge in addressing opioid prescription practices in oral health care is that a higher proportion of younger patients continue to receive opioid prescriptions following dental visits (McCauley et al. 2016; Gupta et al. 2018a; 2018b). The trend also shows an increase in the quantity of opioids prescribed over time (Steinmetz et al. 2017; Gupta et al. 2018b), which is a source of concern, given the risk of opioid-naïve patients developing drug dependence (Larach et al. 2020) and the incidence of drug diversion among this population subgroup (McCabe et al. 2013). Of particular concern has been the increasing rate of opioid prescriptions provided by dentists to patients aged 11 to 18 years. In 2010, the rate was about 100/1,000 young persons compared to 166/1,000 by 2015 (Gupta et al. 2018b), representing a 65% increase during a period when opioid overdose deaths were substantially rising (Hedegaard et al. 2020).

Similar to other health professions, dentistry has come to grips with the prescription opioid epidemic and adjusted its practices to reduce the unintended impact of opioid use initiated as a result of dental prescriptions. However, as described in the Surgeon General's 2018 Spotlight on Opioids, primary prevention of opioid abuse will require the development and implementation of better pain management strategies (U.S. Department of Health and Human Services 2018a).

Smoking/Tobacco Use Cessation in Dental Practice

The dental workforce is committed to curbing the negative health consequences of tobacco and related products. A visit to the dentist provides a teachable moment during which members of the dental team can relate oral health and systemic problems associated with tobacco use and provide evidence-based brief interventions to patients who use tobacco (Stevens et al. 1995; Gordon and Severson 2001; McBride et al. 2003; Flocke et al. 2014). These interventions include asking patients at every visit about their tobacco use, relating oral health findings to the patient's tobacco use, providing direct and nonjudgmental advice to quit, and providing immediate access to cessation resources and pharmacotherapy for people interested in quitting (Tobacco Use and Dependence Guideline Panel 2008).

Dentistry has long recognized the connection between tobacco use and oral health and the value added by oral health professionals in addressing the issue (Cohen et al. 1989; Secker-Walker et al. 1989). The American Dental Association, the American Dental Hygienists' Association, the FDI World Dental Federation, and the World Health Organization Framework Convention on Tobacco Control all promote the provision of evidence-based tobacco cessation treatment by dental professionals.

Several models have recently emerged for using the Screening, Brief Intervention, and Referral to Treatment (SBIRT) approach for delivering evidence-based tobacco treatment (U.S. Department of Health and Human Services 2020b). *A Clinical Practice Guideline for Treating Tobacco Use and Dependence: 2008 Update* (Clinical Practice Guideline Treating Tobacco Use and Dependence Update Panel 2008) advocates for the use of "5 As": Ask, Advise, Assess, Assist, and Arrange. The "Ask" step includes regular assessment and documentation of tobacco use status at every visit. "Advise" encourages all practitioners to relate tobacco use to the presenting complaint and provide nonjudgmental advice to quit. "Assess" focuses on the patients' readiness to quit, and "Assist" offers assistance to aid those efforts. This assistance can take the form of behavioral counseling (including a quit plan, which includes a quit date), cessation resources, referral to treatment, and pharmacotherapy, as indicated. Finally, practitioners should "Arrange" to follow up with patients on or around their quit date and at the next dental visit to check on progress (Clinical Practice Guideline Treating Tobacco Use and Dependence Update Panel 2008; Fiore and Jaen 2008). Motivational interviewing techniques offer a promising strategy for working with patients not yet ready to quit. This method is designed to help patients move through ambivalence related to action steps for health (Miller and Rollnick 2012).

Three similar, although more streamlined, SBIRT models are “Ask-Advise-Refer” (Hudmon et al. 2004), “Ask-Advise-Assist” (Gordon et al. 2010a), and “Ask-Advise-Connect” (Vidrine et al. 2013). In these programs, practitioners provide the same “Ask and Advise” steps as described in the “5 As” approach. However, instead of assessing the patients’ readiness to quit, providing assistance to quit, and arranging for follow-up care, practitioners refer patients to tobacco cessation resources in one of three ways: (1) provide a traditional referral to the patient who must initiate the call to the quitline or provider; (2) fax a referral to the cessation resources provider, who then contacts the patient; or (3) electronically transmit the referral data, which enables a quicker response. These abbreviated approaches accommodate professionals’ lack of training or time and reimbursement issues. They also serve to overcome dentists’ lack of confidence in prescribing tobacco cessation medication (Gordon et al. 2010a; Romito et al. 2012).

Over the past 2 decades, telephone quitlines have emerged to help individuals quit using tobacco; these are toll-free, telephone-based tobacco cessation services that offer an evidence-based, efficient, centralized, and highly scalable way to support tobacco cessation. They are available in all 50 states, the District of Columbia, Puerto Rico, and Guam. The North American Quitline Consortium reported that since 2009, an estimated 515,000 users, or about 1.2% of all smokers, have contacted quitlines each year (North American Quitline Consortium 2009; 2011).

Although dental teams can be effective in providing tobacco cessation treatment, significant improvements are needed to increase the adoption, implementation, and maintenance of evidence-based tobacco cessation treatments into routine dental care (Gordon et al. 2006). Barriers for individual practitioners include lack of training and confidence that they can be effective, and fear of offending patients (Hu et al. 2006). Systems-level barriers include lack of time in the busy dental office and reimbursement issues. The absence of integrated EHRs also remains a problem in most practices (Rindal et al. 2013; Neumann et al. 2019). Continuing education for dentists, dental hygienists, and other members of the dental team can overcome barriers at the individual level. However, more concerted efforts are needed to disseminate evidence-based training in tobacco treatment at a profession-wide level through the use of engaging and effective educational methods.

Each member of the dental team can play a role in the delivery of evidence-based tobacco treatment, reducing the burden on any one individual and creating a supportive environment for patients (Gordon and Severson 2001; Gordon et al. 2009). Because of the length of the hygiene visit and its focus on education and prevention, dental tobacco cessation interventions rely primarily on the dental hygienist to deliver the majority of program content (Gordon and Severson 2001; Gordon et al. 2009). The dentist then reinforces the advice to quit and can play an important role in the discussion about, and provision of, a prescription for pharmacotherapy (e.g., nicotine replacement therapy, varenicline, bupropion) (Gordon et al. 2009). Front office staff may collect information about patients’ tobacco use and update the information regularly. In addition, front office staff can initiate referrals to tobacco quitlines and provide information on other cessation resources (Severson et al. 1998; Andrews et al. 1999; Gordon and Severson 2001; Gordon et al. 2006; Gordon et al. 2007; Gordon et al. 2009; Gordon et al. 2010b).

A 2012 Cochrane Collaboration systematic review evaluated the effectiveness of dental office-based interventions for tobacco treatment (Carr and Ebbert 2012). The review included 14 randomized clinical trials conducted between 1998 and 2010. Based on more than 10,500 participants, tobacco interventions in the dental setting were considered effective with outcomes similar for smokeless tobacco users and smokers. A subsequent review of studies published between 2012 and 2019 (Ajiboye et al. 2019) identified six additional randomized trials of tobacco interventions for smokers or smokeless tobacco users (Shelley et al. 2011; Carpenter et al. 2012; Garvey et al. 2012; Walsh et al. 2012; Virtanen et al. 2015) and one long-term follow-up (Nohlert et al. 2013). The findings from five of these studies reinforced the conclusions from the earlier Cochrane Collaboration’s meta-analysis (Carr and Ebbert 2012). Only one study conducted in a National Dental Practice-Based Research Network reported equivocal results (Houston et al. 2013).

Including Other Substance Use Screenings and Referral in Dental Practice

Although a review of studies has found some evidence that brief interventions can reduce alcohol consumption by harmful drinkers compared to minimal or no intervention in primary care settings where the health care visit was not focused on alcohol treatment (Kaner et al. 2018), little is known about such interventions in dental care settings. However, building on the model of tobacco screening and cessation activities in dentistry, some studies have investigated the effectiveness of dentists and dental hygienists in screening for alcohol use disorders (Neff et al. 2013; Roked et al. 2015; Neff et al. 2015a; Neff et al. 2015b; Ntouva et al. 2019). The results of these studies suggest that oral health professionals offering screening for alcohol misuse and brief advice is feasible. Three recent surveys concluded that most dentists and dental students felt strongly that they should screen for heavy drinking and use of illicit drugs (McNeely et al. 2013; Paquette et al. 2015; Bakr et al. 2016). These surveys also indicated that dental students lack knowledge and skills to intervene with patients, and although most dentists screen patients for alcohol and drug use, few provide treatment, referral, or follow-up (McNeely et al. 2013; Paquette et al. 2015; Bakr et al. 2016). Self-reported barriers to providing these services echo those for tobacco—lack of training, reimbursement, and systems-level support (McNeely et al. 2013).

Although screening and referral for alcohol misuse seems practical and a natural extension in oral health care, challenges remain with implementation, including the development of practice guidelines, and provider acceptance. Oral health care providers generally believe they lack appropriate training and their patients are unwilling to discuss substance abuse with them (Miller et al. 2006). Time pressures in a fee-for-procedure dental office have been cited as a major barrier; however, oral health providers have indicated some interest in receiving more training about substance use and more information about referral resources and local treatment facilities (McNeely et al. 2013). Ntouva and colleagues (2018) reported that providers increased their knowledge, positive attitudes, alcohol screening, and brief intervention behaviors by participating in a program to provide these skills. Parish and colleagues (2015) found that 50% of U.S. dentists did not agree that screening for substance abuse was their role, although dentists aged 50 years or younger, and especially women dentists, did. Furthermore, those in group practices were more willing to screen for substance use than those in private practice. There is virtually no research on the effectiveness of screening and treatment for other SUDs (e.g., methamphetamine abuse) that have both oral and systemic health effects, and which dental practitioners are in a prime position to identify and address.

Integrating Social History and Trauma-Informed Care into Oral Health Care

The concept of trauma-informed care is largely unknown in the practice of dentistry, although social adversity, violence, and abuse are known for their association with poor overall health outcomes. Mental health issues, including depression, anxiety, low self-esteem, and suicide are associated with trauma, especially early-life trauma. In this respect, traumatic experiences during childhood that bear on health outcomes are increasingly addressed in clinical practice under the framework of trauma-informed care (Purkey et al. 2018; Sweeney et al. 2018; Cutuli et al. 2019). This concept is based on the findings of the Adverse Childhood Experiences (ACE) Study, which investigated the long-term impact of 10 different types of childhood trauma/abuse on physical, mental, and social-emotional well-being of more than 17,000 individuals from their adolescence to adulthood. The more ACEs reported, the greater the chances for negative physical, mental, and/or social-emotional health outcomes in adulthood. Of note, persons with six or more ACEs were at risk for living 20 years less, on average (Hammett et al. 2019).

Trauma and stress linked to adverse life experiences also have a negative impact on oral health. A study by Crouch and colleagues (2018) found that people with ACE scores of four or more were less likely to receive adequate dental care as children. Children with any number of ACEs were more likely to have significant tooth decay (Bright et al. 2015). This effect on oral health appears to be greater if multiple ACEs are confirmed. In adolescents, a single incident of abuse was associated with a twofold incidence of poor oral health (Annerback et al. 2014). ACEs also were associated with waiting longer than 2 years between dental visits and with having more than six teeth extracted. These negative oral health outcomes appear to have a cumulative effect. A higher ACE score is associated with a higher prevalence of dental disease (Akinkugbe et al. 2019). Other areas of trauma and abuse impact oral health outcomes, including elder mistreatment/abuse and intimate partner violence (Fanslow et al. 1998; Gaioli and Rodrigues 2008; Russell et al. 2012; Murphy et al. 2013). Intimate partner violence is involved in more than half of female homicides, and intentional injury to the head, including the oral cavity, is more frequent than to any other body part (Breiding and Armour 2015).

Taking a social history is not considered a standard of care in dentistry, but given the integral role of dental services in health care delivery, a change in practice is needed. The significance of a social history is illustrated by the fact that abuse and neglect play an important role in an individual's oral health (Chaffin et al. 1996).

When adolescent and adult patients present themselves with higher than usual rates of dental disease, as well as other suggestive findings such as xerostomia or bruxism, substance abuse or mental illness may be a likely reason. A social history can help identify social parameters underlying observed disease. A social history includes inquiries about substance use, diet, exercise, travel, and sexual orientation, and captures important information about social support, lifestyle, education, and the occupational and recreational aspects of a patient's life. It helps a provider understand the patient's sources of support, social habits, interests, resilience, and personal coping mechanisms.

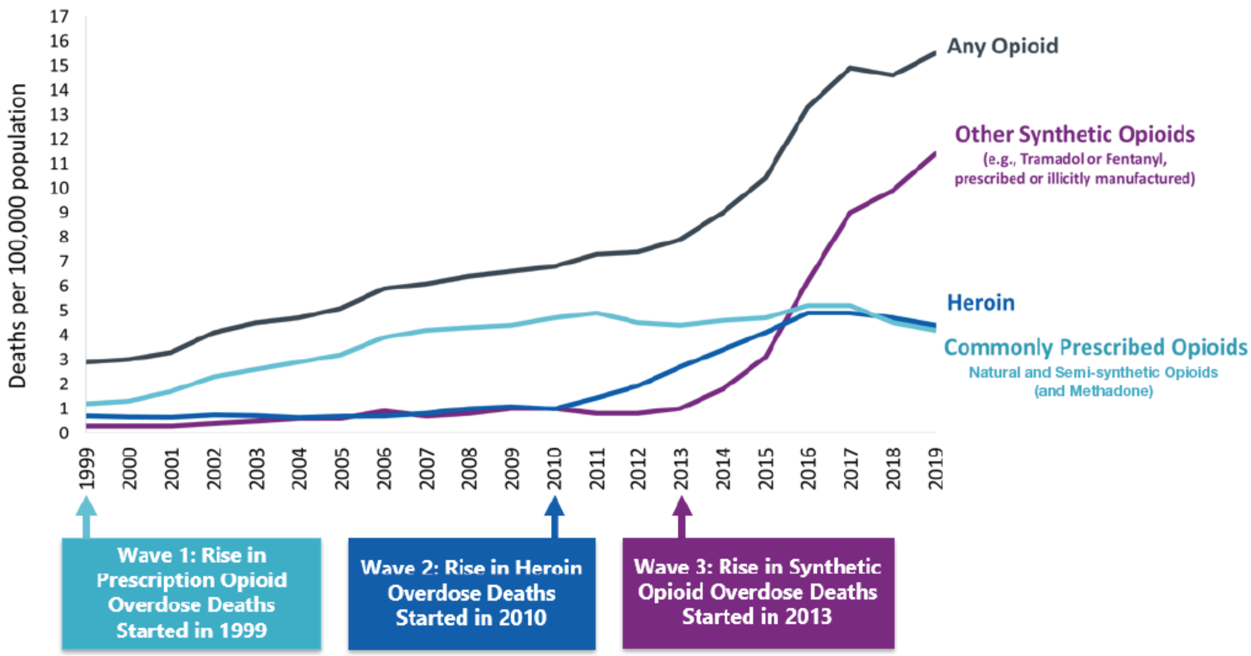
There are challenges to routine inclusion of a social history in clinical care, along with recognition and appropriate response to social determinants of disease. The limited time typically assigned in the dental office for taking a social history seems to work against yielding meaningful information. Consequently, the patient's perception of the encounter may feel judgmental or even accusatory. Considering the prevalence of mental illness and substance abuse, high levels of sensitivity and care are needed in taking social histories, and training is essential to appropriate use of this information. The history provides an opportunity to refer patients in need to additional health services as well as to reduce the chance of contributing to the opioid crisis. For the oral health profession to realign itself in the framework of primary care, a commitment to the taking of a social history will be necessary as part of any encounter in the dental office.

Public Health Initiatives to Reduce Opioid-Involved Overdose Fatalities

Our country continues to struggle with an opioid epidemic that has claimed the lives of more than 841,000 Americans since 1999, with more than 70% of these deaths involving an opioid (Centers for Disease Control and Prevention 2021e). The rise in overdose deaths can be described in three distinct waves beginning in the late 1990s with overdose deaths involving prescription opioids, a second wave involving heroin, followed by significant increases in overdose deaths involving synthetic opioids, particularly with illicitly prepared fentanyl (Figure 11). In 2019, 70,630 drug involved overdose deaths were reported in the United States (Mattson et al. 2021). Opioids—mainly synthetic opioids (other than methadone)—currently are the main driver of drug overdose deaths. Opioids were involved in 49,860 overdose deaths in 2019, which amounted to almost 70% of all drug overdose deaths (Mattson et al. 2021). The overwhelming majority of fatalities are traceable to the illicit use of extremely potent opioids, such as fentanyl and its analogs, used alone or in combination with heroin. Fatal overdoses involving synthetic opioids continue to rise. Deaths involving synthetic narcotics other than methadone, but including fentanyl and fentanyl analogs, have continued to rise, with 36,359 overdose deaths reported in 2019 (National Institute on Drug Abuse 2021c). Provisional figures for 2020 indicate a significant acceleration of overdose deaths in 2020 (Centers for Disease Control and Prevention 2020a; National Center for Health Statistics 2021).

In 2017, the U.S. Department of Health and Human Services declared opioid misuse a public health emergency and announced a 5-Point Strategy to Combat the Opioid Crisis (U.S. Department of Health and Human Services 2018b). In early 2018, the Surgeon General released a Spotlight on Opioids, bringing attention to addiction and calling for action to mitigate the opioid crisis (U.S. Department of Health and Human Services 2018a). Other recent public health campaigns have sought to increase awareness of the availability of overdose treatments such as naloxone (Narcan®), which counteracts the respiratory depression associated with opioid overdose and is the drug of choice for administration by laypersons (Box 5).

Figure 11. Three waves of the rise in opioid overdose deaths



Source: Centers for Disease Control and Prevention, National Center for Health Statistics (2020b).

NARCAN® (*naloxone HCl*) Nasal Spray is an FDA-approved nasal form of naloxone indicated for the emergency treatment of opioid overdose. Designed to be easily applied with minimal training, available from a pharmacist without prescription, and covered under most insurance plans, naloxone is an essential tool that can be used by family, friends, and first responders. In most states, people who are at risk or know someone who is at risk for opioid overdose can go to a pharmacy or community-based program to get the drug, be trained on its administration, and learn about what to do afterward. Laws in effect in most states protect health professionals from civil and criminal liabilities for prescribing the antidote, and Good Samaritan laws shield persons who administer naloxone (O'Donnell et al. 2017a; O'Donnell et al. 2017b).

Naloxone is already carried by many first responders, such as emergency medical technicians (EMTs) and police officers. The Surgeon General now recommends that more individuals, including family, friends, and those who are personally at risk for an opioid overdose, also keep the drug on hand (Box 5). Several federal and state agencies have developed toolkits and widely disseminated important information in support of the initiative (Guy et al. 2017). Oral health providers should have naloxone available in their offices.

Box 5. U.S. Surgeon General's Advisory

"I, Surgeon General of the United States Public Health Service, VADM Jerome Adams, am emphasizing the importance of the overdose-reversing drug naloxone. For patients currently taking high doses of opioids as prescribed for pain, individuals misusing prescription opioids, individuals using illicit opioids such as heroin or fentanyl, health care practitioners, family and friends of people who have an opioid use disorder, and community members who come into contact with people at risk for opioid overdose, ***knowing how to use naloxone and keeping it within reach can save a life.****"*

Source: U.S. Department of Health and Human Services Office of the Surgeon General (2018c).

Avoiding Addictive Drug Exposure During Brain Development

The subject of exposure to addictive drugs during human brain development—prenatal up to about age 25—deserves greater attention from the public as well as prescribing professionals because the personal and societal impact of exposure in this age bracket may be far greater than has been assumed (Chambers et al. 2003). The oral health workforce can play a significant role in helping to curb prenatal exposure to drugs, appropriately managing the prescription opioid pain medications to women of childbearing age and avoiding prescription opioids for persons younger than 25 years. These vulnerable time periods in brain development when it comes to exposure to drugs of addiction remain largely unrecognized by the practicing community.

The concept of sensitive periods of development during the human life span assumes that there are stages of development during which individuals are more responsive to particular environmental inputs and more readily acquire or are predisposed to risky behaviors, including drug seeking. Sensitive periods are believed to be associated with elevated plasticity in the brain, potentially allowing the use of drugs to exert a long-term impact on neural development (Andersen 2003; Knudsen 2004; Andersen 2005).

Most drugs of abuse cross the placental barrier and can have long-lasting effects on fetal brain development that may differ from those attributable to drug exposure during adolescence or adulthood. Even paternal exposure to substances of abuse, such as cocaine, during spermatogenesis can affect brain development of the fetus (Killinger et al. 2012; Vassoler et al. 2013). Table 2 provides an overview of the literature regarding the long-term consequences for growth, behavior, cognition, language, and achievement as the result of fetal exposure during pregnancy to frequently used substances. The under-recognized middle school years represent another prime risk period concerning the use of these drugs and later behaviors (Gallimberti et al. 2015). This is particularly relevant for dentistry because adolescence can coincide with dental surgical interventions such as tooth extractions or surgeries in support of orthodontic treatment.

Improving Practitioner Attitudes Toward People with Chronic Pain, Mental Illness, and Substance Use Disorders

Problems with oral health, such as dental caries, oral abscesses, periodontal diseases, mucosal dysplasia, xerostomia, tooth wear, and tooth loss are among the most common comorbidities associated with mental illness and substance misuse (Baghaie et al. 2017; Yazdanian et al. 2020). With very limited coordination of care among medical, dental, and behavioral health services, including attention to shared concerns about safety and self-harm, oral health is often an afterthought when it comes to providing comprehensive care. However, the magnitude of oral health problems among many with mental illness and SUDs calls for increased attention by clinicians and policymakers to work toward an effective integration of dental services into programs for these populations (Hewson and Wray 2012; Hanson et al. 2019).

Features of the U.S. health care system, including misaligned incentives and the lack of adequate preparation for health care professionals, sometimes serve to shape current treatment practices in less than desirable ways. Commonly held attitudes toward people with persistent pain, mental illness, and substance use disorders also contribute to the lack of support for high-quality mental illness and addiction services. Primary care practitioners are less likely to refer patients with mental illness than those without mental illness to appropriate specialty services, perhaps because of assumptions that their problems are primarily psychological (Corrigan et al. 2014).

People with severe oral disease, as well as those with mental illness and SUDs, frequently are stigmatized and marginalized, and poverty can make matters worse (Room 2005). Furthermore, the combinations of any of these conditions remain seriously undertreated (Yang et al. 2017). In 2001, a review of studies revealed that the public perceives people with SUDs as most likely dangerous and unpredictable and blames them for their conditions (Link et al. 2001). Health care providers, including dentists, are not immune to social biases shared by the public at large. One study from this review looked at the experiences of patients with SUDs when they visited a dentist.

Table 2. Long-term consequences for growth, behavior, cognition, language, and achievement resulting from maternal exposure to frequently used substances during pregnancy.

	Growth	Behavior	Cognition	Language	Achievement
Alcohol	**Strong Effect**	**Strong Effect**	**Strong Effect**	Effect	**Strong Effect**
Nicotine	No consensus	Effect	Effect	Effect	Effect
Marijuana	No effect	Effect	Effect	No effect	Effect
Opiates	No effect	Effect	No consensus	Lack of data	Lack of data
Cocaine	No consensus	Effect	Effect	Effect	No consensus
Methamphetamine	Lack of data	Lack of data	Lack of data	Lack of data	Lack of data

Source: Behnke and Smith (2013).

Some felt misunderstood when they were blamed for their poor oral health, made to feel inferior, unworthy, or unwilling to change their behavior. Some felt providers withheld pain medications from them, assuming they were drug seekers. Patients with SUDs also felt that extractions were favored over restorative care. They reported minimal interaction and limited eye contact with their providers, along with rushed appointments and insufficient time for anesthesia to take effect. A minimal amount of time was allotted to answering their questions. Patients had more positive experiences and were more likely to return if their providers were perceived as kind, caring, patient, courteous, gentle, helpful, and fair (Brondani and Park 2011; Tsai et al. 2019). Twenty years later, similar health care provider attitudes appear to impact stigma, including willingness to prescribe new treatments and to develop clinical relationships (Shreffler et al. 2021).

Since 2000, additional progress and protections have been implemented through the Americans with Disabilities Act (1990), the Amendments Act (2008) and, most notably, the Affordable Care Act of 2010. However, public perceptions of persistent pain, mental health, and SUDs seem to have been influenced only marginally by these legislative actions (National Academies of Sciences 2016). Four years later, the National Academies of Sciences, Engineering, and Medicine reiterated that "despite the high rates of comorbidity of physical and behavioral health conditions [which include mental health and substance-related and addictive disorders] integrating services for these conditions into the American health care system has proved challenging" (National Academies of Sciences 2020b). The statement from the 2020 Workshop on Key Policy Challenges and Opportunities to Improve Care for People with Mental Health and Substance Use Disorders further indicated that "part of the explanation lies in a historical legacy of discrimination and stigma that made people reluctant to seek help and also led to segregated and inhumane services for those suffering from chronic pain, mental health, or substance use disorders. Furthermore, health insurance programs often provided limited coverage of services for these disorders compared to services for other conditions" (National Academies of Sciences 2020b).

Advances in the Policy Landscape

Important progress in tobacco control measures has been made over the past 20 years. The number of states with comprehensive smoke-free laws (statutes that prohibit smoking in indoor areas of worksites, restaurants, and bars) increased from zero in 2000 to 26 in 2010 and 27 in 2015 (Tynan et al. 2016). The percentage of the U.S. population impacted by these laws increased to 47.8% in 2010 and 49.6% in 2015 (Tynan et al. 2016). As of 2021, 28 states, accounting for 61.2% of the U.S. population are now covered by these laws (American Nonsmokers Rights Foundation 2021). Policies also have been implemented to reduce the sale and consumption of tobacco on military facilities, including the elimination of tobacco's tax-free status in commissaries and on-base establishments, which led to a 25–35% price increase in 2016 (Secretary of Defense 2016). At the population level, there have been new campaigns such as "Truth," "*Tips from Former Smokers*®," and "The Real Cost"—all developed within the past decade—which focus on the harmful consequences of smoking (Centers for Disease Control and Prevention 2020c; U.S. Food and Drug Administration 2020a; The Truth Initiative 2021). Some of these campaigns have featured oral health conditions, such as the association between smoking and tooth loss.

Intensified efforts also have been made to increase insurance coverage for smoking cessation. As of December 31, 2018, 17 states covered all nine evidence-based cessation treatments for all traditional Medicaid enrollees, up from 6 states at the end of 2008 (Centers for Disease Control and Prevention 2021f). Within the past 2 decades, several key federal legislative acts have addressed comprehensive tobacco control and prevention. An example includes the Family Smoking Prevention and Tobacco Control Act, which gave the U.S. Food and Drug Administration (FDA) the authority to regulate the design, manufacture, and marketing of tobacco products. In 2016, FDA finalized a rule providing the agency the foundation to review manufacturing processes, ingredients, and health risks of all tobacco products including electronic nicotine delivery systems (ENDS) (U.S. Food and Drug Administration 2016). The rule was later clarified regarding the agency's enforcement policies on flavored e-cigarettes (U.S. Food and Drug Administration 2020b). Moreover, several states have made significant advances in tobacco prevention and control policies, some of which exceed those at the federal level. For example, several states have prohibited the sale of flavored tobacco products, including menthol (Campaign for Tobacco Free Kids 2020). Several states and jurisdictions have raised the minimum age of sale for tobacco products to 21 years (Berman 2016; Ali et al. 2020), and federal law also now sets the minimum age of sale for tobacco products, including e-cigarettes, to 21 years.

Chapter 3: Promising New Directions

A few promising initiatives suggest that a better future is at hand in relation to the challenging issues of pain, mental health, substance use, and their impact on oral health. Better coordination of health services, based on electronically integrated health information systems, and the emerging models of interprofessional collaborative care and trauma-informed care are beginning to emerge that will be essential to that future. Adjustments to predoctoral and continuing dental education programs will prepare and adapt future and current dental practitioners for the necessity to achieve the integration of dental and behavioral care into a comprehensive health system.

Equally important will be new and creative approaches to eliminate the stigma attached to substance use and mental health challenges. Major steps are being taken by organized dentistry and the professional providers of oral health care to address the most prevalent substance use—tobacco—which also has perhaps the most well-documented direct effects on oral health. Changes in prescribing practices related to opioids and emerging interest among dental professionals in addressing the problems of substance use among their patients will result in a more vigilant and responsive health system in terms of prevention as well as treatment. Finally, new research in pain management is suggesting novel ways to use currently available solutions to ameliorate the need for opioids.

Interprofessional Care and Integrated Health Information Systems

Major development of educational resources in support of team-based or collaborative care have occurred in the past 10 years, and these have laid a foundation for the integration of all health professions (Health Professions Accreditors Collaborative 2019). Accreditation standards issued by the Commission on Dental Accreditation (CODA) calling for the training of dental students in interprofessional practice will increasingly produce a dental workforce better positioned to navigate the fragmented care practices that dominate health care today (Commission on Dental Accreditation 2019). Strong consideration given by dental school admission committees to recruit diverse student bodies will result in a stronger, culturally and linguistically competent dental workforce in the future.

The U.S. Department of Health and Human Services Oral Health Strategic Framework for 2014–2017 outlined the importance of advancing oral health to improve the overall health of Americans, including the need to accelerate the integration of mental and dental health care delivery systems into primary care. The Framework acknowledged the importance of detecting oral health problems in behavioral health care settings, and how to effectively link behavioral health clients to oral health care through SAMSHA supported initiatives (U.S. Public Health Service Oral Health Coordinating Committee). However, renewed efforts are needed with the emphasis on managing the oral health of patients affected by mental health issues and substance use to improve the health of people with mental illness and substance use disorder (SUD). A small number of federally qualified health centers with co-located primary care, dental care, and behavioral health are beginning to explore this important issue to determine how they can improve efforts to strengthen integration leading to better health outcomes (Langelier et al. 2019a). Integrated electronic health records (EHRs) within these community health centers form the foundational elements needed to make health integration a more functional possibility and a promising new direction for oral health.

To support dental practitioners in bridging professional divides and to offer them a real-time view of patient health status, the implementation of a shared, bidirectionally operable EHR is a necessary communication tool. As of this date, four U.S. dental schools—Columbia University, University of North Carolina, University of Mississippi, and University of Utah—have already implemented such communication tools. That number is small, but it is an important beginning.

Several community health centers provide co-located primary care that includes oral health, behavioral health, and pharmacy services. For patients with chronic illnesses and comorbid mental illnesses or substance use disorders, having access to these services offers a greater likelihood that their medical, dental, and behavioral health needs will be addressed (Langelier et al. 2019b). Services that promote a high level of care coordination, either through co-location of services or increasingly via telehealth, will gain traction by delivering a better care value and greater convenience for patients.

Integrating Tobacco Cessation Efforts into Dental Practice

Promising strategies for improving curricula in support of tobacco cessation include adding opportunities for simulated practice in talking with and providing support to patients about tobacco and other substances. Professional accrediting bodies should explore national standards for clinical competencies, and more experiential opportunities for building clinical skills are needed to increase self-efficacy and demonstrate proficiency related to support for tobacco cessation. Consideration also should be given to graduate, postgraduate, and continuing education courses to include comprehensive information regarding new and emerging tobacco products (such as e-cigarettes), tactics to address patients' receptivity to tobacco treatment in the dental setting, skill development in brief intervention models, information about tobacco quitlines and other cessation resources, as well as methods for referral and in-depth training regarding pharmacotherapy and prescribing practices.

Tackling Opioid Prescription and Diversion

In the wake of the national opioid crisis, initially triggered by over-prescription of opioid analgesics, several states have proposed opioid prescribing guidelines (Lutz 2019). In 2018, the American Dental Association (ADA) strengthened its policy on opioid prescribing to include mandatory continuing education with a special focus on drug overdose, chemical dependency, drug diversion, statutory limits on opioid dosage, and limiting the duration to 7 days for prescriptions for acute dental pain (American Dental Association 2018). Because many adolescents and young adults may have their first exposure to prescription opioids for orofacial pain relief, special attention is now being given to prescribing practices related to the surgical extraction of third molars (wisdom teeth) (Barzel and Holt 2019).

Managing pain during the 2 to 3 days following dental surgery is the primary driver for the use of prescription opioid analgesics until the pain is reduced enough to be managed with nonprescription analgesics. However, evidence that opioids are essential is not fully persuasive

(Moore et al. 2018). Yelp reviews by patients and caregivers describing their experiences with prescribed opioids report lower endorsement scores as opposed to those receiving other forms of pain control (Graves et al. 2018). In a clinical trial (Daniels et al. 2011) and in a systematic review of research studies (Moore et al. 2018), acetaminophen co-administered with ibuprofen was found to be superior to opioid-containing regimens and was associated with lower rates of adverse events.

Stepping into that gap, nonopioid acute pain management approaches should include the preventive use of anti-inflammatories such as nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and the administration of longer-acting local anesthetics. Administering NSAIDs such as ibuprofen prior to administering local anesthesia can both delay postoperative pain and reduce its intensity (Dionne and Cooper 1978; Dionne 1986). The use of ibuprofen at a 400-mg dose has been found to be superior to higher doses of acetaminophen, aspirin, and aspirin in combination with codeine or dihydrocodeine in an oral surgery model (Cooper et al. 1977; Jain et al. 1986; Forbes et al. 1990). Although acetaminophen alone is generally less effective than NSAIDs in the treatment of postoperative dental pain due to its lack of anti-inflammatory activity, when combined with NSAIDs, acetaminophen provides additive analgesic effects to further reduce pain following dental surgery. In contrast, opioids provide only minimal additive analgesic effects when combined with long-acting local anesthetics. Such agents include tetracaine, bupivacaine, etidocaine, and ropivacaine. Bupivacaine hydrochloride is the only long-acting local anesthetic solution available in a dental cartridge under the brand names of Marcaine, Sensorcaine, and Vivacaine. Administered either before or immediately following surgery, long-acting local anesthetics can reduce postoperative pain when compared to standard short-term anesthetics such as 2% lidocaine (Gordon et al. 2010c). Adding NSAIDs to the regimen has been found to offer superior pain relief to patients compared to those who received a standard local anesthetic and an opioid afterward (Dionne et al. 1984).

Based on this body of evidence, the use of opioids is no longer considered a therapeutic option of choice for dental postoperative pain. Instead, a flexible strategy is recommended to optimize pain relief based on patient response. A long-acting local anesthesia and NSAID should be administered prior to, or immediately following, a dental surgical procedure. A prescription dose of an NSAID such as ibuprofen, ketoprofen, or naproxen should then be continued for 2 to 3 days following the procedure using the recommended dosing interval for the NSAID. Acetaminophen can be coadministered or dosed alternately with the NSAID for improved pain relief. In cases where pain is not adequately addressed by these regimens, patients can be provided with a 3-day prescription of Ultracet®, an opioid that has a lower potential for misuse (Moore et al. 1998). This approach individualizes pain relief therapy within the currently available medications for outpatient settings and reduces the risk of harm to individual patients as well as to society at large.

One example of how health care providers and insurers can have a significant impact on opioid prescription practices for dental pain is realized in the context of a collaboration of dental practitioners with Aetna, a large health insurance company with an extensive claims database. Frequent opioid prescribers were identified, along with prescriptions from reports of dentists and oral surgeons. Aetna then sponsored educational efforts at professional meetings and developed guidelines for responsible opioid prescription practices. When CVS Health acquired Aetna, the newly combined company developed an innovative program to reduce opioid use following dental surgery. This successful partnership is described in more detail in Box 6.

U.S. National Pain Strategy

Following the 2011 Institute of Medicine report, *Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education, and Research* (Institute of Medicine 2011a), which highlighted pain as a significant public health problem, calling for cultural transformation in pain prevention, care, education, and research, the Assistant Secretary for Health (HHS), asked the Interagency Pain Research Coordinating Committee to create and provide oversight of a National Pain Strategy (NPS) (National Institutes of Health 2021a). The overarching vision of NPS is to decrease the prevalence of pain across its continuum from acute to high-impact chronic pain and its associated morbidity and disability across the life span by stimulating critical research and the extension of federal efforts to include public-private partnerships.

Box 6. How can an insurance company partner with other organizations to reduce the use of opioids for dental pain?

As a large health insurance company, Aetna has contacts with patients, dentists, oral surgeons, and pharmacists, as well as societies of oral health professionals. Recognizing the risks surrounding the misuse of opioids and that opioids are prescribed by dentists to treat dental pain, Aetna worked with its partners to help reduce opioid prescribing. These initiatives included identifying frequent opioid prescribers from dentist and oral surgeon claims data and communicating with these professionals. Aetna also sponsored educational efforts, including a symposium to provide education on new guidelines for prescribing pain medication provided at the 104th National Dental Association Annual Convention in 2017.

In a 2018 business venture, CVS Health acquired Aetna, and the combined company now provides innovative programs to help reduce opioid misuse. To address the need for proper disposal of unused opioid pills, CVS Health launched a safe medication disposal program. This program includes more than 2900 disposal units in CVS Pharmacy locations nationwide, more than 1000 disposal units donated to police departments across the country, and participation in the U.S. Drug Enforcement Administration's National Prescription Take Back Day. Since its inception, more than 2.5 million pounds of unwanted medications have been placed in the disposal units. The company also created Pharmacists Teach, an innovative community education program, and collaborated with Discovery Education, a leader in standards-aligned digital curriculum and professional learning for K-12 classrooms. Through these programs, CVS Pharmacy has educated more than 800,000 students and parents about the dangers of prescription opioid misuse and abuse.

This longer-term initiative intends to produce significantly better pain prevention and care of persons affected by pain. One important element of the NPS that represents a promising new direction is better coordinated efforts focusing on gaining control of the U.S. opioid crisis (National Institutes of Health 2021b).

Chapter 4: Summary

Our understanding and treatment of mental illness, substance use disorders, and their relationship to oral health have undergone important changes over the past 20 years. Significant changes have occurred with respect to the demographics of disease. Americans increasingly suffer from a host of chronic health conditions, including some cancers and HIV/AIDS, which are now increasingly considered chronic conditions because of remarkable advances in treatments. Chronic multimorbidity is not unusual, although its treatment is hampered by the fragmentation of care that dominates the U.S. health system. Since the 2000 Surgeon General's report on oral health, great progress has occurred in science and technology, but the health system has not been able to deliver substantial improvements in the integration of oral health and overall well-being for many Americans, particularly those with chronic pain, stress, mental health issues, and substance use disorders. From 1990 to 2010, levels of chronic disease comorbidity have increased, and mental illness and substance use disorders have become a major source of disability, exceeding that associated with medical conditions (U.S. Burden of Disease Collaborators 2013).

Taken together, mental illness and substance use disorders are common, recurrent, and treatable. But these illnesses can present complex challenges to oral health. For example, oral health may be worsened by the direct effects of substance misuse, and it can simultaneously be impacted by medications prescribed for the treatment of underlying problems that may have led to substance use. Overcoming some of these challenges will require a fully functional, integrated electronic health record that supports real-time bidirectional information flow to identify and manage patients with comorbid medical, dental, and mental health issues (see Figure 5, Section 6).

The misuse of controlled or illegal substances often begins with a search for the relief of pain, either physical or mental. A toothache is a major motivator for people to seek dental care and is why people with acute dental pain often turn to emergency departments for relief. Recent research has improved the understanding of the relationships among pain, addiction, mental health disorders, and oral health status. Unfortunately, medical and oral health providers too often are reluctant to inquire about these issues with their patients. In addition, their perceptions and biases can impact care delivery. This may be partly related to limited knowledge or understanding of the effect of substance dependence and mental health disorders on oral health. The repeated nature of dental visits and the establishment of an ongoing relationship with patients build a foundation of trust that can offer novel opportunities for primary care in the oral health setting.

The safety net in place for dental emergencies is far from optimally effective. Too often, emergency settings have been the point of care for dental pain, where administering antibiotics and pain medications with addictive potential, without addressing the root cause from a dental perspective, was common. The recent Covid-19 pandemic has demonstrated that pain linked to dental conditions should not be expected to be managed in already overcrowded emergency departments. The pandemic further amplified what was already known—significant levels of dental disease exist in low-income and vulnerable populations, often severely affecting those with multiple morbidities, including people with mental health and substance use issues.

In the last decade, an epidemic of opioid overdose deaths has swept through the United States, initially driven by diversion and misuse of prescription opioids. In 2017, the U.S. Department of Health and Human Services declared a public health emergency and announced a 5-Point Strategy to Combat the Opioid Crisis (U.S. Department of Health and Human Services 2017; 2018b). Because many people, particularly vulnerable adolescents and young adults, have their first exposure to prescription opioids as pain relief for third molar extractions or other dental procedures, the American Dental Association in 2018 called for mandatory continuing education in prescribing opioids and other controlled substances, with an emphasis on preventing drug overdoses, chemical dependency, and diversion (American Dental Association 2018). Efforts to fight the opioid crisis continue to show promising results with respect to the prescription pattern of dentists. Appropriately managing orofacial pain will lead to better health outcomes and improved well-being for those with both acute and chronic pain.

Use and abuse of licit and illicit substances also have an impact on oral health and disease and deserve greater recognition among oral health care providers. The use of marijuana, because of rapidly increasing state-by-state legalization and dispensing, is a growing issue. Relatively little is known about the impact on oral health of smoking and vaping marijuana or its extracts. Additional research will begin to clarify the potential dangers.

Even with cigarette smoking among American adults being at a historic low of 14%, tobacco use remains an important public health challenge with well-documented oral health consequences, especially with regard to periodontal disease and oral cancer (U.S. Department of Health and Human Services 2020b). More than $225 billion (in 2014 U.S. dollars) per year in health care spending was spent for health care services for smokers during 2010–2014. That means that about 11.7% of yearly personal health care services (inpatient, outpatient, physician and professional services, prescription drugs, and other services) in the U.S. was attributable to adult cigarette smokers (Xu et al. 2021). In spite of the falling rates of cigarette smoking in the United States, the rapid emergence of e-cigarettes and vaping is a burgeoning public health dilemma with potential for substantial negative oral health issues. Further research will help the health care community identify the risks and determine safeguards for oral health and overall health. Dentists have a responsibility to better understand the rapidly diversifying landscape of tobacco products and to provide counseling and other services for helping tobacco users to quit.

Because of the rise in diagnosed mental illness, especially among adolescents and young adults, a complex and ever more pervasive public health issue continues to be the interrelationship among substance use and abuse, mental illness, and chronic pain. Shared neurobiological mechanisms are still being discovered. While that continues, new paths of inquiry are being explored to better understand the impact of stress, pain, substance use, and mental illness upon oral health. Addressing this complex array of issues requires raising awareness among oral health professionals, increasing interprofessional and interdisciplinary research, and developing practice protocols focused on the integration of collaborative care into the nation’s health care system. Box 7 presents Key Summary Messages and Calls to Action to address these issues and challenges.

Box 7. Key summary messages for Pain, Mental Illness, Substance Use, and their significance to Oral Health

- Substance misuse and mental illness can have negative effects on oral health and well-being.
- Oral health professionals have responded to the opioid epidemic with improved prescription and treatment practices for orofacial pain, including pain associated with oral surgery.
- Most opioid prescriptions for dental conditions are provided in emergency departments—an expensive and often ineffective practice.
- Tobacco use is a major risk factor for gum disease and cancers of the oral cavity and pharynx. By more actively engaging with their patients in tobacco cessation practices and programs, oral health professionals could substantially reduce the risk of these diseases.
- Marijuana use is associated with reduced salivary flow, and some associations have been found with higher levels of decay and gum disease. Because these effects often are compounded by tobacco use, research is needed to refine the specific effects of marijuana on oral health.
- Methamphetamine misuse has devastating oral health consequences that severely affect salivary flow, resulting in specific patterns of extensive tooth decay, broken teeth, and diseased gums, as well as serious consequences for overall health.
- Early research on e-cigarette use shows that it has many of the same negative effects on gums and soft tissue seen with tobacco use, including increased risks for oral malignancies.
- Because of the impact of many mental illnesses—from depression and anxiety to schizophrenia and other serious mental illnesses—many who suffer from these conditions are deprived of the cognitive and emotional energy needed for personal care behaviors that sustain good oral health.

Call to Action:

- In order to participate fully in an integrated system of health care, oral health professionals must acquire new competencies related to the behavioral health aspects of substance use and mental illness to provide optimal oral health care for, and appropriately refer, those with substance use disorders and mental health problems.

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Emerging
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Oral Health in America: Advances and Challenges

Section 6: Emerging Science and Promising Technologies to Transform Oral Health

Chapter 1: Current Knowledge, Practices, and Perspectives

We are living in a period of transformational change in which information abounds and choices are often daunting. Advances in science and technology are driving the evolution of health care practices. However, although new scientific tools are being used to identify previously unknown mechanisms of disease and enable a fresh view of previously held beliefs, new technology and state-of-the-art scientific approaches must be adapted in a way that is well thought out, evidence-based, and available and accessible to all.

Tackling the challenge of achieving optimal health requires innovations from basic research, their translation into clinical treatments, and their effective implementation across highly diverse populations. Research takes a variety of forms including basic, translational, clinical, implementation, and health services and policy research. Both discovery and translation are needed to address the spectrum of conditions that affect the oral cavity: dental caries and periodontal disease, craniofacial diseases and disorders, oral and oropharyngeal cancers, pulpitis, salivary gland dysfunction, temporomandibular joint dysfunction, mucosal disorders, and so many others. To achieve these goals, basic science, technologic innovation, and implementation science require supported systems; a dedicated, diverse, and highly educated workforce; and attention to sustainability during the revision and reevaluation of existing knowledge.

Foundational Sciences in Oral and Craniofacial Health

Foundational sciences in oral and craniofacial health encompass basic biological and physical sciences; population, social, and behavioral sciences; and ethics, all of which provide the foundation for clinical practice. A major advance in foundational science knowledge occurred in 2003, with the completion of the Human Genome Project. The Human Genome Project sequenced the entire human genome, thereby accelerating gene mapping for complex traits that comprise oral and craniofacial conditions. The ability to analyze different cell populations at the single-cell level has furthered our understanding of variations among same cell types that can influence susceptibility to disease and treatment effectiveness. This increased understanding gives us the potential to analyze illnesses at the cellular and molecular level and to devise unique treatments designed to match individual genetic profiles within the context of environmental influences.

Omics, Gene Editing, and Single-Cell Technologies

Genomics

The Human Genome Project's successful sequencing of the human genome made virtually all modern omics possible. The project's offshoot, the Genome Reference Consortium (National Library of Medicine 2021a), periodically releases updated versions of the human reference genome. Publicly available DNA sequences are accessible to anyone online through GenBank®, a genetic sequence database (National Library of Medicine 2021b). Standardized genome annotation is available through the Reference Sequence collection (RefSeq), which provides a collection of reference sequences and genes against which individual variations can be compared (National Library of Medicine, 2021c)

A particularly fruitful application of these genomic tools has been genome-wide association studies (GWAS), analyses of complex human traits and diseases that allow investigators to focus on plausible areas of the genome harboring one or more risk genes for the trait of interest. Since the first successful genome-wide association study in 2005, thousands of GWAS have been carried out for hundreds of trait phenotypes (characteristics) (Buniello et al. 2019).

Other subtypes of genomics support functional elucidation (Hasin et al. 2017), clarifying how specific genetic variants lead to the phenotype of interest. These omics include *transcriptomics*, which evaluates RNA levels to determine expression of particular genes in particular tissues or at particular time points (see https://www.facebase.org/); *proteomics*, used to evaluate post-translational modification in genes' protein products; *metabolomics*, which quantifies multiple small-molecule types (metabolites) in cells or tissues; and *epigenomics*, which focuses on characterization of reversible modifications to DNA or its proteins. To characterize the genetic component of periodontal disease pathogenesis, several groups have utilized GWAS with large patient cohorts and have identified genetic targets associated with disease (Offenbacher et al. 2016; Zhang et al. 2016).

Phenomics

Phenomics is the systematic measurement and analysis of high-dimensional phenotypic data on an organism-wide scale (Yong et al. 2014). The phenome is the set of phenotypes (including physical, biochemical, and psychological traits) produced by an organism during its life span in response to genetic, epigenetic, and environmental factors.

This relatively new discipline offers a unique perspective within which mechanisms of oral disease can be linked to clinical impact. For example, phenomics may support the investigation of complex craniofacial traits (such as cleft lip and/or palate and chronic orofacial pain) or craniofacial-systemic links, as well as dental anthropologic and forensic dentistry analyses. Deep phenotyping requires the integration of multiple micro and macro data sources, including dental and medical electronic health records (EHRs) and health claims, laboratory and imaging databases, national vital statistics records, national cohort studies, and pharmacy and emergency medical services data. Phenomics results will then support health care transformation through the implementation of precision dentistry and medicine for diverse patient populations (Denny and Collins 2021).

Single-Cell Omics

The concept of using single-cell resolution analyses in heterogeneous cell populations has become of great interest (Irish et al. 2006; Junker and van Oudenaarden 2014). Targeted measurements of single cells' activities further the understanding of such cells' variabilities and explain the differences among individuals in their susceptibilities to disease and reactions to treatment. To apply this technology, single cells are isolated, observed, and analyzed in detail. Scientists have developed diverse approaches for the isolation, trapping, and manipulation of single cells in a microfluidic device (Shapiro et al. 2013; Macaulay and Voet 2014; Lo and Yao 2015). Subsequent analyses have been applied at the single-cell level to measure the molecular signatures of different aspects and functions (Wang and Bodovitz 2010). Single-cell omics rapidly collect a substantial amount of data, which can be sorted into genomics, transcriptomics, epigenomics, proteomics, and metabolomics (Prakadan et al. 2017) and subjected to further analysis using DNA and RNA sequencing and other advanced technologies, such as chromatin immunoprecipitation, mass spectrometry, and nuclear magnetic resonance. These areas of single-cell omics provide exciting potential for precision cancer detection (including detection of head and neck cancer) at various stages of disease. Single-cell analyses also are useful for identifying cells for pharmaceutical targeting in cancer and oral conditions that affect the mucous membranes.

Microbiome/Inflammasome/Virology

The human microbiome encompasses the entire microbial community, including bacteria, fungi, protozoa, and viruses associated with humans (Baker et al. 2017). The microbial community has a rich and complicated genetic content (Fischbach 2018), making the microbiome an active player in human health and disease (Proctor et al. 2017).

The oral microbiome is a distinct and diverse group of microbes that inhabit the oral cavity's hard and soft surfaces (Takahashi 2015). Studies among humans have uncovered its vital role in the two most prevalent oral infectious diseases—dental caries and periodontitis—as well as in a wide range of physiological and pathologic processes essential to overall health (Bowen et al. 2018; Lamont et al. 2018). The oral cavity harbors more microbes than any other part of the body except the gastrointestinal tract. Most of the microbes in the mouth live within biofilms (dental plaque) attached to soft (tongue, gingiva, and oral mucous membranes) and hard (tooth) tissue surfaces.

The mouth provides distinct habitats, including saliva, tongue, mucosal, and tooth surfaces, all colonized by site-specific microbial assemblages (Human Microbiome Project Consortium 2012a). The development of high-throughput DNA sequencing has allowed these distinct groupings to be characterized. Studies have sequenced aspects of genetic regions to obtain an overview of the oral microbiome according to oral health status (Griffen et al. 2012; Gross et al. 2012), presence of systemic disease (Diaz et al. 2013; Starr et al. 2018), environmental exposures and behavioral habits (Mason et al. 2015), heritability (Demmitt et al. 2017), and a variety of genetic defects (Abusleme et al. 2018). Studies in twins show that both heritable and environmental factors shape the oral microbiome (Gomez et al. 2017). Behaviors such as smoking (Mason et al. 2015), genetic mutations (Abusleme et al. 2018), and disease (Griffen et al. 2012; Imabayashi et al. 2016) affect the homeostatic (optimally healthy) balance of the oral microbiome and host tissues.

A web-based human oral microbiome database was established and then enlarged as the expanded Human Oral Microbiome Database (eHOMD) (Escapa et al. 2018). Along with another oral microbiome database, the CORE database (Griffen et al. 2011), eHOMD provides a valuable platform for oral microbiome studies. These tools enable clinically relevant studies to be conducted by identifying new species (Beall et al. 2018a), new metabolic pathways (Verma et al. 2018), or novel biosynthetic gene clusters (Medema et al. 2014) associated with health and disease. A comprehensive road map to oral microbial assembly has emerged, revealing the oral microbiome's resilience to a variety of environmental challenges (Gomez and Nelson 2017).

Studies of the gut (gastrointestinal) microbiome also are relevant to oral health and have led to the concept of dysbiosis, which is broadly defined as shifts in the microbial community that feature a reduction in the species diversity of microbes, changes in metabolic and signaling activity, and adverse health consequences (Honda and Littman 2016). The increase in biomarker microbe species rather than the acquisition of new species, which is observed in both dental caries and periodontitis patients, supports a current model (the polymicrobial synergy and dysbiosis model) in which imbalances and altered metabolic pathways among microbes already present in the oral cavity cause these two diseases.

The interrelationship of the oral microbiome, gut microbiome, and systemic health has received considerable attention, with several investigations reporting an association between the oral microbiome and systemic diseases with an inflammatory component, such as rheumatoid arthritis (Potempa et al. 2017), colorectal cancer (Kostic et al. 2012), oral cancer (Hayes et al. 2018), and Alzheimer's disease (Dominy et al. 2019).

Oral Microbiome Communities as Determinants of Oral Health and Disease

Several common oral diseases, including dental caries, periodontal diseases, and oropharyngeal candidiasis (fungal infection), are microbial in origin (Lalla et al. 2013; Lamont et al. 2018) and result from the interaction of microorganisms and host factors. Dental caries are a disease triggered by a microbial community in which interactions among various microbes play a role by modulating the net effect of dietary sugars and carbohydrates on tooth demineralization. *Streptococcus mutans* is the dominant microbial species in patients with dental caries (Gross et al. 2012). An intriguing association also has emerged between the fungus *Candida albicans* and early childhood caries (Xiao et al. 2018) and suggests that, like dental caries, periodontitis is a disease that results from the interaction of individuals' microbial communities with the inherent and unique biological characteristics of their mouths. The development of periodontitis is linked to genetic and environmental determinants that modify an individual's inflammatory response to the microbiome (Moutsopoulos et al. 2014; Offenbacher et al. 2018). Human clinical longitudinal (across the life span) studies and investigations in experimental animal models show that a dysbiotic microbiome community with an increase in certain microbial species, virulence (harmfulness) factors, and metabolic activities is required for the development of periodontitis (Dutzan et al. 2018).

The Oral Microbiome and Systemic Disease

Oral microorganisms can influence systemic diseases. Studies suggest that the microbiome in the oral cavity can colonize and participate in disease processes in other parts of the body that become systemic (Gao et al. 2018). For example, *Porphyromonas gingivalis*, a bacterium strongly associated with periodontitis, has been detected in the brain of patients with Alzheimer's disease. An animal model showed the plausibility of *P. gingivalis* as a contributor to the disease development (Dominy et al. 2019). In addition, protein activities associated with a dysbiotic oral microbiome have been shown to mediate autoimmunity in rheumatoid arthritis (Potempa et al. 2017). These and other findings will require deeper investigation into disease mechanisms to help us better understand complex disease interactions that would differentiate between association and causality.

The Coexistence of Viral Infections and Bacterial Infections in the Oral Cavity

Periodontitis was once thought to be exclusively a bacteria-driven disease process, but it is now understood that viruses also are frequently detected in infected tissues (Slots 2015). These viruses include herpes simplex virus, human cytomegalovirus, Epstein-Barr virus, and Kaposi sarcoma-associated herpesvirus (Slots 2015). Human papillomavirus, a potentially cancer-causing oral pathogen, has been detected in gingival disease (Hormia et al. 2005), along with DNA tumor viruses associated with cancer development. Each of these viruses replicates in the oral epithelium and is shed into saliva. Their replication may result in oral transmission of the virus, as well as the development of viral lesions. In the case of DNA tumor viruses, viral gene expression has been associated with the development of oral cancers (Speicher et al. 2016). The periodontal pocket may serve as a reservoir for multiple viral infections that influence the establishment of periodontal disease (Rickinson 2014).

There also is a need to be keenly aware of a multitude of new infectious agents as well as old organisms that mutate or resurge. Severe acute respiratory syndrome (SARS) coronavirus rose to affect localized areas in the world at the turn of the 21st century, and Ebola raised fear more than a decade later. However, neither resulted in the damage seen from the surge of coronavirus disease 2019 (COVID-19) through an unprepared world in early 2020, with an unquestionable impact on human health on many levels. A pandemic such as COVID-19 has a profound impact and requires strong science combined with strategic public health measures to minimize the damage. From an emerging science perspective, we need to realize the importance of mobilizing science and technology to ensure the country's health and prepare for the unknown. Knowledge gained from the COVID-19 pandemic is demonstrating this and is highlighting how the emergence of new infectious agents may have major ramifications for oral health that will unfold day by day, often requiring changes in our response.

Inflammation and the Inflammasome

Inflammation science has rapidly evolved and expanded across medical fields (Medzhitov 2010), including dental medicine. The function and structure of a network of proteins, called the *inflammasome*, directs the processing and release of key proinflammatory cytokines (signaling cells) (interleukin [IL]-1β and IL-18) and cell death (Martinon et al. 2002; Lamkanfi and Dixit 2017). Whereas acute inflammation is part of the body's natural protective response to ensure the removal of harmful stimuli and promote tissue repair, chronic inflammation is a central component of many diseases (Majno and Joris 2004). Chronic inflammation (Majno 1998; Hotamisligil 2006) is essential to a number of metabolic, infectious, degenerative, autoimmune, and cancerous conditions (Darveau 2010). The pathophysiological entities that underlie most dental, oral, and craniofacial diseases involve inflammation as a direct or indirect disease mechanism (Van Dyke and Kornman 2008). Periodontal diseases, dental caries, root canal infections, mucosal infections, premalignant lesions, and head and neck cancers have in common a programmed inflammatory response that regulates their initiation and severity. In the context of the whole body, oral inflammation can significantly influence systemic events and vice versa (Joshipura et al. 2000; Engebretson and Kocher 2013).

A more precise picture of inflammation's central role in this reciprocal relationship between oral health and overall health has emerged (Barnett 2006). Our bodies have a vast immune repertoire that can sense and respond to danger signals. Among the first genes activated by disease-causing microorganisms (Darveau 2010) are proinflammatory cytokines, such as IL-1 (Dinarello 2010). Distinct patterns of IL-1 family genes and other cytokine gene networks have been associated with unique inflammatory profiles in several complex diseases, including periodontitis, cardiovascular disease, rheumatoid arthritis, and osteoporosis, and during and following damage to dental pulp (Kornman 2006; Fouad et al. 2020).

Regenerative Medicine, Dental Materials, and Bioinspired Materials

Restoration and rehabilitation of hard and soft dental, mucosal, and craniofacial tissues to functional integrity require sophisticated orchestration integrating materials, cellular elements, mediators, and technology in a temporal and directed manner. The number of new technologies and biomaterials for restoring or replacing missing dental and other oral structures has surged. The availability of durable and highly aesthetic biomaterials has revolutionized the replacement of broken and severely decayed teeth. Nanotechnologies have transformed the design and manufacture of restorative and regenerative materials.

Biomaterials are substances, other than food or drugs, contained in therapeutic or diagnostic systems in contact with tissue or biological fluids (Peppas and Langer 1994). Dental biomaterials are used to restore and replace missing tooth structure, prevent further loss or damage to tooth structure and gum tissue, and replace missing teeth and other oral structures.

Materials primarily used in dentistry today are dental adhesives that bond restorative materials to tooth structure and create a seal around the restoration, resin-based dental composite materials that restore lost or damaged tooth structure, dental ceramic materials used as dental crowns and bridges to mimic natural tooth structure, and dental implants that replace the roots of lost teeth and support single or multiple tooth restorations. The materials most often used for restoring anterior and posterior teeth are adhesive-bonded dental composites. However, these materials do not last as long as dental amalgam fillings (Rasines Alcaraz et al. 2014) and often require replacement, resulting in significant costs to patients in terms of convenience, discomfort, and expense. Dental amalgam alloy is composed of elemental mercury, which binds to a mixture of metals. Studies funded by the National Institute of Dental and Craniofacial Research (NIDCR) have shown dental amalgam to be safe for human health, but for environmental reasons there is an international effort to phase down the use of dental amalgam, as articulated in the Minamata Convention. In 2020, the U.S. Food and Drug Administration (FDA) issued further communication recommending the use of non-mercury restorations (fillings), when possible and appropriate, for individuals in certain high risk groups (U.S. Food and Drug Administration 2020a). This provides another urgent reason for research into alternative restorative materials (Ajiboye et al. 2020). The primary reasons for replacement are recurrent tooth decay near the existing restoration and fracture of the restoration itself or the surrounding or supportive tooth structure (Demarco et al. 2012; Opdam et al. 2014). As a result, new materials, including biomaterials designed to interact with biological systems, are actively being sought.

Biomaterials

There are many examples of promising new technologies designed to produce better restorative materials that are more durable, stimulate the formation of new tooth-like mineral to repair defects and replace lost tooth structure, have improved aesthetics (better mirror the properties of enamel and dentin), support function (mirror the wear of natural tooth surfaces), repel or kill damaging bacteria to stop the formation of new cavities, and regenerate lost tooth components. Structural and mechanical functions are generally considered the biomaterials' most valuable functions or properties. However, biological properties, such as biocompatibility and biodegradability, also are important.

Biomaterials are considered to be *biocompatible* if they are inert and cause no undesired negative effect on the body. In contrast, *bioactive* materials intentionally regulate biological functions of cells or tissue. *Biomimetic* materials imitate specific composition, structure, or characteristics of biological materials or systems. *Bioinspired* materials have specific advanced properties or functions inspired by a biological system. It is critical to remember that the safety of these new materials, not only for the patient, but also for the health care provider and the environment, must be studied.

A large portion of the biomaterials used today in dental or oral health treatment are biocompatible, inert materials. However, development of bioactive materials—such as bioceramics, bioglass, and biocomposite materials—used in dental and craniofacial bone repair and restoration has been increasing. The bioactive components in these biomaterials are mainly inorganic materials, including bioceramics (crystalline) and bioglass (noncrystalline). Calcium phosphates, such as hydroxyapatite and tricalcium phosphate, are widely used bioceramics with structures similar to the minerals in bone and teeth (Chu et al. 2001; Hench 2015) and have been made into porous scaffolds for bone and dental tissue regeneration (Hench and Polak 2002; Denry and Kuhn 2016). To overcome their shortcomings, many biocompatible materials have been made into composite materials with polymers to enhance processability and mechanical properties. Such bioactive composite materials are biomimetic (designed to mimic components of natural bone and dentin) and bioinspired (inspired by the structure of biological materials).

Nanotechnology

Nanotechnology is the control of materials at dimensions between 1 and 100 nanometers. It involves imaging, measuring, modeling, and manipulating matter at this scale. Applications of nanotechnologies in dentistry include the development of tools that enable probing and imaging of biological systems with high precision, as well as designing and manufacturing preventive and restorative dental biomaterials. As a result, dental biomaterials have become more bioinspired and biomimetic (Jefferies 2014), which enhances some of their properties in comparison to the same materials at larger scales. Nanomaterials are now a part of the majority of restorative dental composites (Ferracane 2011), remineralizing agents (Hannig and Hannig 2012), and antimicrobial systems (Cheng et al. 2017).

Biodegradable Polymers and Nanofibrous Scaffolds

Biodegradable polymers, such as polylactic acid, polyglycolic acid, and their copolymers (polylactic-co-glycolic acids) have good biocompatibility, controllable biodegradability, excellent processability, and desirable initial mechanical properties. They are widely used to fabricate highly porous scaffolds, but there are other ways to make nanofibrous materials. Electrospinning is a popular technique to generate nanofibrous materials from various polymers (Doshi and Reneker 1993; Boland et al. 2001). In addition to tissue-engineering scaffolds, biodegradable polymers can be used to fabricate microparticles or nanoparticles for controlled release of drugs or molecules. For example, antibiotics have been incorporated into dissolvable particles to treat periodontitis (Williams et al. 2001), and various kinds of extracellular matrixes have been used for soft-tissue regeneration around teeth (in tooth recession defects) or around dental implants in situations involving reduced tissue thickness or implant exposures (Tavelli et al. 2020).

Periodontal Regenerative Medicine

Clinicians are currently using techniques and products created for periodontal regeneration (Larsson et al. 2016). Guided tissue regeneration (GTR), the most well-documented technique, employs a barrier membrane to promote the selective repopulation of periodontal defects using tissues capable of reattaching, such as alveolar bone and periodontal ligament (Karring et al. 1993). Attempts also have been made to use bioactive molecules, such as enamel matrix derivative and platelet-derived growth factor, to promote periodontal regeneration (Giannobile and Somerman 2003; Nevins et al. 2013). Results have been comparable to those obtained with GTR, although complete regeneration remains elusive in the vast majority of clinical cases.

Orofacial Muscle Regenerative Medicine

The face is a highly organized mixture of elements, composed of an underlying bone and cartilage framework that supports muscle and subcutaneous and skin tissue (See Figure 1, Section 3A) (Susarla et al. 2011). These components are attached to one another with ligaments and interact dynamically within a neurovascular network that allows the face's complex animation. Each subregion of the face constitutes an aesthetic unit, so that reconstruction has to be considered on the basis of the unit (Rose 1995; Mureau and Hofer 2009). Hence, reconstruction of the maxillofacial region is challenging. Current treatments of extensive craniomaxillofacial defects include static reconstruction, free vascularized muscle transfer (Tate and Tollefson 2006; Ghali et al. 2011), and composite tissue allografting (Siemionow 2017). Tissue-engineering strategies that employ inductive scaffolds or scaffolds combined with growth factors or cells have been broadly applied to generate functional skeletal muscle (Larkin et al. 2006; Passipieri and Christ 2016). Because of the greater inflammatory and fibrotic response associated with common degradable synthetic polyesters, the field has been focusing on materials of biological origin such as alginate, gelatin or collagen, and fibrin (Passipieri and Christ 2016). The loading of specific growth factors into scaffolds has been shown in multiple cases to induce the desired response of increased angiogenesis (new blood vessels), myogenesis (new muscle tissue), or neurogenesis (new nerve cells), or in some cases, a reduction of fibrosis (scar tissue) (Passipieri and Christ 2016). In summary, orofacial regenerative medicine holds great promise for improving patients' health. Technologies in this area will reduce the number of procedures requiring autologous (self-transplant) donor tissue, which result in significant patient morbidity. They will provide less invasive and less costly treatments without donor harvest and with targeted (personalized) replacement constructs that can lead to more predictable treatments for patients.

Stem Cell Biology

Stem cells are undifferentiated cells in embryonic and adult tissues in the body that can self-renew and differentiate into different types of cells. Mesenchymal stem cells (MSCs) have been extensively studied in craniofacial regenerative applications involving stem cell therapy. The unique properties of MSCs—namely, their ability to differentiate into multiple cell types, produce bioactive factors involved in tissue regeneration, travel to distant sites of injury, and escape the body's immune response—have made them a desirable population for stem cell therapies. MSC therapies currently are under preclinical and clinical investigation and are being administered to specific sites to replace damaged or deficient hard (bone, cartilage) and soft (gingiva, dental pulp) tissues, promote tissue neovascularization, or reduce inflammation (Polymeri et al. 2016). Because of their therapeutic potential, identification of MSCs from craniofacial and oral tissues has created excitement in the field of regenerative dentistry.

Science and Technology for Practice

Dentistry is at a pivotal point with regard to the technology used in practice and the potential for new scientific diagnostic and therapeutic approaches that can improve oral health. Computer-aided design/computer-aided manufacturing (CAD/CAM) as well as three-dimensional (3D) printing technologies have rapidly spread worldwide. Current dental technology and practice innovations are focused on precision health, laser and light imaging, digital dentistry, and pharmacologic approaches. Sensor-based technologies have been introduced to support oral health behaviors outside the clinic setting.

Genetics- and Genomics-Based Precision Medicine

Specific gene variations have been linked to more than 10,000 human diseases (World Health Organization 2020). Powerful research approaches and large, multidisciplinary research efforts are improving our understanding of the genetic basis of health and disease (Collins and Varmus 2015; Cheifet 2019). Defining diseases by their genetic and environmental drivers and identifying the biological pathways involved will profoundly affect disease classification as well as provide the ability to develop diagnostic tests, determine susceptibility, and create variant-specific treatment intervention strategies. Until recently, genetic information has been most useful in diagnosing relatively rare Mendelian genetic disorders, rather than parsing the complex genetic origins of more common diseases, such as heart disease, diabetes, and periodontitis.

Thousands of genetic diseases manifest symptoms in the oral cavity or craniofacial complex. Major clinical findings for a number of these conditions, such as amelogenesis imperfecta or isolated cleft palate, are found in the oral cavity. For others, such as dentinogenesis imperfecta and syndromic forms of orofacial clefting, symptoms may manifest both orally and in the vascular system, bones, and kidneys. In some conditions, dental symptoms are the most prominent; therefore, a dentist may be the first to recognize the need for further testing to confirm a genetic condition (Pallos et al. 2001).

Laser- and Light-Based Imaging Technologies

Dental carious lesions are routinely detected using visual methods coupled with radiography and, when needed, complemented with tactile exploration methods. Despite their common use, these methods are insufficiently sensitive or specific for diagnosing early noncavitated carious lesions. Radiographic methods lack the sensitivity to detect early dental decay, particularly occlusal lesions, and, by the time the lesions are radiolucent, they often have progressed well into the dentin, making surgical intervention necessary. If carious lesions are detected early enough, nonsurgical means such as fluoride therapy, antibacterial therapy, or dietary changes can reverse or arrest them.

Two different fluorescence-imaging systems have been introduced commercially. The first method, commonly called quantitative light fluorescence, uses blue or ultraviolet light with green fluorescence. The loss of fluorescence from the underlying sound tissue owing to increased light scattering by demineralization is the mechanism for increased contrast between the lesion and sound areas (Ten Bosch and Angmar-Mansson 1991). Fluorescence images provide increased contrast between sound and demineralized tooth structure, but the method is limited because stains and plaque fluoresce strongly and make detection difficult (Stookey 2005). A second approach relies on the red fluorescence from bacterial-produced porphyrins (Konig et al. 1999; Lussi et al. 2004). Porphyrins accumulate in highly porous subsurface lesion areas in dentin, causing hidden occlusal lesions to fluoresce (Lussi et al. 2004). However, this method has some drawbacks. Because the dental decay-causing bacterium *S. mutans* does not contain porphyrins, this approach is not an effective way of monitoring cariogenic bacteria. Moreover, it has poor sensitivity for lesions confined to enamel because porphyrins do not accumulate there (Shi et al. 2000). Several clinical devices that measure both red and green fluorescence currently are commercially available.

Digital Dentistry, Computer-Aided Design/Computer-Aided Manufacturing, and 3D Bioprinting

Dental medicine widely employs digital dental technology, including intraoral scanning, 3D imaging, reconstructive processing using CAD/CAM, and artificial intelligence (AI). This boom in technology in the areas of CAD/CAM and the expanded use of 3D bioprinting to create synthetic and natural dental tissues have made the production of dental restorations faster and simpler, and often less expensive.

CAD/CAM technologies for fabricating dental restorations have rapidly spread worldwide (van Noort 2012). To date, the most commonly used CAD/CAM methods in dentistry are subtractive, such as computer-controlled milling machines that drill a block of material to achieve a desired shape. Dentistry has profited greatly from this technology (Alghazzawi 2016), which makes it possible to create accurate restorations while saving time (Bindl and Mormann 2005). Using solid blocks of material results in fewer internal defects, which are common in handmade restorations and compromise their strength (Belli et al. 2017). Significant strides have been made in the field of 3D bioprinting—an additive manufacturing process—of regenerative scaffolds and cell-laden craniofacial structures, which are being developed as the next generation of bone, vascular, periodontal, and dental grafts (Murphy and Atala 2014).

Chemotherapeutics/Drugs in Dentistry

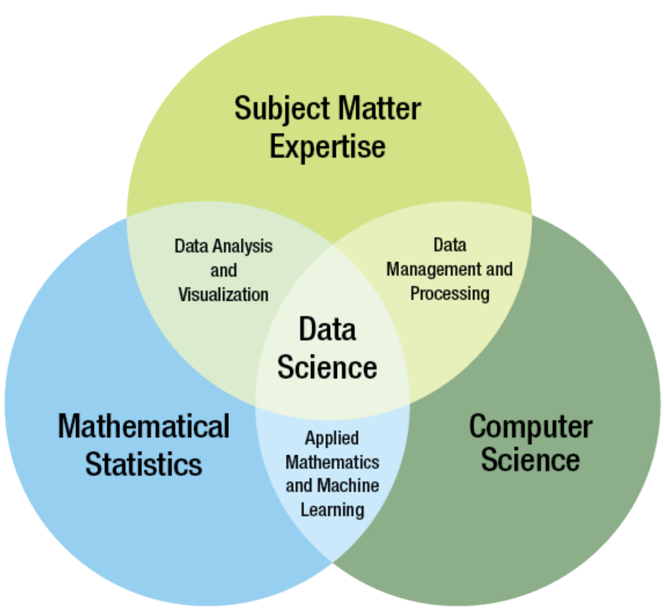
There are many types of medications, supplements, and other chemotherapeutics available in the marketplace that are promoted as preventing or managing dental diseases. However, the majority have not been approved by the FDA. Dental drugs that have been approved by FDA since the 2000 Surgeon General's report include, but are not limited to, (in alphabetical order): Arestin, Articaine, Atridox, Colgate's Total, Cuvposa, Evoxac, Oraqix, Oraverse, Kepivance, Kovanaze, Orabloc, PerioChip, Periostat and Salagen. FDA has determined a number of over-the-counter (OTC) drugs for oral health as generally recognized as safe and effective for the general population without the need to seek treatment from a health professional. The most common examples of OTC drugs employed in dentistry are those used to prevent dental caries, including sodium fluoride, stannous fluoride, and sodium monofluorophosphate. Dentists can dispense or provide products with higher levels of fluoride than those available OTC, as well as prescribe chlorhexidine as an intraoral antimicrobial rinse. Noninvasive diagnostic tools with improved sensitivity and specificity in detecting active dental caries lesions are needed, as are new drugs for treating periodontitis.

The National Center for Complementary and Integrative Health defines *complementary* and *alternative medicine* as non-mainstream approaches used together (complementary) or in place of (alternative) conventional medicine. These two approaches are brought together by *integrative medicine,* with the aim of caring for the whole person rather than just treating disease (National Center for Complementary and Integrative Health 2021). Most complementary and alternative medicine systems in oral health care are biologically based, such as botanical products and holistic medical systems such as (e.g., Ayurveda, homeopathy, Chinese medicine). Most complementary and alternative medicine systems have insufficient clinical evidence for their safety or efficacy (Shi and Heber 2013; Rigassio Radler 2014).

Information and Data Science

Data science is a growing field built on interdisciplinary research connecting subject-matter expertise in a particular domain with mathematical statistics and computer science (Figure 1). Areas within data science such as data modeling, machine learning, deep learning, big data, and AI have developed at a rapid pace during the last 2 decades, becoming important to health care and health informatics. By facilitating more accurate diagnosis and effective treatment, data science is important to evidence-based health care.

FIGURE 1. Data Science: The intersection of Subject Matter Expertise, Mathematical Statistics, and Computer Science



Source: Adapted from Palmer (2015).

Data modeling integrates the study of data and the use of oral health information by establishing relationships among data from different sources across broad patient populations. Using data modeling to store, retrieve, and analyze data for basic, translational, and clinical research studies makes clinical decision-making more effective and informative. Data modeling provides database structure diagrams upon which highly advanced computer applications can arrange complex information that characterizes oral diseases and conditions. In light of the increasing size, complexity, scope, locations, and sources of data, the National Institutes of Health (NIH) is exploring new models for data management resources, including partnerships with trusted organizations. To achieve this goal, NIH created a trusted partners federated data ecosystem for data storage and distribution of human genotype and phenotype data. This ecosystem includes, for example, BioData Catalyst, KidsFirst, AnVIL, and the Database for Genotypes and Phenotypes (dbGaP)(Office of Data Strategy, 2021). The National Library of Medicine provides support for registration and data access approval for the ecosystem.

Electronic Health Records

The implementation of EHRs is a strategy for reducing errors and improving health care delivery and outcomes (Song et al. 2011; Gold and McLaughlin 2016). Advances in the understanding of the connections between oral and total body systems and a shift toward individualized care have created a demand for an integrated medical and dental health care delivery system. The integrated medical and dental EHR has created new opportunities to exchange medical and dental information electronically, leverage resources, and improve patients' oral and overall health care. EHRs have made it possible to develop an oral health care system that is better integrated with our country's medical and behavioral health care systems (Acharya 2016; Faiola and Holden 2017; Shimpi et al. 2019a). Recognizing strategies to reduce the incidence of chronic diseases and improve the effectiveness and efficiency of care through the application of informatics is of paramount importance (Liu and Rubin 2012; Glurich et al. 2019; Shimpi et al. 2019b; Shimpi et al. 2019c). Unfortunately, an integrated EHR does not yet exist for most of the U.S. population.

Teledentistry

Telehealth includes telemedicine (the use of technology to deliver health care services at a distance) as well as patient and health professional education and public health and administrative activities (Daniel et al. 2015). Telemedicine has been introduced in rural and remote communities and in federal health programs to improve access to care. Various medical specialties and subspecialties in the United States and in other parts of the world now employ the technology supporting telehealth (Kvedar et al. 2014; Daniel et al. 2015). In addition to documented improvements in the flexibility of health services and high levels of acceptance among patients and providers, the benefits of telehealth include increased accessibility, improved quality of care, multidisciplinary collaboration, and education (Gilman and Stensland 2013; Banbury et al. 2014; Wade et al. 2016; Powell et al. 2017).

Although teledentistry has been slower to spread, it is now becoming more widely utilized across the country and in other parts of the world (Kopycka-Kedzierawski et al. 2008; Irving et al. 2018). The arrival of the COVID-19 pandemic has further fueled its use. See Section 4 for more information on the uses and practices of teledentistry.

Learning Health Systems

Efforts to create learning health systems (LHSs) at various levels of scale—organizations, networks of organizations, states and regions, and entire nations—promise to transform human health. The general idea is that a systems problem needs a systems solution. The National Academy of Medicine (National Academy of Engineering 2011) defines LHS as an integrated health system in which "progress in science, informatics, and care culture align to generate new knowledge as an ongoing, natural by-product of the care experience, and seamlessly refine and deliver best practices for continuous improvement in health and health care."

The core building blocks of LHSs are learning cycles, which begin when communities share a common passion around a specific individual or population health problem and form a learning community targeting that problem. Learning communities typically consist of multiple stakeholders, including researchers, care providers, and patients and their families, and draw on expertise from diverse disciplines. From a national perspective, a large-scale learning community may consist of several entities (Figure 2).

Learning cycles proceed in three stages: capturing health experience in computable forms, learning from the data to generate new knowledge, and mobilizing new knowledge to inform decisions and change performance (Friedman et al. 2017). The right knowledge must be delivered to the right person, at the right time, in the right dose, through the right route, in the right form, with the right documentation, and for the right reason (Federico 2015). Each new cycle of learning begins where the previous one leaves off, making health improvement repeated and continuous in nature as exemplified in Figure 3.

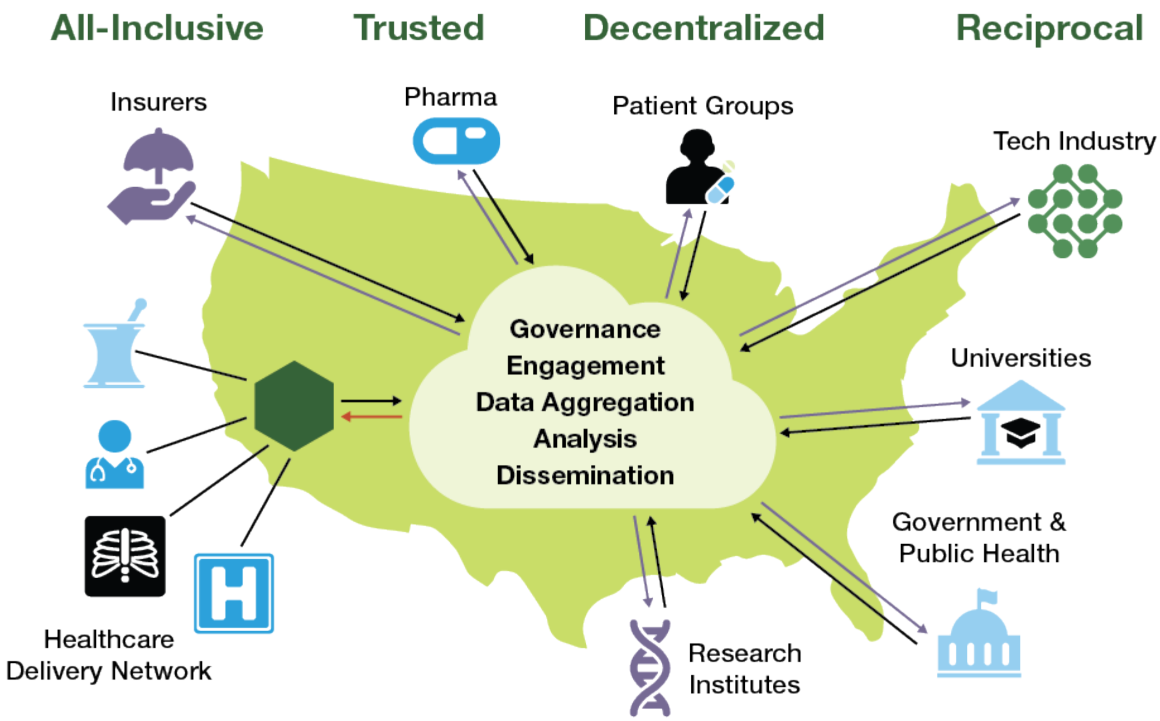
Implementation Science

Implementation science, the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine care to improve the quality and effectiveness of health services (Eccles and Mittman 2006), is characterized as a series of phases ultimately leading to a change in practice and better health outcomes (Figure 4). These steps may take into account the individual patient, the complexities of health disparities, and a broad, community-level approach. An early example of an implementation science study in dental medicine, which focused on identifying effective interventions to increase providers' implementation of dental sealants, demonstrated that a combination of evidence-based education and fee reimbursement most effectively facilitated the adoption of this new technology (Clarkson et al. 2008). This study illustrates an important aspect of implementation science research: The focus is not on identifying effective dental treatments, but on finding effective methods to increase providers' implementation of them.

Evidence-Based Approaches to Introduce New Technologies into Clinical Applications

One important aspect of implementation science is evidence-based practice. Providers' adoption of evidence-based dental practices is expanding due to the growing emphasis on improving population health, controlling cost of care, and delivering value for patients and care purchasers. Long lag times between the dissemination of evidence and its eventual adoption into routine practice limited the initial development of evidence-based practice

FIGURE 2. National perspective of an ultra-large scale learning health system



Source: Friedman and Rubin (2016). With permission from Charles P. Friedman, PhD.

in the 1990s. For example, even after compelling scientific evidence had accumulated in 2001 that fluoride varnish was superior to other modes of fluoride administration, 6 years later only 15.7% of general dentists and 30.8% of pediatric dentists in Texas reported that fluoride varnish was the topical fluoride they used most often (Bansal et al. 2012). Providers' failure to change their practice patterns in response to scientific evidence demonstrates that scientific evidence alone is not sufficient to change these patterns.

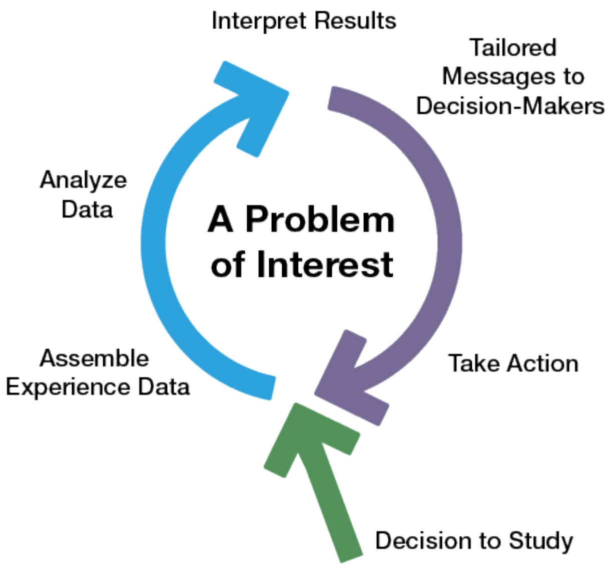
Practice-Based Research Networks

Practice-based research networks (PBRNs) are an important component of NIDCR's implementation science portfolio. A PBRN is a consortium of practitioners, clinical scientists, and health organizations focused collectively on conducting research to improve the health of their patients and communities. PBRNs link clinicians with health services and clinical researchers to improve the transfer of science to practice. This improvement is accomplished by fostering quality improvement through participation in research, addressing questions of high priority to the practitioners, and translating new knowledge into everyday clinical practice. Although medical PBRNs began in the 1970s, no oral health-focused PBRN existed in the United States before 2002. Because PBRNs can make substantial, unique improvements to clinical practice, they have continued to grow in number and breadth and now comprise a diverse array of health care practitioners.

PBRNs have as their foundation the understanding that the experience, insight, and practical wisdom of everyday practitioners and their patients, coupled with rigorous scientific studies, are powerful forces to advance population health. The oral health care system can play an active role in these advances, showing that knowledge transfer takes place not only from research to practice, but also from practice to research.

NIDCR funding has kept the National Dental PBRN in continuous operation since 2005 and has productively engaged thousands of clinicians in the research process.

FIGURE 3. View from the ground: How learning happens: "Virtuous cycles" of study and change



Source: Friedman and Rubin (2016). With permission from Charles P. Friedman, PhD.

Sixty studies have been conducted as of 2021, leading to more than 175 peer-reviewed scientific publications in 58 different journals, many with clinicians as coauthors. Examples of topics include risk factors for osteonecrosis of the jaw, dental material selection for crowns, and the use of rubber dams during root canal treatments. Practitioners from diverse settings are willing to engage in the excitement of discovery and to partner with fellow practitioners and academicians to improve daily clinical practice.

The National Dental PBRN also conducts studies of drug or device effectiveness as well as studies to test methods of evidence dissemination and implementation. The network continues to make significant contributions to research priorities and to help close the research-to-practice gap (Gilbert et al. 2013). In addition to exploring optimal means for disseminating evidence (Melkers et al. 2019), the network has conducted research to expand the scope of dental practice and to foster studies at the intersection of dentistry and medicine. These studies have been related to osteonecrosis of the jaw, cessation of tobacco use, blood glucose screening, human papillomavirus screening, opioid prescription patterns, and medical risk screening.

Research Workforce, Training, and Education

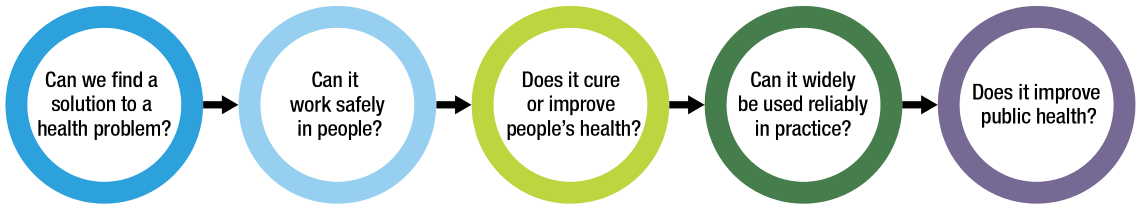
Studies suggest that dentists have the highest training costs of all health professionals in the United States and Canada (Gawel 2018). Skilled and effective dental faculty are essential to achieving the educational, patient-care, and research missions of dental schools and the profession (Haden et al. 2002). American dental schools face persistent faculty shortages (Kennedy 1995; Wanchek et al. 2016), worsened by the escalation in student debt, a widening income gap between private practitioners and dental faculty, and, at the time, the robust state of the U.S. economy (which favors private practice), all of which have had a negative effect on the oral health academic workforce (Wanchek et al. 2015).

The top two sources of dental faculty are advanced education programs and private practice. However, lack of exposure to and knowledge about academic careers hinders dental students in making informed decisions on this option (Schenkein and Best 2001; Rupp et al. 2006). A 2020 American Dental Education Association survey of dental school seniors from 59 of the 66 accredited U.S. dental schools found that only 0.3% had plans to enter academia (Istrate et al. 2021).

Foreign-trained dentists who have received advanced specialty training in the United States are an increasingly important source for filling vacant clinical faculty positions. They often have less student debt than U.S.-trained dentists, view faculty positions as prestigious, and can practice dentistry more easily as a faculty member than in the private sector. However, many lack research training and are unlikely to pursue independent research programs.

Students who have completed a Doctor of Philosophy (PhD) degree or combined Doctor of Dental Surgery (DDS)/Doctor of Dental Medicine degree and PhD training also are well suited for dental faculty positions. The number of U.S. dental schools increased from 54 to 66 during a 20-year period, but the number of oral health science PhD programs increased only from 16 to 17 over the same period. From 1994 to 2016, oral sciences PhD programs enrolled 33 new students on average per year, with 26 new graduates each year. Graduates were largely successful in their post-program pursuits. Many (35%) held faculty positions in U.S. academic institutions, 13%

FIGURE 4. Implementation science: Turning discovery into health, benefiting all



were faculty members in foreign institutions, 11% were employed by industry or government agencies, 12% worked in private practice, 12% were enrolled in postdoctoral training, and 11% were in residency or other advanced training (Herzog et al. 2018).

For many years, the general public viewed dental schools as entirely clinical entities, often with good reason. Eight of the nation's dental schools established since 2010 are clinically focused, and a substantial number of dental schools historically have not emphasized support and recruitment of faculty members into active scientific research programs. Institutions with human capital and resources are likely to follow systematic approaches to preparing junior faculty for career success, whereas institutions with more limited resources tend to focus on their core educational mission rather than on building and retaining their faculty workforce. As a learned profession, oral health professionals have an obligation not only to generate new knowledge but to apply it to clinical care, and hence research is an integral component of a high-caliber dental education.

The single most influential organization for dental faculty workforce and oral health research is NIDCR, whose mission is to improve the nation's dental, oral, and craniofacial health. To support and achieve this mission, NIDCR invests in the development of a strong and diverse workforce with the skills and knowledge to conduct oral health research across a broad range of disciplines and approaches, including new and emerging technologies. To build and sustain this workforce, NIDCR supports training opportunities at its campus in Bethesda, Maryland, and at multiple academic institutions across the United States. There are research training programs in basic, translational, clinical, and health services research for trainees from high school through established investigators.

Education and Training for Oral Health Scientists

Major advancements in knowledge in the oral health sciences have made it increasingly important to train the next generation of leaders on how to translate basic science innovations into clinical practice. Oral health scientists include PhD basic scientists, clinical research scientists, and those trained in health services and dental public health. Scientists who focus on oral health come from many diverse disciplines—sometimes with a clinical emphasis, but often without. All make essential contributions to the basic, applied, developmental, and implementation levels of research to inform clinical practice, population health management, and policy development as well as serve as educators of the workforce pipeline. Traditional dental education begins with an early focus on foundational and biological sciences and progresses to clinical focus in later years, a path that does not always lead to an appropriate level of exposure to population health issues. Integrating research experience into the predoctoral curriculum sets a foundation of critical thinking and inquiry that has value for evidence-based clinical decision-making. An ideal dental school graduate would be a highly skilled clinician with a deep understanding of the scientific foundation of dentistry, an appreciation of population health issues, and the compassion to serve. In the first 2 years of most dental schools, the vast majority of education consists of didactic instruction and simulation. Although the final 2 years are spent primarily in providing patient care, the likelihood is that most programs offer sparse instruction on understanding the health and social needs of low-income and underserved minority populations. Few dental programs offer supplemental public health electives.

To understand population-based research, oral health professionals need a basic understanding of epidemiology and biostatistics, health policy and management, health and wellness promotion, evidence-based dentistry, risk assessment at the individual and population levels, behavioral and social determinants, and health literacy. In addition, exposing future oral health professionals to real-world conditions—which can be accomplished through clinical rotations in community health centers, public health units, and other settings—provides them with experience treating low-income and underserved minority populations. Such exposure might also take place if they later enroll in Advanced Education in General Dentistry and General Practice Residency programs, which frequently serve these populations. In addition to these postdoctoral training programs, others can pursue public health training through a combined DDS and Master of Public Health or PhD program, thereby gaining valuable tools for research in underserved populations.

Imperative for preparing the next generation of scientists in oral health are core elements that the National Academies of Sciences, Engineering, and Medicine (2018a) recommend for all doctoral-level education. These include the cultivation of scientific and technologic literacy, the conduct of original research, and the development of leadership, communication, and professional competencies. PhD candidates should acquire deep, specialized expertise through the kind of original research that requires rigorous standards of investigation, as well as ethical responsibilities for the design and dissemination of science. They also should develop the ability to work collaboratively across scientific disciplines and be integral members of team science efforts (Hall et al. 2018).

Chapter 2: Advances and Challenges

Not only have substantial advances in genomics expanded our knowledge of factors affecting oral and craniofacial health in the past 20 years, new discoveries bridging microbiology and genetics have provided novel opportunities to better understand the role of microbiota in health and disease. Understanding the composition and ecology of the microbiota in our mouths opens new possibilities for treating conditions that link oral health and overall health, including systemic diseases.

Scientific breakthroughs in the past 20 years have significantly enhanced our understanding of stem cell biology and how to procure, isolate, and cultivate stem cells from embryonic and postnatal human tissues. Using stem cells to develop novel strategies for oral and craniofacial tissue regeneration is an exciting prospect. In the field of regenerative medicine, the identification of mesenchymal stem cells (MSCs) (stem cells found in skeletal and oral tissues that can be used to generate craniofacial structures or repair anomalies or damage) holds enormous promise for therapeutic applications.

In addition to scientific breakthroughs, we are in an age of accelerated technologic advancement that requires dedicated attention to make sure that new developments continue to promote health equity. Digital dentistry and the digital workflow are transforming all areas of dentistry. The health professions have opportunities to collaborate with industry, federal agencies, nonprofit organizations, and other entities to provide new strategies to improve care for all Americans.

An area of significant development since 2000 is the increasing availability of diverse data sources with the potential to inform dental care delivery and improve population oral health. The adoption of electronic health records (EHRs), including electronic dental records, during the past 2 decades has increased the availability of patient care documentation and can be used to improve communication and access to care. A growing number of social determinants of health datasets that describe communities' social, economic, and physical environments now are available and provide context for a community's overall and oral health (National Institutes of Health 2020a). Analysis of these datasets offers opportunities to improve oral health at the population and patient levels. The strategic inclusion of relevant oral health parameters makes it possible to provide a comprehensive picture of oral health as a part of overall health.

Foundational Sciences in Oral and Craniofacial Health

Omics/Gene Editing/Single-Cell Technologies

Single-cell technology was a conceptual vision in 2000 but has expanded into many areas of biomedical research in the past 5 years. Although oral and craniofacial research has lagged behind other types of research, some advances have been made. In the case of oral infectious diseases, the single cell sequencing of genomic amplicons (pieces of DNA or RNA that are the source or product of amplification or replication events) has been exploited to correlate the presence of uncultured bacterial species with oral health (Campbell et al. 2013; Beall et al. 2018b), and to detect severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in various sites of the oral cavity (Huang et al. 2021), both of which open new pathways for salivary diagnostics. In looking at the levels of single-cell gene expression in patients with head and neck cancer, molecular heterogeneity among the same types of cells warrants attention because it can influence the effectiveness of an individual's treatment strategy (Stucky et al. 2017). A single-cell analysis linked expanded salivary gland T cells to glandular dysfunction (Joachims et al. 2016) and revealed a higher frequency of activated T helper 17 cells (an immune cell population) in patients with Sjögren's syndrome (Voigt et al. 2018).

Genome-wide association studies (GWAS) of oral and craniofacial diseases may show limited concordance among them due to random and systematic errors incorporated during study implementation (Agler and Divaris 2020). For example, in periodontal tissue studies, inherent genetic differences between the study populations, as well as inconsistencies in the precise definition of periodontitis cases and controls across studies, may be a problem. Given the multifactorial nature of periodontitis and the decisive roles of environmental factors such as bacterial exposures and cigarette use, it is reasonable to conclude that genetic information will explain only part of the variance of the disease at the population level. In the current post-genomic era, our inadequate understanding of crucial epigenetic mechanisms and transcriptional controls that regulate gene expression is slowing progress (Barros and Offenbacher 2014; Larsson et al. 2015).

To date, the majority of published single-cell techniques have been in embryology, neurology, and oncology. Although the applications of single-cell technology show promise, they have barely touched the mechanisms involved to affect applications in oral health and personalized dentistry.

Next-Generation Sequencing and Oral Diseases

During the last 20 years, next-generation sequencing (NGS) has become the norm for studying oral ecology, oral diseases, and the associations between the oral microbiome and systemic conditions. In addition to advances in understanding the basis of oral ecology, oral microbiome research has significantly expanded our knowledge of oral health and disease. In endodontics, the complexity and diversity of the microbiome associated with different root canal infections and treatment outcomes have been better defined, along with their relationships to clinical features (Sanchez-Sanhueza et al. 2018). In oral cancer research, several studies have found unique microbial signatures (Banerjee et al. 2017; Furquim et al. 2017; Zhao et al. 2017). Studies of the peri-implant microbiome have demonstrated its commonalities with the periodontal microbiome, including how smoking behaviors modulate it (Schincaglia et al. 2017). In addition, prominent members of the oral microbiome have been associated with several conditions, including colorectal cancer (Kostic et al. 2013), pancreatic cancer (Fan et al. 2018a), and lung cancer (Yan et al. 2015).

Pioneering studies of periodontal metagenomics (Duran-Pinedo et al. 2014) and metatranscriptomics (Yost et al. 2015) have confirmed the importance of classic pathogens. NGS has been an important tool for determining signature periodontal dysbiosis (Meuric et al. 2017), the microbial basis of the clinical stages of periodontitis (Boutin et al. 2017), and the latter's initiation and progression (Yost et al. 2015). This technology has led to a broader study of the effects of periodontal treatment (Califf et al. 2016) and the individual and concomitant effects that smoking behaviors and diabetes (two risk factors for periodontitis) have in promoting an at-risk microbiome (Giannobile 2013; Ganesan et al. 2017).

Microbiome/Inflammasome/Virology

Microbiome research has grown significantly because of the availability of polymerase chain reaction (PCR) methods mentioned in the 2000 Surgeon General's report on oral health. Over the past 20 years, there has been an evolution in methods and a revolution in knowledge. One of the greatest advances in oral health is the greatly expanded knowledge of the diversity and biology of the microorganisms found in the oral cavity.

Microbiome studies have evolved from the use of bacterial-specific probes (Dewhirst et al. 2010) to the characterization of the entire microbiome community (Escapa et al. 2018). Such in-depth characterization has led to greater understanding of the microbial community, its interactions with the host, and its contributions to health and disease. Technologic advances are revolutionizing the traditional concepts of microbial virulence and pathogenesis (Lamont et al. 2018; Al-Hebshi et al. 2019). Oral pathogens, long regarded as key contributors to the development of dental caries and periodontitis, have now been recognized as mediators in tuning microbe-host interactions and in tipping the balance between microbial synergy and dysbiosis (Lamont et al. 2018). Human microbiome studies that selectively target specific organisms are revealing conserved biochemical activities and signaling cascades (Olsen and Potempa 2014; Garcia et al. 2017), which have led to promising compounds that make precision therapy possible.

Oral Microbiome and Oral Diseases

The number of studies using molecular approaches to characterize the periodontal and dental caries microbiomes has increased enormously during the past few years. These studies indicate that a large number of non-cultivable species are associated with oral biofilms during periodontal inflammation (Wade 2013), making it clear that periodontal and dental caries pathogenesis does not result from the actions of a single or even a few bacterial species, but instead requires complex and subtle interactions between specific bacterial species and the host. The polymicrobial synergy and dysbiosis hypothesis proposes that a potentially pathogenic community arises from the actions of a few bacteria, termed *keystone pathogens* (Darveau et al. 2012).

Important advances for the study of the oral microbiome during the past 20 years include the development of the Human Oral Microbial Database (HOMD) (https://www.homd.org) (Chen et al. 2010), as well as myriad innovative molecular techniques to identify new and emerging microorganisms associated with disease. The HOMD catalogs partial and complete genomes of more than 800 of the most common microorganisms that colonize the oral cavity, including uncultivated taxa. As a result of collective efforts in the field, this segment of the microbiome, which was once estimated to constitute 50% of the oral microbiome, is now estimated to be 30%—in part because of the cultivation of previously uncultivated taxa (Vartoukian 2016).

As information about the composition of the oral microbiome continues to grow, its influence on other aspects of health are becoming more apparent across the life course. For instance, the relationship between the composition of the oral microbiome and adverse pregnancy outcomes continues to strengthen (Saadaoui et al. 2021). In addition, the mode of delivery (cesarean section vs. vaginal birth) (Lif Holgerson et al. 2011) and early diet (breastfeeding vs. formula), as well as the maternal microbiome and tooth eruption (Mason et al. 2018), are shown to have an impact on the structure of infants' and children's oral microbiomes. With regard to adults, new insights have been gained into the harmful interactions between microbial communities and heavy alcohol consumption (Fan et al. 2018b), diabetes (Ganesan et al. 2017), and possibly Alzheimer's disease (Dominy et al. 2019), among others.

Despite major advances in microbiome research, gaps in knowledge remain. The complexity of the dental, oral, and craniofacial environments contributes to varied biological ecosystems that dictate the progress of disease. Research challenges related to unresolved dental pulp and periapical infections need to be considered. Microbial signatures of disease activity, progression, and risk have been identified, but have not yet been effectively translated into clinical use to predict disease activity, recurrence, and response to different types of treatment. In addition, even though the most common oral diseases are infectious, and knowledge about them has expanded, there is a need to better understand the basis of current antimicrobial treatments, the rise and transmission of bacterial antibiotic resistance, and the development of new antimicrobial approaches. Despite improvements in understanding the causes and progression of oral diseases and the connection between the oral microbiome and systemic health, it still is unclear whether the microbiome can be used as a tool to predict disease risk and response to specific treatments. Larger epidemiologic and mechanistic studies are needed to identify and validate early disease markers.

Current studies rely on the taxonomic grouping of microorganisms at a species level, with very scarce strain-level information. Although studies performed before the high-throughput sequencing era showed that different strains of microorganisms possess distinct pathogenic attributes, progress in understanding microbiome-wide strain associations with disease and the functional significance of strain variability has been limited.

The development of methods to manipulate the oral microbiome is a continuing challenge. Although several disease-related synergistic interactions among microbiome members have been described, little progress has been made in the development of methods to control microbiome communities that target key microorganisms or to manipulate environmental conditions to preserve health-associated communities.

There are other challenges. Most oral microbiome studies fail to reference microbiomes residing in other parts of the body (Graves et al. 2019), but given the connectivity between oral and other microbiomes, disregarding key partners may give rise to biased conclusions. Moreover, investigators involved in oral microbiome research have not directly addressed the possibility of selection bias in their samples. Reports have shown that GWAS have been overwhelmingly dependent on participants of European ancestry (Popejoy and Fullerton 2016), and that same bias may be reflected in studies of the oral microbiome. If so, those who are experiencing the greatest disparities related to oral disease, and who could most benefit from this research, may be underrepresented in key studies, thereby compromising the validity and applications of this work. Microbiome studies also yield enormous amounts of data with large variations. Finding a pattern in microbial genes, species, and pathways associated with a specific function of interest in the sea of big data is a complex task (Pinu et al. 2019). The cost and logistics involved in studying the microbiome longitudinally may prevent investigators from compiling a complete picture of how it responds to environmental and host cues over time.

Choosing the right path forward to develop microbiome-targeted therapies also is challenging. Exciting discoveries in new species (Berdy et al. 2017) and in polymicrobial and microbe-host interactions (Stacy et al. 2016; Lamont et al. 2018) offer opportunities to develop effective treatments. Designing and developing drugs that target bacterial factors or inhibit select bacteria are on the horizon (Zhu et al. 2015; Koo et al. 2017; Stone and Xu 2017). However, given the complexity of the microbiome community (Baker et al. 2017), it is challenging to predict how therapeutic options would prevail without a complete understanding of the molecular details of the targeted microbiome. The study of the microbiome and inflammasome is still in its infancy (Stulberg et al. 2016), and further basic and translational science with clinical applications is needed.

Genetics Versus Environment

The last 2 decades have provided important information in determining if inherited traits or life experiences play a greater role in health. Comparing dental plaque and saliva samples from non-Hispanic Black, White, Latino, and Chinese persons (Mason et al. 2013) showed ethnicity-specific microbial signatures. In a subsample of two large Ashkenazi Jewish families (Shaw et al. 2017), the environment (i.e., sharing the same household) was more strongly associated than genetics (i.e., kinship) with the salivary microbiome. The microbial analysis of supragingival plaque microbiomes of 485 dizygotic and monozygotic twins showed that oral microbiome similarity increased with shared host genotype (Gomez et al. 2017). In another study examining the genetics of transmission by comparing the oral microbiota of biological versus adoptive mother-child pairs, findings supported the conclusion that shared environment and contact is more important in oral bacteria acquisition than genetic susceptibility (Mukherjee et al. 2021). Collectively, these findings suggested that under high genetic similarity (i.e., kinship vs. ethnicity), the environment's effects on disease development may prevail.

Epigenetic Modification of Viral Genomes by Oral Pathogens Links Viruses and Bacteria

The field of epigenetics, almost unknown at the time of the 2000 Surgeon General's report on oral health, has now exploded into a highly relevant area for understanding oral disease pathogenesis. Viruses and bacteria have developed diverse mechanisms to directly affect host cell epigenetics, driving pathogenesis and cancer development.

Significant progress has been made during the past 20 years in understanding oral environmental triggers that engender epigenetic reprogramming related to tumor viral pathogenesis in the mouth. The mouth harbors billions of oral bacteria at any given time (Dewhirst et al. 2010). It is now understood that bacterial metabolites can affect virally infected cells, particularly in a setting of viral latency (Morris et al. 2007; Gorres et al. 2014). Findings have suggested that bacterially secreted products may alter both host and viral gene expression through epigenetic regulation. Active viral replication and shedding occur in the oral cavity, suggesting an oral environmental trigger that allows reactivation from a viral latent state.

Human papillomavirus (HPV) hypomethylation is associated with cervical cancer and with head and neck cancer, and progressively less methylation was seen in patients with carcinoma, compared to those with precancerous lesions and asymptomatic infections (Faraji et al. 2017). Studies have suggested that periodontopathic bacteria are a factor in the regulation of cancer-associated viral oncogenes (Cunningham-Glasspoole 2015) and have suggested an additional link between bacteria and HPV-associated cancer.

Inflammation and Inflammasome

The term *inflammasome* did not exist at the time of the 2000 Surgeon General's report on oral health. Since then, more than 30,000 articles have been published with *inflammasome* as a keyword, and nearly 700,000 have been published with the keyword *inflammation*. A patient with cancer, periodontal disease, or type 2 diabetes can now be monitored and treated for uncontrolled inflammation-associated tissue by measuring inflammasome levels in saliva, gingival fluid, and oral tissues, which have positive correlations with systemic and blood inflammasome levels. Saliva is the most readily available source for testing and can be sampled noninvasively (Isaza-Guzman et al. 2017; Lee et al. 2018). Available therapeutic approaches aimed at inflammation control are focused on medications such as nonsteroidal anti-inflammatory drugs and selective anti-inflammatories that suppress essential inflammatory pathways but come with risks. Developing new strategies to activate beneficial anti-inflammatory pathways, such as pro-resolution mediators of inflammation (e.g., resolvins, transforming growth factor beta, and interleukin [IL]-10) could offer medications with fewer side effects. Successful targeted therapy against IL-1 has been developed to control inflammation in rheumatoid arthritis. Developing targeted drugs specific to dental, oral, and craniofacial diseases would be beneficial for controlling local and systemic inflammatory signals.

Inflammation accompanies disease development, tissue changes, and tissue loss. Although genetics and multiomics have advanced during the past 20 years, there have been limits to effectively applying this knowledge to clinical practice. Current methods for diagnostics and disease monitoring fail to capture the complexity of inflammation kinetics at the individual and population levels. In diagnosis and monitoring of periodontal diseases, tissue levels are taken into consideration without regard to molecular levels of inflammation. Furthermore, the translation of knowledge about mediators of inflammation into clinical applications that mitigate tissue destruction has been slow and needs to be advanced.

Regenerative Medicine, Dental Materials, and Bioinspired Materials

There has been an explosion of new technologies introduced to dentistry for regenerative applications (Bayne et al. 2019), most especially in the areas of aesthetic dentistry and in less-invasive techniques to conserve tooth structure through prevention and early treatment of diseased tissue.

Regenerative Medicine and Dental Repair

Continuing challenges regarding existing biomaterials include a relatively high incidence of recurring decay around bonded dental restorations; a higher than desirable rate of fracture of dental composite fillings because of their limited strength; a lack of ideal aesthetics for the highest strength ceramic materials, such as zirconia; and a higher than desirable incidence of infection around dental implants that may lead to premature failure. Other key challenges include the development of materials that have biological effects, such as inhibiting bacterial adhesion and colonization at sensitive tooth-adhesive interfaces, and materials that promote the production of new tooth mineral to replace lost tooth structure. The development of a material that can replace infected pulp tissue to avoid endodontic therapy or tooth extraction could be critical for saving severely damaged teeth. Despite the great success of dental implants, problems leading to failures and implant loss still occur. One area of intense interest is to better understand the incidence of peri-implantitis, in which tissues become inflamed where the implant emerges from the bone and is in contact with the gingival tissues (Berglundh et al. 2019).

Perhaps the area that appeared the most promising 20 years ago but has seen relatively little practical advancement because of its tremendous complexity is the in situ regeneration of new teeth (Monteiro and Yelick 2017). Natural-appearing teeth have been grown in small animals (Yelick and Vacanti 2006) and in larger mammals (Wu et al. 2019), but the implantation of such teeth, or the regeneration of new, anatomically correct hard tooth structure within a human mouth, remains a more distant goal.

Dental Adhesives and Dental Composites

Today, adhesive and composite materials have mostly replaced dental amalgam as the primary restorative materials. Dental adhesives and dental composites are similar polymer-based materials that restore lost tooth structure by bonding to and sealing the tooth to maintain its integrity and resist further tooth decay (Bedran-Russo et al. 2017; Pfeifer 2017). New dental adhesives and composites represent a true revolution in dental treatment as a result of intense research and product development, especially for the resin component (Fugolin and Pfeifer 2017). As a result of significant advances in the past 20 years, current materials may last for decades when placed appropriately and in patients with good oral health (van de Sande et al. 2013). Research into advanced formulations of the materials has mostly solved the situation of excessive wear on posterior teeth from chewing, a major problem 20 or more years ago (Ferracane 2006).

Many clinical studies have shown average lifetimes for restorations that approach 15–20 years or more in both anterior and posterior teeth (Bayne et al. 2019). However, other studies have shown much lower rates of success and the need for earlier intervention, possibly within 6–7 years of placement (Kopperud et al. 2012; Rho et al. 2013). The reason for this discrepancy is at least threefold. First, the most common reason for failure was secondary dental caries. Second, the adhesive and composite materials have characteristics that require a demanding, multistep placement technique that can lead to premature failures. Third, composites also shrink during curing, which may produce stresses that challenge the adhesive's bond to the tooth. One approach to address this issue is the development of new resin formulations with reduced contraction stress (Meereis et al. 2018). Many commercial products have been produced, including easier to place bulk-fill composites (Veloso et al. 2019). Another approach has been the development of adhesives that directly bond to the tooth but do not require the tooth to be pretreated with an acid solution to promote bonding. Some of these self-etch adhesives have shown favorable clinical results (Peumans et al. 2010; van Dijken 2010). Another important factor influencing premature restoration failure is that many patients' diets and oral habits predispose them to recurrent dental caries. In the future, it is critical that research focuses on the production of materials that are more robust, simpler to use, and inherently effective against the attachment of bacterial plaque.

Dental Ceramics

Dentists are familiar with the use of and indications for metal alloys, which have provided stable and durable restoration of tooth structures for more than 100 years (Donovan et al. 2004). Although predominantly gold-based alloys have been the primary material for dental crowns and bridges that replace one or more teeth, dental ceramics (such as dental porcelain) have emerged as a viable and sought-after option to minimize or eliminate the use of metals in the mouth (Zhang and Kelly 2017).

Dramatic advances in materials that provide strong and tough ceramics, such as lithium disilicate and zirconia, have revolutionized the replacement of broken and severely decayed teeth with materials that are durable and resemble natural teeth (Denry and Kelly 2014; Zhang and Lawn 2018). These new materials, especially lithium disilicate, are highly aesthetic and strong, although their use in heavy dental occlusion is still limited. Increased use of zirconia ceramic, which is nearly twice as strong as any other dental ceramic and requires less tooth reduction, has had a noted impact in dental care (Ghodsi and Jafarian 2018).

Dental Implants

In the past, tooth loss was treated by placing a dental bridge, which requires cutting away the two sound adjacent teeth to prepare them as abutments to hold the bridge with the replacement tooth crown. In the past 20 years, however, dental implants, which offer distinct advantages over dental bridges, have become a normal part of dental treatment (Howe et al. 2019). Dental implants typically are made from titanium because of its strength and excellent biological response, although new high-strength ceramics, such as zirconia, are increasingly being used in areas where metal may partially show in the mouth because of their high biocompatibility and improved aesthetics. Dental crowns or bridges are placed on the implant. The survival of tooth-supported and implant-supported three-unit fixed dental prostheses has been shown to be similar (Pol et al. 2018). The key to the greater success of the dental implant is that it becomes solidly anchored through the growth of new and supportive bone around the device, a process called osseointegration (Bosshardt et al. 2017). Several factors have been shown to affect this process. Effort is now focused on better understanding the optimal implant surface texture, such as roughening on the micro- or nanometer scale, to create an optimal tissue response at the implant surface (Albrektsson and Wennerberg 2019). Implant characteristics, together with local and systemic host factors, may affect susceptibility to peri-implantitis, which remains one of the most common biological complications of functional implants (Rakic et al. 2018; Hashim and Cionca 2020).

Biological factors offer significant potential for tissue regeneration around teeth and for dental implant site development (Larsson et al. 2016). Enamel matrix derivative (EMD) is the earliest-studied biologically active product for periodontal regeneration (Koop et al. 2012). EMD is available commercially as an injectable gel solution containing enamel matrix proteins (amelogenins and other enamel proteins) and a carrier, propylene glycol alginate. Systematic reviews have shown that EMD delivers improved clinical outcomes compared to open-flap debridement (Esposito et al. 2009; Koop et al. 2012). Recombinant human platelet-derived growth factor-BB, combined with β-tricalcium phosphate, is another commercially available product that has shown promising results for addressing regenerative intrabony and furcation (bone loss in the area where the tooth branches off from the root) defects in periodontal treatment (Nevins et al. 2013). Other growth factors, such as fibroblast growth factor 2, have been under clinical development and have demonstrated promising results in human clinical trials (Cochran et al. 2016).

Nanotechnology

The safety of nanoscale materials is a continuing challenge. Nanoparticle toxicology is still an emerging field, with inconsistencies in the published literature. Tests to determine nanoparticle toxicity have not reached consensus (Webster 2009). Furthermore, although many nanomaterials have been claimed to lead to unprecedented improvements in efficacy—in terms of physical properties, biological interactions, and control—dental materials and technologies that rely on nanoscale systems have yet to deliver paradigm-shifting outcomes. Improvements have mostly been incremental and on par with those from many traditional microscale technologies.

Stem Cell Biology

Over the last 2 decades, advanced molecular biology tools and bioinformatic capabilities have become available that use machine learning algorithms to rigorously characterize different stem cell populations on the basis of their molecular signatures. This deeper understanding of stem cells' unique molecular profiles will enable more targeted therapies for specific applications.

In 2000, the fields of tissue engineering and regenerative medicine were just emerging, stem cell therapy for craniofacial regeneration was merely a concept, and bone marrow was the only known source of MSCs. Since that time, tremendous technologic, clinical, and scientific advances have led to a deeper understanding of MSC biology, including how MSCs interact with other cells, how to isolate them from different tissues, how to control their behavior with different signals and microenvironments, and how to deliver them to local and distant sites. A new paradigm has been proposed for the mechanisms of action of MSCs in the laboratory, on the basis of their potent immunomodulatory, anti-inflammatory, and multifaceted trophic (stimulatory or growth) effects, such as proangiogenic, tissue-remodeling, antioxidant, and antiapoptotic effects (Shi et al. 2018).

MSCs can migrate to injured and inflammatory sites, actively sense the signals or cues from damaged cells, and communicate with other types of cells, particularly immune cells. Once activated, MSCs respond with increased proliferation activity, including secretion of several biological factors to modulate immune cell functions, promote blood vessel growth, suppress cell death, and reduce reactive oxygen species (also sometimes called free radicals), thus establishing a regenerative microenvironment.

To date, more than 800 clinical trials using MSCs have been registered with ClinicalTrials.gov; in those trials, MSCs of different origins are being tested for their therapeutic effects on a wide spectrum of autoimmune, inflammatory, and degenerative diseases (Shi et al. 2018). Although there are a number of MSC products being used to treat patients with dental, oral, and craniofacial conditions under the practice of medicine, there are no MSC products yet approved by the U.S. Food and Drug Administration (FDA) (U.S. Food and Drug Administration 2020b).

Despite their potential to differentiate into cells of all three germ layers, the clinical use of embryonic stem cells (ESCs) faces several major challenges. There are critical ethical challenges, difficulties involved in the differentiation of transplanted ESCs into mature and physiologically functional cell types capable of integrating into the relevant damaged tissues, long-standing issues of immunogenicity, and potential tumorigenicity as a result of genomic instability (Guhr et al. 2018; Prentice 2019).

The use of MSCs of different tissue origins as therapeutic products in regenerative medicine presents many biological, manufacturing, and clinical challenges (Martin et al. 2019). More stringent methods of characterizing these heterogeneous cell populations are needed to elucidate the mechanisms underlying cell variability (Huang et al. 2009; Bianco et al. 2013). Another challenge is to determine the best modality in which to deliver stem cells. Different rigid and injectable polymers have been used as scaffolds, but information has been insufficient to drive clinical efficacy. Overcoming these challenges with robust, well-designed clinical trials utilizing fully characterized source materials is instrumental for gaining FDA approval.

Cost-effective reimbursement models and protocol logistics for the isolation, expansion, and delivery of stem cells need to be established to bring technologies to clinical adoption. Stem cell manufacturing that meets the appropriate regulatory and safety standards likely will be expensive and increase the costs for the clinician and the patient. In addition, current reimbursement by dental insurers provides insufficient coverage for regenerative therapies in dentistry. As a result, these approaches may widen health disparities. Despite a considerable market for bone (an estimated US$750 million) and dental pulp (an estimated US$200 million) regeneration, many companies are cautious about committing resources because of existing limitations and inadequacies of third-party reimbursement for new treatment procedures. Academic partnerships with industry will need to be fostered to establish cost-effective models for autologous stem cell production.

Discussions of stem cell biology would be incomplete without mentioning the progress during the past 20 years in understanding cancer stem cells' role in the development, progression, and therapeutic resistance of cancer (Baillie et al. 2017). Cancer stem cells can self-renew and proliferate, have been identified in head and neck cancer, and are highly capable of forming tumors. Advances in their identification and characterization have stemmed from the cell and molecular technologies developed and explored during the past 20 years and are currently being expanded with new technologies such as single-cell approaches (Qi et al. 2019).

Science and Technology for Practice

Over the past 20 years, biotechnology and digital and information technology are emerging trends that have strongly influenced the diagnosis, treatment, prevention, documentation, and management of oral diseases. In the context of new technologies for clinical application, bioethical implications at both the individual and society levels need to be continually considered (Anderson and Anderson 2019; Resnik 2019; Scheper 2019). In the educational setting, academicians must be aware of potential conflicts of interest if they associate themselves with pharmaceutical or technology companies. The speed with which new technologies can be incorporated into practice needs to be tempered with accurate information and evidence-based investigation. The potential of new advances to reduce health disparities also is a critical consideration.

Genetics- and Genomics-Based Precision Health

As the costs of sequencing DNA have decreased during the past 20 years, the use of whole-exome (the part of the genome that codes for proteins) and whole-genome (the entire 3 billion base pairs of DNA) sequencing has increased. These tests have revealed genetic mutations underlying dental conditions, such as amelogenesis imperfecta (Smith et al. 2019), tooth agenesis (Salvi et al. 2016), and latent transforming growth factor-betabinding protein 3 (LTBP3)-related disorders (Intarak et al. 2019). LTBP3 pathogenic variants are associated with amelogenesis imperfecta, short stature, and predisposition to thoracic aortic aneurysms and dissections (Guo et al. 2018). Many dental genetic variants are associated with more severe conditions. Dental findings, including radiolucencies (defects that appear as darkened areas on radiographs), have been associated with some types of mucopolysaccharidosis and Gaucher disease (Saranjam et al. 2013). Oligodontia (an absence of six or more teeth) can be associated with colon cancer (Lammi et al. 2004). One genetic variant of amelogenesis imperfecta with gingival hyperplasia is associated with nephrocalcinosis (an increase of calcium levels in the kidneys). These findings suggest that persons with these oral signs should be referred for a renal workup (Koruyucu et al. 2018).

The advent of new approaches, such as clustered regularly interspaced short palindromic repeats (CRISPR)-associated protein 9 and the expanded capabilities for gene editing, including ex vivo cell therapy and in vivo gene editing (Raaijmakers et al. 2019), as well as DNA vaccines, chimeric antigen receptor therapies, pharmacoepigenetic approaches to manipulate targeted genomic expression, and gene replacement therapies show promise for improved clinical strategies in genetic conditions.

In contrast with disorders caused by a single genetic variant, most chronic diseases are complex and caused by the interactions of multiple genes, environmental exposures, and lifestyle factors. These multifactorial origins characterize conditions such as diabetes, heart disease, hypertension, and common cancers. Environmental factors can modify DNA or the histone proteins in chromatin, altering gene regulation and expression and influencing disease (Berdasco and Esteller 2019).

Factors other than the actual nucleotide sequence play a role in gene expression. Changes that do not affect the actual DNA sequence are epigenetic in nature and involve methylation of DNA or histone modifications. The environment can cause epigenetic modifications, for example, through diet, smoking behaviors, exposure to microbial agents, gender, aging, drugs, and toxins (Niller and Minarovits 2016; Berdasco and Esteller 2019). Such environmental exposures are important in the development of many conditions dentists encounter, such as dental caries, periodontal disease, and oral cancers. Many pathologies of the oral cavity are linked to systemic conditions such as diabetes, heart disease, and obesity, which also have epigenetic components in their development.

Advances in understanding genomic architecture and the role of RNA biology have altered our perception of how the genome functions and interacts with genetic and environmental factors to regulate health and disease, yet much is still unknown (Jukam et al. 2019). To fully participate in these genomics initiatives, the dental community will need to overcome barriers to the integration of all health care records and interprofessional training (Regier and Hart 2016; Weitzel et al. 2016).

Pharmacogenetics, which is increasingly playing a role in dental care, uses information about an individual's genome to choose drugs and drug doses likely to work best for that person's unique genetic profile—a departure from the one-drug/one-dosage-fits-all approach. Pharmacoepigenomics target pharmacologic treatments that may reduce or reverse epigenetic effects in diseases. Clinical applications of pharmacoepigenomic interventions have increased and show promise for treating oral and craniofacial diseases that result from a combination of genomic, metabolic, epigenomic, and environmental factors (Teijido and Cacabelos 2018; Jones et al. 2019). An example of progress in which genetic strategies may be particularly valuable is a targeted approach aimed at the tumor suppressor p53 protein, which shows promise in sensitizing head and neck cancer stem cells to chemotherapy (Rodriguez-Ramirez and Nör 2018).

One of the most revolutionary advances in medicine in the last 20 years has been the incorporation of genetic information into clinical care. The dramatic reduction in the cost of acquiring genomic information and the use of information technology to understand clinically useful relationships among genomic data, health, and disease are accelerating the process. Genomic data linked to extensive phenotypic and health information are being collected on millions of individuals across ethnic groups, enabling clinical research in data biobanks and creating the possibility of asking more complex genetic questions (Tyler-Smith et al. 2015; Stark et al. 2019; Verma et al. 2019), which will help characterize healthy states and disease-associated conditions, identify robust predictive associations (clinical validity), and facilitate evaluation of clinical utility (Ioannidis and Khoury 2018). Careful clinical characterization, including longitudinal data, will facilitate identification of disease-associated genetic variants in humans. Despite promise, the genetic information revolution has had very limited impact on dental care, with yet untapped potential for managing oral health in the future.

A continuing challenge to the dental community is the integration of increasingly available genomic information into clinical practice in valid and useful ways. Barriers need to be overcome, including data collection, recording, and interpretation. Surmounting these barriers will likely require changes to health records and introduction of multidisciplinary health teams. Regulatory challenges and determination of evidence for clinical utility need to be addressed. Dental education and training will need to incorporate genetics education and interprofessional collaboration (Johnson et al. 2008).

Although big data has a role in precision medicine, certain risks do exist. Ethical, legal, and social tenets of genomics need to be applied to ensure privacy and confidentiality (Dolley 2018). Maximizing the utility of genomic information in clinical care requires integration of health records and the incorporation of genomics into EHR systems (Ohno-Machado et al. 2018). Standards for best practices in analysis and interpretation of clinical genomic information are needed (Brownstein et al. 2014; Lu et al. 2018). Because genomic factors affect many diseases across the life span and across clinical disciplines, no single professional group encompasses the entirety of this field, reinforcing the need for genomics education and interprofessional practice (Schully et al. 2015).

Diagnostics

Innovative Diagnostic Imaging Systems

Examples of the technologies currently being used in dental therapeutics include digital planar and 3D radiography, static occlusal and jaw-tracking software, and intraoral scanning of hard and soft tissues for disease diagnosis and digital treatment. In addition, computer-aided design and manufacturing workflows can assist in procedures such as endodontic access, crown fabrication, and surgical guides for complex head and neck surgeries (Shah et al. 2014). Emerging technologies, including optical coherence tomography, allow clinicians to peer through mucosal tissues to underlying teeth, bone, and cartilage. Ultrasound and magnetic resonance imaging (MRI)-based soft tissue scanning systems have been developed for use in dentistry to better assess patients' oral health status with extensive physiological and pathologic information. Some additional tools, such as Raman spectroscopy, which reveals the molecular and related health status of scanned tissues, are being explored for their capacity to further enhance dentists' diagnostic capabilities, accuracy, and efficiency. However, the size and cost of MRI scanners and other neuroimaging tools (e.g., positron emission tomography, magnetoencephalography) are substantial challenges that need to be overcome to realize their broader clinical applications in dental care.

Diagnostic Biomarkers in Saliva

Since 2000, omics studies have greatly accelerated the discovery of biomarkers of human genetics and the oral microbiome associated with dental diseases. Rapid sequencing has made genomic analysis of the microbiome more widely applicable. Growing databases with improved software make analyses more accessible and increase the opportunities to explore systemic linkages with oral health.

Saliva-based genomics offers unique advantages, above and beyond oral health diagnostics. The presence of our entire genome in saliva has been used to access personal genomic information pertaining to ancestry, health, and wellness. Saliva samples and NGS can reveal genomic variants (e.g., single nucleotide polymorphisms) that confer risk for health conditions (e.g., cancer, such as variants in the genes for breast cancer type 1 and type 2 susceptibility proteins) and can reveal ancestry information. Using a noninvasive approach—gathering a saliva sample—to derive genomic information for personalized and precision medicine applications has promising potential.

Liquid biopsy can now detect circulating extracellular RNA (exRNA), circulating exosomes, and circulating tumor DNA (ctDNA) in human biofluids. This approach is used to detect lung cancer cells using saliva markers of the epidermal growth factor receptor gene mutations. Anticancer drugs can target this gene and improve lung cancer patients' survival rates (Wei et al. 2018). Cell-free DNA shed from tumor cells into the circulatory system, or ctDNA, can be detected in a number of body fluids, including blood, urine, and saliva, where its mutations distinguish it from normal cell-free DNA. The most common technologies for the detection of ctDNA are NGS and digital PCR. Salivaomics-based liquid biopsy for exosomes and exRNA and ctDNA detection has potential for clinical translation; however, challenges remain on documenting robust evidence for the sensitivity, specificity, accuracy, and reproducibility of these assays.

Digital Technology for Advancing Diagnostics

There has been dramatic progress in digitization in dentistry, which has created a new market and value network that will disrupt existing norms. Digitization has the potential to improve early detection of dental diseases, reduce cost of treatment, and increase treatment reliability by decreasing errors in dentistry. These innovations offer an opportunity to rethink oral disease prevention and health care delivery in the context of providing public health programs to underserved populations. Current versions of intraoral scanners, using a laser fluorescence detector or near-infrared light transillumination, have incorporated dental caries detection, and because they are relatively easy to use, these technologies have the potential to become important diagnostic tools for the early detection of dental diseases. However, clinical validation and accuracy assessments suggest that further development work is needed for these technologies to perform equivalently to traditional visual-tactile detection methods (Abogazalah and Ando 2017; Kocak and Cengiz-Yanardag 2020).

Current radiographic methods present challenges in their sensitivity for detecting occlusal lesions and underestimation of the depth of penetration of proximal lesions (Ricketts et al. 1997). Stain and plaque interfere with porphyrin-based fluorescence systems (Shi et al. 2000).

Although the use of fluoride has greatly reduced the prevalence of dental caries, methods are needed for the quantitative assessment of fluorosis, which has become a growing problem (Baker et al. 2017). Current methods rely on subjective visual examination and use an ordinal scale poorly suited for identifying differences in the severity of mild fluorosis among communities. Angmar-Mansson and colleagues (1994) studied several optical techniques for improving the assessment of dental fluorosis, which is characterized clinically by diffuse opacities. Quantitative light-induced fluorescence (QLF) has been used as a potential diagnostic tool for assessing fluorosis because the subsurface porosities scatter light in a manner similar to demineralized carious lesions (Li et al. 2003).

McGrady and colleagues (2012)(Pretty et al. 2012) employed QLF in an epidemiologic fluorosis survey in fluoridated and non-fluoridated communities in England and Thailand. The Centers for Disease Control and Prevention has developed a system building on that work using both QLF and polarized visible light for oral health examiners in the United States.

Unfortunately, visible and fluorescence-based optical measurements suffer from the interference of extrinsic stain, specular reflection (glare), variations in tooth color, variations in enamel thickness, and low contrast between normal and hypomineralized enamel. However, interference from stains does not affect imaging systems operating at longer wavelengths, which have advantages for assessing the severity of fluorosis (Fried et al. 2013). Optical coherence tomography at near-infrared wavelengths is ideally suited for measuring the subsurface structure of fluorotic lesions to quantify their depth and severity (Hirasuna et al. 2008). It has not been confirmed that the pattern and distribution of the lesions attributable to fluorosis are a unique occurrence. A method that can measure the depth of defects may provide a measure of severity, which can be used to determine the feasibility of removal or treatment.

Three-Dimensional Bioprinting and Additive Manufacturing

Developments in the past 20 years are shifting trends in dental reconstruction away from conventional impression technologies and toward digital imaging. Cone beam computed tomography (CBCT) and intraoral scanners are now used to design and produce dental prostheses and surgical guides that can be fabricated using additive manufacturing, as well as the more traditional subtractive manufacturing technologies (Abduo 2019). Additive manufacturing, or additive layer manufacturing, is the production name for 3D printing in which a computer-controlled process creates 3D objects by layering materials. Technologies of this type have made complex treatment feasible for most dentists and have decreased manufacturing time. Potential challenges include consistent dimensional accuracy and material suitability.

A wide selection of platforms, printable materials, and applications now is available in medical 3D printing (Tappa and Jammalamadaka 2018). Materials include most major classes: thermoplastics, thermosets, gels, ceramics, and metals. Each material requires specific processing strategies and precursor materials—for thermosets, a liquid resin; for metals, specially prepared powders. Because biomaterials have a variety of advantages and disadvantages, this lends them to specific or potential uses in health care (Table) (Tappa and Jammalamadaka 2018).

Perhaps the most widely adopted technology in dentistry is vat polymerization, in which a light source (such as a laser) is directed onto a photocurable resin to build it up layer by layer. Examples of the products of this technology include orthodontic aligners, mouthguards, and surgical guides. Several metal printers have been advocated for dental use to fabricate fixed and removable partial-denture frameworks as well as to fabricate custom implantable devices (Forrester et al. 2019). Several variations of vat photopolymerization, including continuous liquid interface production, digital light projection, and stereolithography, are used by many laboratories to print patterns for fixed partial-denture frameworks for conventional casting methods. The availability of aligner software for orthodontic movement of teeth and fabrication of provisional restorations has increased demand for faster printers (Abduo 2019; Gonzalez Guzman and Ohara 2019).

Conventional tissue engineering approaches have limitations for fabricating vascularized and functional tissues and organs (Ozbolat and Hospodiuk 2016). In the last decade, advances in stem cell biology, biomaterials science, tissue engineering, and 3D bioprinting technology have significantly advanced the fabrication of implantable artificial tissue complexes for regeneration of both soft and hard tissues (Gomes et al. 2017). Bioprinting is a computer-driven, rapid prototyping technology that utilizes computer-aided design software to generate blueprints for highly accurate biomimetic tissue constructs (Kang et al. 2016). This state-of-the-art platform for fabricating complex biomimetic tissues using biocompatible bioinks mimics the chemical, physical, and physiological properties of native tissues. Various types of synthetic or natural polymers, different types of cells, and growth factors have been implemented as the cellular and noncellular components for 3D bioprinting for regenerative purposes (Nagarajan et al. 2018). Because of their ability to become different types of cells and their regenerative potential, MSCs have been extensively explored as the seed cells for generation of tissue engineering and regenerative medicine products, including 3D bioprinting of biomimetic tissue constructs (Snyder et al. 2015).

Despite advantages, the use of printed objects in dentistry is still limited. Definitive restorations (e.g., crowns, bridges) cannot yet be manufactured because of the lack of suitable materials. In subtractive manufacturing, the most commonly used materials for definitive restorations are reinforced ceramics, metals, and composite resins. In additive manufacturing, some polymer prototypes and metals are starting to find their way into clinical practice, although 3D-printed ceramics for dental applications are still struggling to be accepted (Dehurtevent et al. 2017). Metal is commonly used for conventional prosthodontic treatment, and promising clinical outcomes have been reported with posterior single-unit metal-ceramic crowns (Abou Tara et al. 2011; Atzeni and Salmi 2015). Despite its good mechanical properties, metal is not suited for modern microinvasive and aesthetic treatments, whereas 3D-printed reinforced polymers show better potential for final restorations, but they need further development.

Table. Biomaterials classification with their advantages, disadvantages, and applications			
Type	**Advantages**	**Disadvantages**	**Applications**
Metals and metal alloys	High material strength	Corrosive	Orthopedic implants, screws, pins, and plates
E.g., gold, platinum, titanium, steel, chromium, cobalt	Easy to fabricate and sterilize	Aseptic loosening	
		Excessive elastic modulus	
Ceramics and carbon compounds	High material strength	Difficult to mold	Bioactive orthopedic implants
E.g., calcium phosphate salts (HA), glass, oxides of aluminum and titanium	Biocompatibility	Excessive elastic modulus	Dental implants
	Corrosion resistance		Artificial hearing aids
Polymers	Biodegradable	Leachable in body fluids	Orthopedic and dental implants
	Biocompatible	Hard to sterilize	Prostheses
	Easily moldable and readily available		Tissue engineering scaffolds
E.g., PMMA*, Polycaprolactone (PCL), PLA, polycarbonates, polyurethanes	Suitable mechanical strength		Drug delivery systems
Composites	Excellent mechanical properties	Expensive	Porous orthopedic implants
E.g., Dental filling composites, carbon fiber reinforced methyl methacrylate bone cement + ultra-high molecular weight polyethylene	Corrosive resistant	Laborious manufacturing methods	Dental fillings
			Rubber catheters and gloves

Notes: *PMMA–poly (methyl methacrylate).

Source: Tappa and Jammalamadaka (2018).

Complementary, Alternative, and Integrative Medicine in Dental and Oral Care

The use of complementary, alternative, and integrative medicine is extensive, but limited by issues of safety, research and evidence, and regulation. These approaches may include nutritional (e.g., herbs, dietary supplements), psychological (e.g., meditation, hypnosis) and/or physical (e.g., acupuncture, massage) interventions (National Center for Complementary and Integrative Health 2021).

Herbal preparations are commonly used by U.S. adults (Wu et al. 2014). Because herbs are regarded as food products, they are not subject to the same scrutiny and regulation as conventional medications. Various herbal supplements have been reported or are suspected to interact with certain dental drugs. The use of some herbal supplements is associated with oral manifestations including aphthous ulcers, lip and tongue irritation, swelling with fever, tongue numbness, dry mouth, oral and lingual dyskinesia, and salivation (Tachjian et al. 2010).

Information and Data Science

Big Data and Health Information Technology Systems

The generation of evidence using real-world data sources in the past 20 years has created the opportunity to transform dental care and redefine dentistry's role within the health care system. Parallel developments include the significant strides made in analyzing genomic information and the discovery of physical, functional, and biochemical biomarkers for disease. These developments offer new approaches for diagnosing and managing diseases instead of relying exclusively on symptoms and clinical assessment. Moreover, the increasing use of electronic devices to track daily activities, such as sleep, physical activities, and diet, is generating previously unavailable data regarding lifestyle behaviors.

The Patient Protection and Affordable Care Act of 2009 and the 21st Century Cures Act of 2016 (National Institutes of Health 2020b) have resulted in dramatic progress toward increasing electronic documentation of patient care in dentistry and medicine and improving provider, patient, and researcher access to electronic health information. Access to electronic health data has led to the development and evaluation of clinical decision support systems, an appreciation for new imaging modalities such as CBCT to monitor disease progression and treatment outcomes, and a better understanding of the natural history of diseases. However, the full potential of these advances can only be accomplished through evaluating and monitoring the quality of their data.

The dental profession has been mostly solo or small group practices. Consequently, there are as many different ways of recording patient encounters as there are practices, and there has been no consensus on a standardized method of data entry into EHRs. Furthermore, data are entered differently at each dental school, and how information is gathered across schools varies, which makes data mining challenging. A data-sharing framework has yet to be developed that allows oral health professionals to send their data to a curated data warehouse.

The choice of EHR has had a limited impact on the way dental medicine is practiced. To date, 72% of U.S. dental practices use an EHR to capture at least some clinical information (Acharya et al. 2017). Momentum for improved utilization of EHRs is building as the dental profession begins to see the advantages gained from using big data in medicine. However, the need remains for a critical paradigm shift with respect to dental data, with more effective and structured pooling of data and consistent use of diagnostic codes.

Most oral health providers cannot imagine a world without EHRs, yet clinicians often struggle with the lack of user-friendliness of available programs (Jha et al. 2018). Dentists are faced with many unmet information needs when using EHRs, such as timeliness of access to information; quality of visual representations of dental problems; access to patient-specific, evidence-based information; and the accuracy, completeness, and consistency of patient records (Song et al. 2010).

Furthermore, there are unmet needs related to access to medical records, genetic data, proteomics data, microbiome data, and biospecimen data. Issues around privacy of medical and dental information also pose daunting challenges to effective data utilization.

Researchers who want to use the vast amounts of data collected in EHRs face other challenges: Clinical notes cannot easily be queried, and there are data quality issues, such as incomplete and missing information or inaccurate and inconsistent data (Song et al. 2013). Although there are many efforts in medicine to address the problem of data fitness for research projects (Zozus et al. 2014), dentistry has lagged behind when it comes to the adoption of standardized diagnostic terminologies (White et al. 2011) and the use of standardized risk assessment tools (Ismail et al. 2013).

Integrated Electronic Health Records

Progress with EHRs has been fueled by technologic developments, allowing for enhanced system features, as well as by greater depth of knowledge and the urgent need for these records. Specifically, today's systems can provide tools for integrated care and quality care metrics across practice locations to meet growing population needs.

Following publication of the 2000 Surgeon General's report on oral health, the Health Resources and Services Administration began to prioritize and fund medicine-focused federally qualified health centers (FQHCs) to initiate or expand dental operations; part of this expansion included funding for development of integrated EHRs. The following health informatics initiatives provide examples of translational research using EHRs to improve patient outcomes and advance the delivery of high quality, integrated care.

FQHCs are uniquely suited to serving large populations with oral health disparities because they understand the advantages of better integration across the medical, behavioral, and oral health domains and because their staffs have spent decades honing skills to eliminate barriers to care and conducting outreach to communities in support of population health objectives. Moreover, utilizing EHRs and a referral management module in FQHCs has the advantage of providing early patient triage and referral to cross-disciplinary providers.

Point-of-Care Clinical Decision Support Systems in the Electronic Health Record

Secondary use of data routinely collected at point-of-care settings in an integrated medical and dental care environment has improved understanding of oral and systemic associations (Acharya et al. 2018). For example, a growing evidence base supports a relationship between diabetes and periodontal disease driven by underlying inflammatory activity (Mealey 2006; Eke et al. 2012; Glurich et al. 2013). Few of the health systems that have EHRs have developed strategies and tools to support integrated care delivery models that might offer better outcomes for patients with diabetes (Shimpi et al. 2016; Glurich et al. 2018; Shimpi et al. 2018; Shimpi et al. 2019d). In the absence of glycemic index monitoring in the dental setting, engaging predictive modeling and artificial intelligence (AI) to create a clinical decision support tool has offered a solution for identifying at-risk individuals. Once integrated into the EHR, this tool sorts available clinical data and identifies at-risk patients in need of triage for further clinical evaluation.

Several challenges still exist for an integrated health care model. Oral health professionals sometimes struggle to fully understand patients' underlying medical conditions because medical and dental records remain largely separate from one another. Physicians also miss critical diagnostic information when they ignore the craniofacial complex. Integrated medical and dental records help dental clinicians use medical information more effectively and make it much easier for all health care providers to understand a patient's health and history at the point of care, which can lead to fewer errors and more individual-centered care (Figure 5). Health disparities in oral health are pervasive and compromise the ability to elevate health for all.

Finally, greater exploration of the effectiveness of care delivery models that integrate oral health risk assessment tools, alerts, and reminders into medical settings is warranted. This may include integration of dental services within oncology practices to support patients' oral health needs before, during, and following exposure to chemotherapy or radiation therapy; integration within pediatric practices to reduce the incidence and prevalence of dental caries through dental assessment and the placement of sealants and fluoride varnish applications; and integration into obstetrics to improve prenatal dental care. Health disparities in the context of oral health delivery present complex problems that rely on critical, multilevel analyses as described in the National Institute on Minority Health and Health Disparities Research Framework (National Institute on Minority Health and Health Disparities 2018).

Development of Quality Metrics and Dental Quality Dashboards

Using an EHR supports the development of quality metrics within a dental quality dashboard (Hegde et al. 2017). A dashboard's summary format presents relevant patient data that respond to the needs of cross-disciplinary providers for patient management (e.g., diagnoses, treatment history, recent health events and procedures, medication exposure, insurance status, compliance with preventive care appointments).

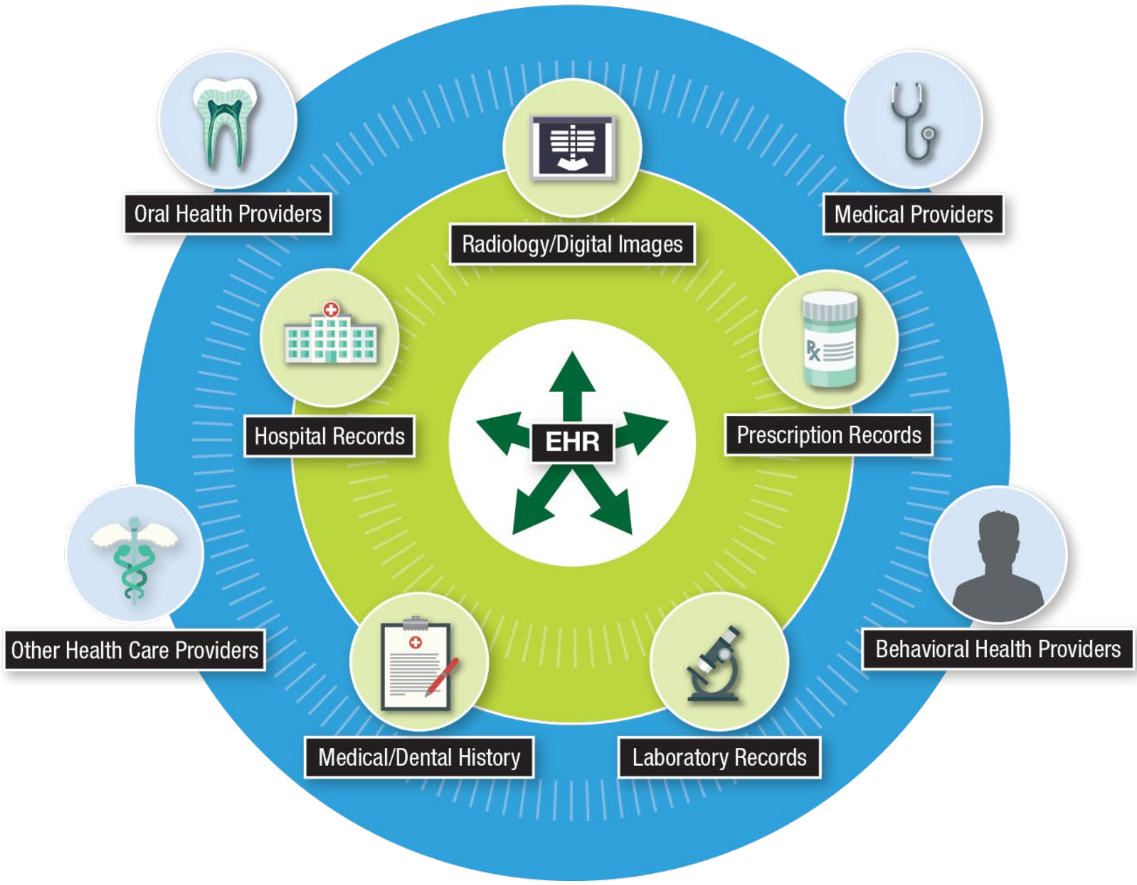
A Dental Quality Analytics Dashboard (DQAD) is a web-based tool that has potential to facilitate data-driven performance reviews for use by dental providers and administrators. Its near-real-time visual analytic platform allows users to monitor, compare, and analyze key clinical, operational, and provider performance and productivity data to identify trends, set goals, and inform improvement activities across multiple providers or clinics. The application may also provide a summary view of the practice population, which may include information on socio-demographic characteristics and medical conditions. An example of an operational DQAD is shown in Figure 6, where sealant applications are tracked against a benchmark to help improve caries prevention activities across clinics (Nycz et al. 2020).

Data Modeling

Health data analytics have grown exponentially during the last decade as electronic data have become available and accessible, and computing power has become cheaper. Today, there is no shortage of machine learning algorithms and deep learning models capable of analyzing large volumes of data of any type within a few seconds.

Multilevel models for health care data promote effective and interoperable biomedical information systems and services. For example, the Unified Medical Language System (UMLS) of the National Library of Medicine gathers several health and biomedical vocabularies as well

FIGURE 5. Integrated electronic health record (EHR)



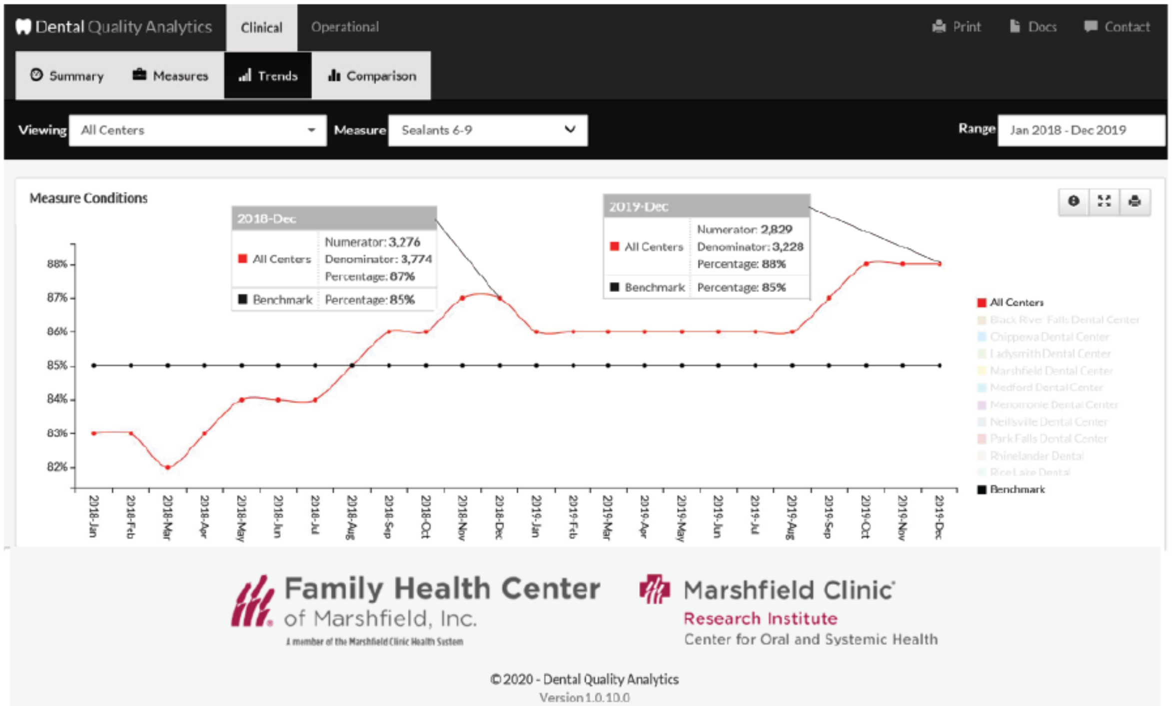
as related items to facilitate interoperability between computer systems (National Library of Medicine 2021d). Additionally, it supports some widely used database models and multiple relational database management algorithms, including MySQL (open source) and Oracle. Computer modeling of data types contained in EHRs (biospecimen, imaging, clinical, genomic, and metadata) now includes descriptive data modeling for data processing and predictive data modeling for in-depth analytics.

Descriptive data modeling offers a system for data analytic strategies. Logical and physical data modeling defines and implements the structures of the different data elements of oral health information, setting the relationships and dependencies between them, such as functional, connectivity, and traceability relationships. The descriptive data modeling output explains the data using a structured form such as clustering or network analysis.

Descriptive modeling studies have suggested exciting associations between oral health and disease and phenotypic measures, but these findings often are not generalizable to other samples. Categorizations using descriptive models of oral conditions—temporomandibular disorders and facial pain; cleft lip, cleft palate, or both; dental caries; periodontal disease; and oral and pharyngeal cancer—often fail to achieve stated objectives because of the complex nature of clinical presentations and clinical progression, which can make the responses to therapeutic interventions unpredictable (Slavkin 2018).

Geometric or spatial descriptive models are used to represent craniofacial geometric or spatial relationships. Such 3D surface and volumetric texture models are used in dentistry to diagnose and plan treatment, assess treatment outcomes, and create physical models for 3D bioprinting of anatomy, appliances, maxillofacial grafts,

FIGURE 6. Screenshot from the Dental Quality Analytics Dashboard (DQAD)



Goal: This measure tracks application of sealants by dental providers to target caries prevention.
Measure Description: Percentage of children in the age categroy of 6-9 years who were seen by a dentist and received a sealant (D1351), or have an existing sealant on one or more first per permanent molar tooth (tooth # 3, 14, 19, 30).
Denominator: Unduplicated number of children aged 6-9 years seen by a Dentist in the reporting period.
Numerator: Children aged 6-9 who were seen by a dentist and received a sealant, or have an existing sealant on one or more first permanent molars in the reporting period.
Timeframe: Reporting period is 12 months.
Benchmark: 85%
Exclusion Criteria: Disqualifying patients with unerupted teeth applied from the reporting month of July 2016 onwards.

Source: Nycz et al. (2020). © The American Association of Public Health Dentistry. With permission from John Wiley & Sons.

and tissue engineering scaffolds. Three-dimensional geometric models that correlate facial morphology with genomic data show great promise in revealing underlying pathology. Utilizing a meta-analysis of genome-wide association studies, a complex pattern of coordinated genomic variants has emerged that governs variation in facial structures (White et al. 2021). Large-scale statistical modeling is required to control for multiple comparisons so that these studies can help provide a better understanding of the links between facial morphology and the genome.

Expert diagnostic systems driven by algorithms, that is, AI, may enhance diagnostic processes when utilized for decision support (Cabitza et al. 2017). It is imperative that researchers, clinicians, and the public engage in dialogue to explore data science's ethical challenges and the interpretability and applicability of the underlying algorithms (Obermeyer et al. 2019). Unambiguous interpretation of the algorithms used in health care data gathering and analysis can ensure that individuals are treated equitably regardless of their race, gender, or ethnicity. Algorithms that determine treatment options, resource allocation, and prognosis of disease must be transparent to facilitate bioethical considerations and to promote public acceptability.

Teledentistry

An overview of U.S. teledentistry (Nichols 2019) describes the progress of this technology. The emergence of COVID-19 in the United States in 2020 and the resulting limitations on in-person care have demonstrated the value of telehealth, resulting in additional policies and applications being rapidly adopted. Most teledentistry functions as a public health service meant to address access-to-care issues, with a focus on risk assessment and prevention. The Center for Democracy and Technology now has specific codes for teledentistry that facilitate filing claims. By the last quarter of 2018, 49 states offered reimbursement for live video encounters, and 11 states reimbursed for store-and-forward (in which video interaction is recorded and viewed later, rather than live). A number of states now have policies allowing public health insurance reimbursement (Medicaid) for teledentistry: Arizona, California, Georgia, Minnesota (for children, pregnant women, and adults [limited benefits]), New York, North Carolina (synchronous only), Tennessee, and Washington (Center for Connected Health Policy 2020).

Teledentistry faces challenges before it can become a viable and widespread adjunct to mainstream clinical dentistry, however. These challenges include dissimilarities and conflicts in state and federal laws, reimbursement limitations, and concerns about data quality and security. Because technology can cross state borders, interstate provider licensure transferability is a key issue. Ensuring privacy and data security has become increasingly important.

Learning Health Care Systems

A learning health system (LHS) is a health care system that "learns." In a LHS, knowledge generation is so embedded into health care practice that it becomes a natural product of the health care delivery process, leading to continual improvement in care (Institute of Medicine 2007). The LHS concept was virtually unknown in 2000. The LHS vision is more than a concept; organizations, networks, regions, and nations are actively working to become LHSs. Prominent health care systems (Ovretveit et al. 2016) and academic health centers (Pronovost et al. 2017) are launching LHS initiatives across the United States, and organizations are routinely coming together to form learning and improvement networks (Califf et al. 2016) with support from recognized public and private funders (Selby et al. 2013).

At a national level, the federal Office of the National Coordinator for Health Information Technology has made it an objective to connect LHSs across the country into a nationwide LHS by 2024 (DeSalvo and Galvez 2015). Initiatives at the Agency for Healthcare Research and Quality (Bindman 2017) and the Patient-Centered Outcomes Research Institute (Selby et al. 2013) complement and amplify this work. Globally, other countries are declaring their intentions to form nationwide LHSs (The Learning Healthcare Project 2021; Boes et al. 2018), and international networks continue to proliferate as well (Ethier et al. 2017).

The ethical, legal, and social implications of LHSs require increased attention (Platt et al. 2018), but daunting challenges exist related to cultivating the data, disseminating the knowledge, and acknowledging their benefits. A major benefit of national-scale LHSs is rapid and effective pharmacovigilance. For example, in a network the size of the U.S. population, post-marketing drug safety signals could be rapidly detected in a few weeks rather than multiple years, preventing unnecessary morbidity and deaths (Friedman et al. 2015). The underutilization of the ability of data to inform best practices and maintain optimal patient safety is an ongoing concern.

Implementation Science

Although the overall field of implementation science has grown steadily, implementation research in oral health has lagged (Clark and Ducharme 2016; Slavkin 2017). A much more systematic approach that goes beyond reimbursement profiles is needed to influence public health policies and reduce health disparities. Understanding preferences and perceived barriers to delivery of quality oral health care by multiple stakeholders is important for appropriately tailoring and effectively implementing services (Gostemeyer et al. 2019). More research is needed regarding the process and structure of implementation, such as the use of surgical checklists (Remiszewski and Bidra 2019) and decision algorithms (Asa'ad 2019; Tonetti and Sanz 2019) for promoting systematic delivery of high quality care across populations. Training curricula also are needed to address social determinants of health and the ways that social factors affect treatment engagement, preferences, decision-making, and outcomes.

Like other health professions, dentistry has not sufficiently examined system characteristics known to promote effective adoption and implementation at the organizational or community level (Ho et al. 2019; Weintraub et al. 2019), including partnerships with other types of service providers or community organizations such as primary care clinics and schools (Zhu et al. 2019a; Zhu et al. 2019b). There also is a need to better understand the impact of local, state, or federal policies on the implementation, funding, and reimbursement of specific oral health practices or programs (Chi et al. 2019; Peck et al. 2019; Reynolds et al. 2019).

Evidence-Based Approach to Introduction of New Technologies into Clinical Applications

The transition from a clinic-centric, business-driven model to one that is patient-centered, that is, more focused on individualized approaches to patient care, is influencing current trends in clinical research. The National Institute of Dental and Craniofacial Research (NIDCR) supports research in implementation science through National Institutes of Health (NIH)-wide and institute-specific dissemination and implementation funding opportunity announcements. Funded provider-related studies have addressed, for example, the use of a clinical decision support tool to aid in prescribing opioid and non-opioid analgesics for pain management following dental extractions (U.S. National Library of Medicine 2018); Rindal et al. 2021); the use of sealants to arrest noncavitated carious lesions (de Assunção et al. 2014); the use of an EHR system to enhance care provided to an ethnic minority population (Northridge et al. 2018); and engagement in an organizational change model to decrease appointment no-show rates (U.S. National Library of Medicine 2017).

Many illnesses have symptoms that present in the mouth. This means dentists and hygienists can help recognize early signs of disease, as well as spot life-threatening conditions such as diabetes and oral cancers at the earliest stage because they see many patients on a routine, rather than problem-driven, basis. Early detection improves the patient's prognosis and helps control costs. For example, one medical insurance company conducted a 3-year retrospective study of 23,441 insured women, analyzing pregnancy outcomes and dental care using the health system's combined medical-dental database. Mothers who received preventive dental treatment while pregnant had 25% lower preterm birthrates and 34% fewer incidents of low birth weight (Albert et al. 2011). However, this conflicts with the results of another NIDCR-funded study examining women in the second trimester of pregnancy that found no effect (Offenbacher et al. 2009).

The 21st Century Cures Act (U.S. Food and Drug Administration 2020c) has significantly modernized the field of clinical research. This Act recognizes the need to expedite the development of investigational medical products (drugs, biologic products, and medical devices) and implement faster and more efficient approaches to patient care. The Act provides the legal framework enabling the FDA to include patients' perspectives in developing investigational medical products.

Implementation science as a field has seen significant growth in the past 2 decades (Norton et al. 2017), including development of guidelines and assessment tools for interventions appropriate for diverse populations, as well as models of community partnership and stakeholder engagement to ensure use of evidence-based practices (Damschroder et al. 2009; Barrera et al. 2013; Stirman et al. 2013; Anderson et al. 2015; Napoles and Stewart 2018). Innovative study designs that test components of complex interventions (Collins et al. 2016) were developed as well as system science approaches that examine the effectiveness of evidence-based practices at the population level (Green 2006). Finally, research methods such as hybrid effectiveness-implementation designs (Curran et al. 2012; Landes et al. 2019) have been developed to accelerate progress through the research pipeline from efficacy through implementation research when used appropriately.

Practice-Based Research Networks

To catalyze the development of dental practice-based research networks (PBRNs), NIDCR funded three regional dental PBRNs from 2005 to 2012 and is supporting a single, unified PBRN (the National Dental PBRN) through 2026. By the end of their initial funding period, the regional PBRNs had conducted numerous studies with thousands of patients and hundreds of practitioners. Studies investigated numerous topics using a broad range of study designs, demonstrated rigor and impact on clinical practice, and showed that dental practitioners could effectively contribute to every step of the research process.

The National Dental PBRN has made meaningful progress in better understanding clinical issues related to oral cancer, sensitive teeth, and root canal treatment, among other oral health conditions. For example, a study of cracked tooth syndrome in 2,858 individuals revealed that a large proportion of these teeth are asymptomatic and may remain stable, with little progression of cracks or symptoms during a year of follow-up (Hilton et al. 2020).

Delays in study implementation as a result of institutional review board requirements and slow initial recruitment of practitioners were early challenges in the development of oral health PBRNs. Many lessons were learned to inform future recruitment (Gilbert et al. 2011; Mungia et al. 2018). Oral health PBRNs have since demonstrated that practitioners from a broad array of practice settings and geographic regions will readily contribute research ideas and participate in studies. Whether and how regional networks of clinicians interface with dental trainees and faculty and whether this transfer of knowledge in clinically relevant areas is integrated into dental research environments are additional challenges the National Dental PBRN faces. Although the nature of PBRN research presents many challenges, these can clearly be overcome when managed appropriately for the improvement of practices and care of patients.

Considerations and Challenges in Clinical Research

Important advances have been made over the past decades through the benefit of large clinical research trials. Such trials are typically supported by private companies (mostly pharmaceutical), government, nongovernment organizations, or are self-funded (e.g., universities). The potential for advances can be tempered by the expense of engaging in clinical trials when sponsorship for large trials is mostly limited to some private entities or governmental funding opportunities. Because the cost of a trial is closely related to the length and number of follow-up visits occurring within a trial, it is important to support robust, well-designed, and well-powered studies to yield useful information for clinical care. Additional strategies to ensure stewardship of support are human participant safety oversight, clinical study monitoring, transparency, and timely reporting of findings.

It can be challenging to recruit participants to studies, and study generalizability may be limited by the lack of representativeness on the basis of, for example, age, race/ethnicity, gender, and even other demographic characteristics such as socioeconomic factors and location of residence. In order to identify causative underpinnings of oral and craniofacial diseases and develop new therapeutics for the treatment of chronic conditions affecting this region, longitudinal studies that are incredibly demanding in terms of years of investigational investment are needed.

Research Workforce, Training, and Education

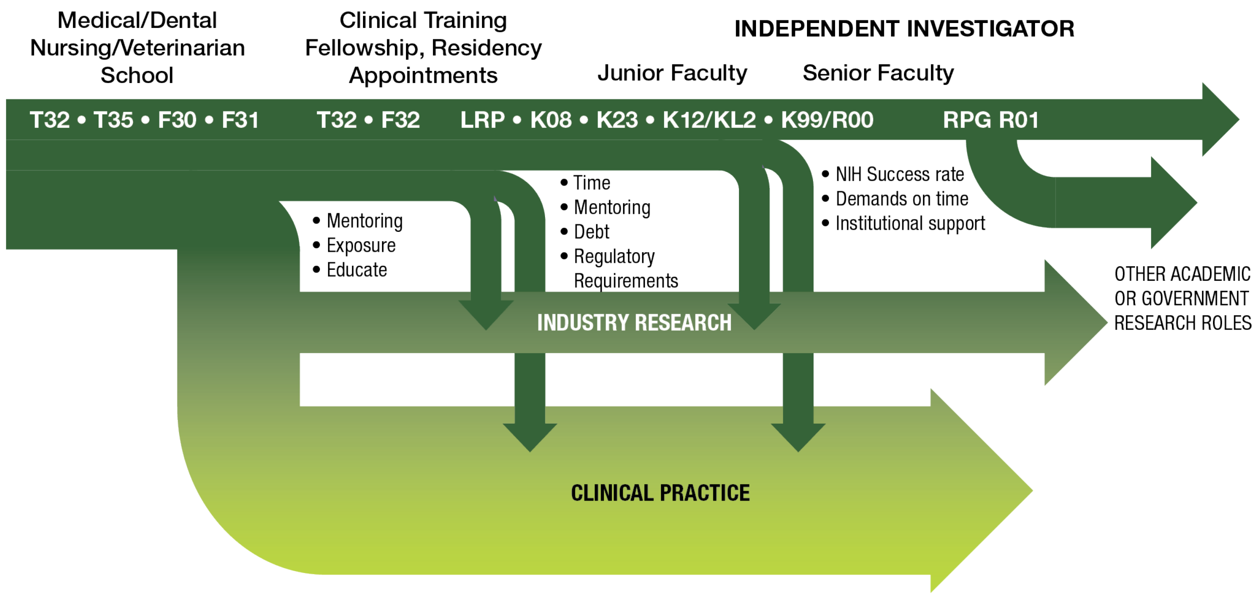
Education and Training

A number of activities in the past 20 years have addressed strengthening and sustaining a robust and diverse research workforce in oral health science. The NIH Common Fund was initiated in 2004 to address emerging scientific opportunities and pressing challenges in biomedical research and research training, including the development of clinician-scientists. The Common Fund includes programs to enhance training opportunities for early-career scientists to prepare them for a variety of career options. The Common Fund's Diversity Program Consortium aims to enhance diversity in the biomedical research workforce by engaging, training, and mentoring students; enhancing faculty development; and strengthening institutional research training infrastructure to enhance the participation and retention of individuals from diverse backgrounds in biomedical research careers (National Institutes of Health 2021a).

During the past 20 years, academic dentistry has undergone several major reforms promoted by the American Dental Education Association (ADEA) that have focused on improving health care providers' overall effectiveness. Exposing future oral health professionals to research can have an impact on their educational experiences. However, related outcomes are not well measured, and approaches vary among institutions (Polverini and Krebsbach 2017). Various training schemes supported by NIDCR and other stakeholders and institutions, such as combined Doctor of Dental Surgery (DDS) and Doctor of Philosophy (PhD) programs and targeted research development programs, are designed to promote entry into academia, but these have fallen short of anticipated outcomes, as shown in Figure 7 (D'Souza and Colombo 2017).

The current demand for dental school faculty and research scientists is not being met. The ADEA task force report on the dental school faculty workforce showed that the number of vacant, budgeted, full-time faculty positions rose from

FIGURE 7. Physician-Scientist Workforce training pipeline



Source: National Institutes of Health (2014).

181 in 1993 to 374 in 2005 (Wanchek et al. 2015). A subsequent decrease to 252 in 2014 was primarily the result of permanent elimination of vacant positions (Garrison et al. 2014) as dental schools managed the shortage by adjusting curricula, increasing the teaching load of existing faculty, and hiring additional adjunct faculty. If faculty retirements and a faculty turnover rate of 33% every 5 years are factored in, it has been suggested that dental schools across the country need 208–218 new faculty members each year (Kennedy 1990). There is a critical need to create and sustain a viable pipeline of dental faculty (Wanchek et al. 2015).

Dental schools currently fail to attract more than 0.3% of their graduating seniors to academic careers (Istrate et al. 2021). Although some programs have been addressing this issue at a local level (Horvath et al. 2016), dental education in the United States now depends on the influx of foreign-trained academics to replace aging faculty. Forty percent of faculty at academic dental institutions are more than 60 years of age (Contreras et al. 2018). U.S. dental public health residency programs admit qualified international dental school graduates and have high percentages of foreign-trained dental graduate applicants and residents. During the 2019–2020 academic year, 62% of all dental public health residents were foreign trained (American Dental Association 2020).

The NIH Physician-Scientist Workforce Working Group Report identified challenges for clinically trained investigators in pursuing research careers, including educational debt as a result of high educational costs, as well as a long period of clinical and research training, which create a vulnerable transition period between research training and independent academic research careers (National Institutes of Health 2014). Competition for prestigious NIH funding has become increasingly intense (Ginther et al. 2011). The average age of first receipt of a major NIH independent research grant (the R01) rose from 36 years old in 1980 to 45 years old in 2013 (Daniels 2015), which can lead to several challenges facing younger researchers in academic settings.

The consensus study report, *The Next Generation of Biomedical and Behavioral Sciences Researchers,* of the National Academies of Sciences, Engineering, and Medicine, prepared in 2018 by the Committee on the Next Generation Initiative Board on Higher Education and Workforce Policy and Global Affairs, defined the core challenges that undercut the vitality, promise, and productivity of the biomedical sciences (National

Academies of Sciences, Engineering, and Medicine 2018a). The percentage of tenure-track opportunities among all positions in academic dentistry has declined steadily (Chmar et al. 2006). Given that vacant faculty positions averaged 257 per year between 1994 and 2015, graduates from the existing 22 oral sciences PhD programs who entered U.S. academic institutions could have filled only 3.6% of the annual vacant dental faculty positions during this time period (Herzog et al. 2018). If the annual number of graduates continues at this low rate, the United States is at risk for a significant compromise in the size of the available academic workforce.

There are no analytic data on trends in enrollment for PhD programs or the placement of their graduates. This lack of program-specific data for oral sciences PhD programs has made it difficult to gauge how many students optimally should be trained to support the dental profession's education and research mission. The report, *Oral Sciences PhD Program Enrollment, Graduates, and Placement: 1994 to 2016*, was the first attempt to summarize oral sciences PhD program outcomes. According to that report, oral sciences doctoral programs have enrolled more women (54.7%) than men (44.5%). Race or ethnicity among these enrollees was reported as White (39.1%), Asian (34.7%), Hispanic (7.1%), Middle Eastern (5.2%), Black (2.9%), Indian (2.4%), and unknown or not reported (8.6%) (Herzog et al. 2018). Clearly, diversity in these programs is less than optimal. Both the growth in student debt and the widening income gap between dental practitioners and academic professionals make recruiting and retaining dental faculty challenging. Although there is a small group of dental students interested in teaching, very few structured mentoring programs exist to guide them in pursuing academic career goals.

The financial pressures on dental schools often lead them to increase emphasis on clinical revenue generation and decrease their emphasis on research (Wanchek et al. 2015). Consequently, the pool of research faculty available to act as mentors for early-career dentist-scientists has diminished. In addition, the amount of student debt upon graduation likely presents a barrier to dentists pursuing careers in academic dentistry.

NIDCR maintains strong partnerships with dental schools and other institutions that have a vital role in educating and training oral health researchers (Feinberg et al. 2015; Ferland and Winstanley 2017; Herzog et al. 2018). However, the institute's total investment in dental schools decreased during the past 15 years (Ferland and Winstanley 2017). These data align with long-standing concerns about dental institutions' diminished research and research training capacities, especially in training the dentist-scientist research workforce (D'Souza and Colombo 2017). This decrease in support compromises dental schools' abilities to generate new science to prevent and treat dental, oral, and craniofacial diseases (Feinberg et al. 2015; Polverini and Lingen 2017; Formicola et al. 2018). When adjusted for inflation, there also has been a steady decrease in NIH funding since the doubling of the NIH budget (Kaiser 2019). One of the consequences of these decreases is a hypercompetitive environment that has too many researchers vying for limited resources and discourages students and postdoctoral scientists from continuing academic research careers (Alberts et al. 2014).

Faculty impediments to conducting research include the paucity of protected time for research and inadequate formal mentoring and career guidance programs for early-stage faculty. Disciplinary silos continue to determine requirements and curricula, with little opportunity for interdisciplinary exploration, creation of scientific networks, and experience with diverse methods and working styles in research groups. In addition, little time and few opportunities exist for development of professional skills on scientific writing, public communication of science, leadership, or learning how to manage projects and staff.

Redoubling Commitments to Diversity and Inclusion

In addressing the preparation of the future scientific workforce, committed action to diversity is essential. In 2018, more than half of first-time graduate students (master's and doctoral level) were women (Okahana and Zhou 2019), and women received more than half of the doctoral degrees in 2017, in fields related to biological and biomedical sciences, health sciences, and public health (National Academies of Sciences, Engineering, and Medicine 2018a). In contrast, reports indicate that in a number of fields related to science, technology, engineering, and mathematics (STEM), including the physical sciences and engineering, no real progress has been made in recruiting underrepresented minority students (National Academies of Sciences, Engineering, and Medicine 2018b; National Science Foundation 2019), and the number of minority doctorate recipients is far below minorities' representation in society (National Science Foundation 2019).

Critically, the National Center for Science and Engineering Statistics lists hundreds of fields and subfields of study, yet it does not include dentistry or oral health sciences among them, making it difficult to estimate the progress, or lack thereof, in developing a diverse cadre of scientists in this area. A 2019 article in *The Atlantic* noted that "in more than a dozen academic disciplines—largely STEM related—not a single Black student earned a doctoral degree in 2017" (Harris 2019). If this trend continues, the diversity and inclusiveness of faculties and leadership will continue to fall. Creating safe and inclusive environments for individuals of different racial and ethnic groups, genders, and socioeconomic status, as well as those with disabilities is an ongoing challenge that requires strategic consideration and fresh approaches to diversifying the academic workforce in oral health.

NIH also has funded efforts to support diversification of the scientific workforce (National Institute of General Medical Sciences 2021a). Examples include the Building Infrastructure Leading to Diversity (BUILD) initiative and the National Research Mentoring Network (NRMN). The BUILD initiative consists of linked grants issued to undergraduate institutions to implement and study innovative approaches to engaging and retaining students from diverse backgrounds (National Institute of General Medical Sciences 2021b). The NRMN is a nationwide network of mentors and mentees from all biomedical disciplines relevant to the NIH mission of providing support to individuals spanning undergraduate education to early-faculty careers.

A special advisory group to the NIH director on diversity in the biomedical workforce was convened in 2011 (Working Group on Diversity in the Biomedical Research Workforce 2012). In addition, the topic of diversity and inclusion in the dental research workforce within the United States was covered in a special issue of *Advances in Dental Research* and discussed by D'Souza and colleagues (D'Souza et al. 2017; Ioannidou et al. 2019). Promising advances in these programs led to new initiatives in 2018 to sustain progress and identify methods and interventions to support sustainable models for enhancing diversity in biomedical research.

Emerging Challenges to Oral and Craniofacial Health

New challenges are continually arising that may have an impact on the oral and craniofacial complex or the manner in which oral health care is provided. Examples include environmental toxins, endocrine disruptors such as bisphenol A (and other derivatives), phthalates, lead, arsenic, and mercury. Exposure to chemicals and toxins can affect the building blocks of teeth, a process that begins during prenatal development (Jedeon et al. 2013; Andra et al. 2015).

Infectious pathogens not only impact overall health, but they also can affect oral health and disrupt dental practice. Following the World Health Organization's declaration of an international pandemic because of COVID-19 and the implementation of emergency health measures in the United States, dental professionals were encouraged or mandated to limit their practices to emergency services. Ongoing clinical and basic research across the biomedical enterprise, including oral health sciences, were disrupted as well. Overnight, new questions emerged about the safety of dental practices relative to viral transmission between patients and clinicians. An article published very early in the pandemic described how one dental school approached a limited emergency-care operation during the outbreak (Meng et al. 2020). Previously in 2004, an article had summarized the impact of an earlier coronavirus epidemic, SARS, on dental practice, but its limited distribution did little to change dental practice, because the era of human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) had already instituted rigorous infection controls (Samaranayake and Peiris 2004).

In contrast to responses to HIV/AIDS and SARS, COVID-19 brought dental care and research to an almost total halt, creating unprecedented challenges for oral health and highlighting questions that had not previously been asked. In fact, because even the profession had not agreed upon the definition of *emergency care*, the American Dental Association had to distribute guidance on what constituted a dental emergency. New questions arose about how to know when and how dentistry was safe to practice. These questions included: "Do we need to consider point-of-care diagnostics to determine whether patients or clinical providers have transmissible infectious diseases?" "What will salivary diagnostic utilization look like in the future?" "What is the immunity profile of such a highly infectious novel agent and how should we gather and use such data?" and "How do we determine the course of disease and viral load for patients?" (To et al. 2020).

A continuing challenge for the profession will be how to embrace new technologies to reduce the spread of highly infectious agents such as SARS-CoV-2 and yet-unknown infectious organisms. Oral health research can play a vital role in this endeavor, as exemplified by the detection of SARS-CoV-2 in various sites of the oral cavity (Huang et al. 2021). However, this challenge is not limited to the capability of responding quickly to orchestrate scientific research to identify potentially harmful agents, but extends to the ability to develop and implement science-based, new approaches that lead to the provision of safe care to patients within the framework of these emerging threats.

Chapter 3: Promising New Directions

New scientific approaches provide opportunities to critically review previously held ideas about important health issues and to update the dental profession's evidence base. The U.S. health care system faces increased challenges at the same time it offers new opportunities. There is an opportunity to use science and technology to spark innovation in health care delivery, with the goal of improving oral health and realizing better treatment outcomes at lower cost and greater convenience to patients. Improving the oral and craniofacial health of every American is now within reach.

Foundational Sciences in Oral Health

Omics/Gene Editing/Single-Cell Technologies

Emerging clinical innovations have already begun to employ the tools of the omics era. Notably, there have been a number of successful genome-wide association studies of phenotypes, including orofacial clefting (Leslie et al. 2016; Leslie et al. 2017; Haaland et al. 2018), dental caries (Wang et al. 2012; Haworth et al. 2018), periodontitis (Divaris et al. 2013; Haworth et al. 2018), tooth eruption and development (Geller et al. 2011; Fatemifar et al. 2013), and orofacial pain (Randall et al. 2017). There also is a long tradition of researchers utilizing microbiomics (Dewhirst et al. 2010; Escapa et al. 2018), metabolomics (Foxman et al. 2016), and metagenomics, notably focusing on dental caries and periodontal disease.

There is a major international effort to develop databases to integrate genomics into health care (Stark et al. 2019) by linking nationwide electronic health records (EHRs) and obtaining DNA samples. At least 14 countries have begun such vital endeavors (Stark et al. 2019). In the United States, the program is known as the *All of Us* Research Program (National Institutes of Health 2021b) and has a goal of engaging 1 million volunteers to reflect the nation's diversity, including all life stages, health statuses, racial and ethnic groups, and geographic regions. *All of Us* and other endeavors, such as the National Cancer Institute's Cancer Moonshot (National Cancer Institute 2020) and the 21st Century Cures Act (National Institutes of Health 2020b), hold great promise for the development of innovative prevention strategies, treatments, and data sharing. It is critical to integrate dental, oral, and craniofacial health phenotypes into these initiatives.

Applications of Genome Editing to Human Cells

We are in an era with access to a variety of highly versatile editing technologies that allow genetic material to be added, removed, or altered at locations across the genome. These technologies offer exciting routes to new therapeutic development by potentially allowing for correction of underlying genetic deficits that exist in a number of human diseases, as well as in microorganisms that compromise health. Several genome editing technologies may influence oral disease and congenital malformations, including zinc-finger nucleases, transcription activator-like effector nucleases, clustered regularly interspaced short palindromic repeats (CRISPR)-associated protein systems, and RNA editing (Baysal et al. 2017; Yu et al. 2019).

In the field of oral health, single-gene disorders, which are caused by mutations in a single gene, are targets of genome-editing technologies for research and therapeutic applications (Figures 8 and 9) (Patil et al. 2014). Many of these disorders feature craniofacial anomalies that can be prevented or reversed with replacement therapies that involve proteins as well as agonist small molecules and antibodies (Jia et al. 2017a; Jia et al. 2017b). Advances in genome editing technologies have raised hope for improving the clinical diagnosis, treatment, and outcomes for patients with craniofacial malformations associated with single-gene disorders (Neben et al. 2016; Yu et al. 2019).

In light of advances in human genome editing, it also is important to consider the potential of microbial genome editing. Although still in its infancy, this field has had some early proof-of-principle studies, including the design of a self-targeting CRISPR system in *Streptococcus mutans*—a primary causative agent of human dental caries—that could reduce the bacteria's pathogenicity. Limited genetic tractability in many bacterial species is being addressed on multiple fronts with newer technologic advances in genetic engineering of bacteria (Cuiv et al. 2015; Johnston et al. 2019).

Single-Cell Technology Applications in Oral Health Research

In the emerging technologies for single-cell omics, single-cell analysis deepens our understanding of cell identity, diversity, development, and function in a way that bulk analysis cannot achieve (Junker and van Oudenaarden 2014). Combining comprehensive analyses of omics studies with single-cell resolution continues to highlight the extent, nature, and role of the cellular heterogeneity (diversity) that arises in organisms with regard to both health and disease (Shapiro et al. 2013; Wang and Navin 2015). By enhancing the ability to comprehensively define cell types and states, diseases with complex etiologies can be better conceptualized, providing more accurate diagnostic tools, prognostic biomarkers, and signaling pathways amenable to therapeutic targeting.

Microbiome/Inflammasome/Virology

The human microbiome has become an attractive drug discovery platform for new therapeutics (Milshteyn et al. 2018). There is increased recognition of the vast numbers of unidentified molecules produced by oral microorganisms that are likely to affect the oral microbiome (Edlund et al. 2017). Promising strategies to engineer and manipulate these communities are emerging. Several prebiotics, which are substances that potentially modulate the microbiome, are being investigated. For example, identifying individuals whose oral microbiomes are exceptionally robust and efficient at reducing lactic acid to protect against tooth decay could provide insight into unique preventive microbial communities. Scientists could identify persons who are genetically prone to periodontal infection but could potentially be protected by a healthy oral microbiome that keeps inflammation in check or limits keystone pathogens (Lamont et al. 2018). Such case studies would provide opportunities to uncover new therapeutic molecules made by unique biosynthetic gene clusters (Donia et al. 2014).

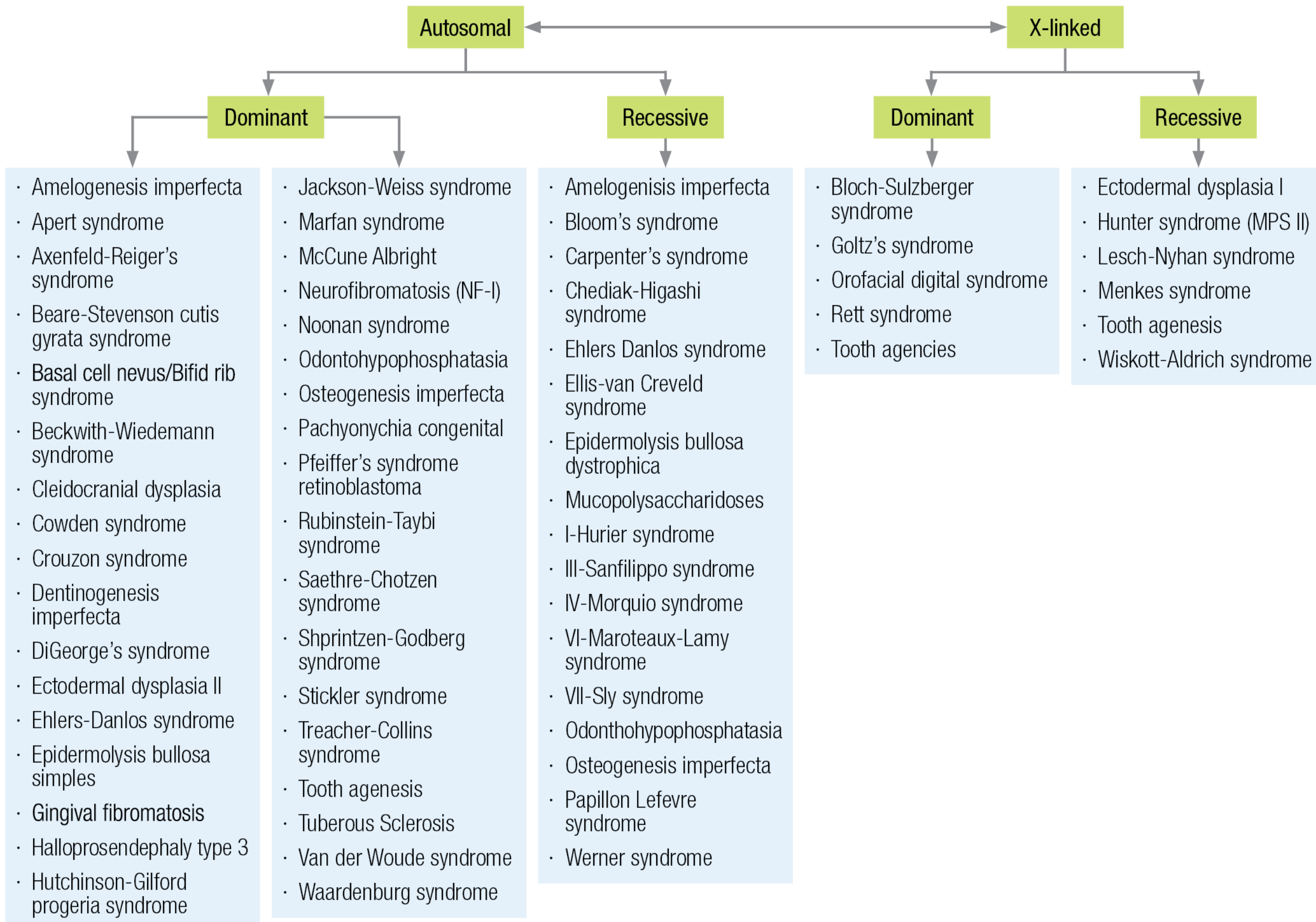
Basic and clinical research should incorporate evaluation of the microbiome, including clinical trials to evaluate new therapeutic regimens and engage scientists and dentists who have a wide range of expertise (Human Microbiome Project Consortium 2012a; 2012b). There also is a need to understand complex microbe-microbe interactions (Mark Welch et al. 2016; Stacy et al. 2016) and microbe-host interactions (Lamont et al. 2018).

Development of new tools would go far to advance microbiome applications. Gnotobiotic mice (animals in which all microorganisms are either known or excluded) colonized with a select group of human gut microbiota have been instrumental in determining the contribution of those microbiota to disease (Fitzgerald 1968; Kashyap et al. 2013; Smits et al. 2016). The establishment of a similar model would provide a powerful tool for evaluating contributions of the oral microbiome, help uncover new keystone players, and facilitate the development of more relevant microbiota-targeted therapeutics. Engineering of the microbiome in the oral cavity in situ remains challenging. Such microbiome engineering (Ronda et al. 2019) should enable the precision delivery of novel genetic and biochemical traits into the oral cavity and open a new frontier in synthetic biology.

Inflammation/Inflammasome

Inflammation diagnostics have advanced, and specific inflammasome sensors are being explored. Interleukin (IL)-1 blockage is an example of a successful clinical translation of basic immunology research that has clinical applications for multiple inflammatory disorders,

Figure 8. Working classification of single gene disorders with oral manifestations



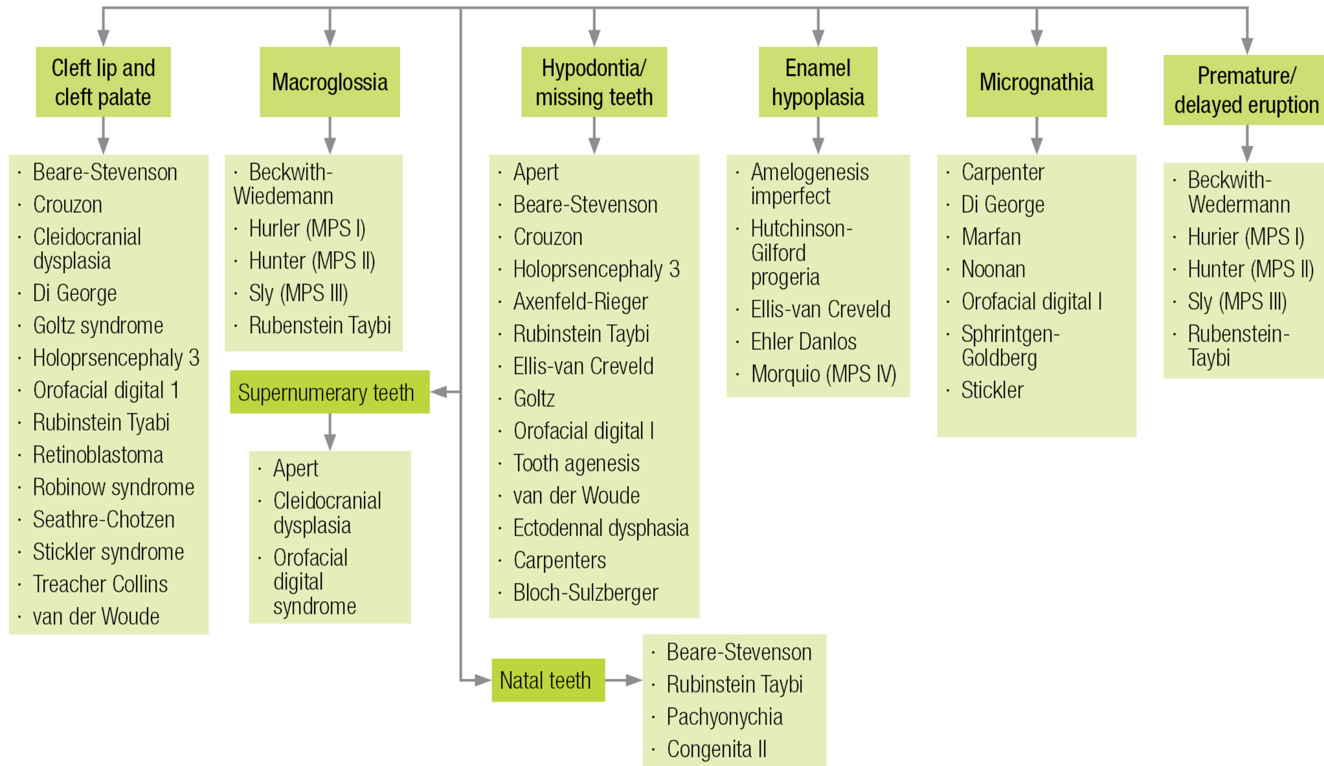
Source: Patil et al. (2014).

including periodontal diseases (Mantero et al. 2018). Excitingly, a number of inflammasome inhibitors (Khalafalla et al. 2017) have been reported.

Small molecules that target the inflammasome can provide specificity and cost-effectiveness (Swanson et al. 2019). Several small-molecule inhibitors, developed to have an impact on inflammasome, IL-1, and IL-18 production (Swanson et al. 2019), have demonstrated therapeutic potential.

In addition to targeted approaches, microbiome modulation, gene therapies, and autotherapies hold promising therapeutic avenues for inflammasome advances (Gomez and Nelson 2017; Polak and Shapira 2018). The specialized proresolving mediators that control immune cells have potential as therapeutics for inflammatory diseases and are entering human clinical trials for gingivitis and periodontitis treatment (El Kholy et al. 2018). This new category of molecules includes lipoxins, resolvins, maresins, and protectins (Serhan et al. 2000; Levy et al. 2001). Their capacity for clinical impact is promising yet underexplored. With an increase in the number of individuals affected by dental and craniofacial inflammatory conditions, as well as aging populations, there will likely be a greater need for the development of new inflammasome-targeted diagnostics and therapeutics that could also provide better systemic health outcomes (Swanson et al. 2019).

Figure 9. Single gene disorders with common oral manifestations



Source: Patil et al. (2014).

Regenerative Medicine, Dental Materials, and Bioinspired Materials

Antimicrobial Materials

The addition of antimicrobial materials to existing dental materials offers an opportunity to improve their longevity and promote better oral health. Materials are being developed that incorporate antimicrobial agents to kill potentially harmful bacteria on contact or prevent them from forming biofilms (Cocco et al. 2015; Stewart and Finer 2019). One example is a biomaterial that releases fluoride into surrounding areas (Hafshejani et al. 2017). Commercial products have been developed for restorations that provide a contact-kill mechanism to keep bacteria from colonizing the area between the restoration and remaining tooth where cavities are thought to begin (Imazato 2009; Makvandi et al. 2018). Continued research into such materials is likely to lead to improved dental restoratives that preserve tooth structure and reduce the need for later intervention.

Remineralizing Materials

New remineralizing materials hold great promise for reducing restorative failure and improving oral health. Many materials have become commercially available that have the potential to promote mineral formation in the oral cavity, either through the addition of fluoride or the incorporation of calcium phosphate, calcium silicate compounds, or bioactive glasses (Taha et al. 2017). Some new materials are designed with nanotechnology-based materials that simultaneously promote remineralization and demonstrate antibacterial effects (Cheng et al. 2015; Zhang et al. 2017). These types of materials currently are primarily used for lining the deeper portions of a dental restoration for direct pulp capping (Paula et al. 2018). Promising results have been shown in promoting dentin material using new and already existing materials, such as calcium hydroxide and mineral trioxide aggregate (Didilescu et al. 2018). Continued work in this area will undoubtedly result in a host of commercial products that can be used throughout dentistry to provide more predictable responses to decayed tooth tissue treatment.

Regenerative Materials for Tooth Replacement and Alveolar Bone Repair

The use of advanced scaffold designs that can guide the spatiotemporal requirements for periodontal regeneration, which is key for new periodontal attachment formation, has the potential to significantly improve therapeutic outcomes (Ivanovski et al. 2014; Vaquette et al. 2018). In regenerative endodontics, there is strong potential in materials, typically built on resorbable polymer scaffolds (Fukushima et al. 2019; Patel et al. 2019), that can be implanted into the removed, damaged tooth pulp to restore healthy form and function. Investigators are exploring the development of materials from three-dimensional (3D)-bioprinted scaffolds implanted with undifferentiated stem cells that can generate vasculature, nerves, and structural cells capable of functioning in much the same way as a natural, healthy tooth (Athirasala et al. 2017).

3D Bioprinting and Additive Manufacturing

Emerging research into the use of 3D bioprinting technologies (also known as additive manufacturing) in dentistry includes the development of bioinspired microstructural arrangements, such as topology optimization (TO). This process maximizes physical performance by optimizing the structural arrangement within the design of an object composed of one or more materials (Bendsoe and Sigmund 2004). Initially, TO was used to modify the macroscopic geometries of objects designed using homogeneous materials (Sigmund 1994), but it is now possible to work at a much higher resolution when combining different materials into designs that incorporate specific microstructures suited to a desired performance.

Use of 3D printing is growing rapidly across many sectors. This innovation encompasses a suite of technologies for fabricating parts directly from 3D digital models. The technology's power lies in its ability to produce high-value, complex, and individually customized parts. The integration of the different types of printable materials, as well as better software and hardware, has dramatically expanded the potential for these approaches (Ligon et al. 2017; Harun et al. 2018).

The quality of 3D products, in terms of speed of production, dimensional control, strength, and biocompatibility, is increasingly meeting the needs of dentistry. At the same time, the capabilities of scanners to generate, digitize, store, and manipulate 3D patient data in a cost-effective fashion continue to grow. In the future, dental offices will be able to produce patient-customized specific parts, such as implants and dentures, by combining the digital powers of 3D scanners and 3D printers (Figure 10) (Galante et al. 2019). This shift will have implications for clinical practice, researchers, materials producers, and equipment manufacturers—with ultimate benefit to the patient (Bhargav et al. 2018; Oberoi et al. 2018).

Nanotechnology

The utilization of nanotechnologies in dentistry is in a young, yet promising, stage of emerging discoveries and breakthroughs. One encouraging new direction uses intracellular nanodelivery tools, such as polymeric or lipid nanoparticles, nanoneedles, electroporation, and other similar methods, including inorganic nanoparticles, to manipulate cellular behavior in situ (Stewart et al. 2016). This will form the basis for the development of next-generation vaccines, precision therapies, and patient-specific regenerative strategies that take advantage of cell reprogramming, differentiation, and tissue engineering and regenerative medicine. Another area of development is nanotheranostics, which employs minimally invasive techniques using nanoscale materials simultaneously for early-stage disease diagnostics and therapy (Cheng et al. 2017). Two more areas that deserve attention are the rapidly emerging fields of nanofabrication and nanorobotics in medicine, as well as exosome engineering (Yim et al. 2016).

Stem Cell Biology

Innovative stem cell approaches should allow first-in-human clinical trials in dentistry for repair of bone defects around teeth, dental implants, cleft and orofacial repairs, and regenerative endodontics. A promising area of development is allogeneic stem cell therapy, which can use stem cell banks as ready sources for stem cells on an as-needed basis. Better coordination among scientists, clinicians, industry, federal regulatory agencies, and reimbursement entities would accelerate the potential for stem cell biology to provide clinical advances.

FIGURE 10. 3D Printed denture teeth processed and seated on supporting dental implants

Notes: Digital denture designed with CAD/CAM software and denture teeth 3D printed. Dentures can be designed in less than 20 minutes and printed in as little as 30 minutes.

Source: Photo courtesy of Gustavo Mendonça, University of Michigan.

Science and Technology for Practice

Genetics- and Genomics-Based Precision Health

Technologic advances have profoundly decreased the cost of sequencing genomes, potentially enabling genetic information to be generally available to guide clinical care (Chiu and Miller 2019). During the next 10 years, genetic and genomic information will increasingly have an impact on dentistry, as they have in medicine, and will be used with other data, including diet and lifestyle, to inform clinical prevention and treatment decisions. Genomic information about an individual will increasingly be used to inform clinical care decisions (for susceptibility, diagnostic, or therapeutic decision-making) as development of national genome-medicine initiatives continue to integrate genomic, epigenomic, environmental, behavioral, and other information in a meaningful way to fulfill the promise of precision health care (Stark et al. 2019). These projects' capacities to integrate data from millions of individuals will provide the power to identify and validate clinically useful data.

Advances in Laser- and Light-Based Imaging Technologies

Higher-performance imaging devices operating at longer wavelengths beyond 1,000 nanometers (nm) will likely become commercially available in the near future as the prices of germanium and indium gallium arsenide sensors continue to decrease. The highest contrast of demineralization on tooth surfaces occurs at longer near-infrared (IR) wavelengths greater than 1,000 nm, owing to reduced scattering in sound tissues and higher water absorption (Chung et al. 2011; Fried et al. 2013). Higher water absorption also can be exploited to yield high contrast of demineralization and dental calculus on root surfaces at wavelengths beyond 1,450 nm (Yang et al. 2018). Stains can easily be differentiated from actual demineralization, which is not possible at wavelengths less than 1,200 nm (Chung et al. 2011). At wavelengths greater than 1,300 nm, near-IR imaging is more sensitive than radiography for the detection of lesions on both occlusal and proximal tooth surfaces in vivo (Simon et al. 2016).

Optical coherence tomography (OCT), a noninvasive technique for creating cross-sectional images of internal biological structures (Bouma 2002), can be used to measure the reflectivity within dental hard tissues to a depth of up to 3–5 millimeters (mm) in enamel and 1–2 mm in dentin, with an axial (depth) resolution exceeding 10 micrometers. Commercial OCT systems are on the horizon to monitor demineralization (Fried et al. 2002; Louie et al. 2010). High-speed OCT systems are now available that can make an image of a tooth in less than a second. In the near future, systems will likely have scanning rates 10 –100 times faster than today. Dedicated dental OCT imaging systems are under development and should be available in the next few years.

Neuroimaging-Based Technologies for Managing Orofacial Pain

Researchers have started to analyze the neurologic signatures of pain using neuroimaging. Portable neuroimaging devices with technical benefits similar to functional magnetic resonance imaging (fMRI) have been developed. Functional near-infrared spectroscopy (fNIRS) detects concentration variations of oxyhemoglobin and deoxyhemoglobin, such as blood-oxygen-level-dependent signal in fMRI, by measuring the absorption of near-IR light at wavelengths between 700 and 1,000 nm. fNIRS, akin to fMRI, can be used to study functional brain activity in the clinical environment. The fNIRS device has the portability, interface, and compatibility necessary for ferromagnetic and electrical environments, so it can be used in many clinical settings to monitor patients' functional brain activity (hemodynamic responses) and functional connectivity. Future dental offices may have the opportunity to localize orofacial pain with much greater accuracy using less invasive techniques and smaller, easier to use devices to improve diagnoses related to oral pain.

New Therapeutic Approaches in Dentistry

Biomarker studies have led to the discovery of new drug targets such as microbiome-modulating compounds (C16G2) or anti-inflammation reagents (resolvins and lipoxins) to treat and prevent dental caries and periodontitis. Various new microbiome-reengineering approaches, such as probiotics, prebiotics, and phage therapy, have promise.

Innovative technologies have been reported for dental caries reduction through an oral microbiome-based preventive approach, such as topical use of the amino acid arginine (Bijle et al. 2019). Another new direction is the application of silver diamine fluoride to a decayed dental surface to stop the progression of a carious lesion (Horst and Heima 2019). Although the use of silver diamine fluoride to inhibit dental caries is not a new therapeutic approach and has been extensively used in other countries, there has been renewed interest in the United States in this product.

Areas that hold great promise for the treatment of head and neck cancers include immunotherapeutics that expand tumor-specific T cell mechanisms and radiation sensitizers that utilize DNA-damage repair agents (Heath et al. 2019; Manukian et al. 2019). Diagnostic and therapeutic precision approaches in the treatment of head and neck cancers also are under intensive investigation on the basis of the delineation of key signaling pathways, and they offer promising therapeutic opportunities (D'Silva and Gutkind 2019). New strategies for stem cell based anticancer therapies are on the horizon that build on the key concepts of precision health (Wang and Aguirre 2018).

Robotics-Assisted Dental-Surgical Treatments

Modern diagnostic tools already described, in combination with artificial intelligence (AI)-assisted surgical robotics, are helping dental surgeons automate or augment complex procedures, such as implant surgery, crown preparation, and placement of orthodontic bands and brackets (Schwendicke et al. 2020; Shan et al. 2021). Similar systems are being used to train providers or allow them to practice clinical procedures. The ability to have these systems monitor and then coach new procedures, while simulating the real-world environment, helps dental professionals learn new techniques and increase proficiency.

Innovation in Preventing Oral Diseases

Emerging preventive-practice technologies are exciting and include novel intraoral cameras, innovative, noninvasive treatments of early carious lesions, and telehealth tools. The revolution of precision medicine and successful dental innovation stories will stimulate more research institutes and scientists to develop innovative technologies and attract more investment funds to support dental technology development.

With regard to diagnostic techniques, modern ionizing and nonionizing radiation techniques with 3D-imaging capacity may supplement traditional X-ray-based tooth imaging systems, when indicated. A downside of 3D-imaging overuse is the higher radiation exposure. Dental offices will routinely use high-resolution, multifunctional, intraoral cameras and scanners. Laser and Raman spectroscopy-based functional imaging systems and ultrasound and magnetic resonance imaging-based soft tissue scanning systems will allow dentists to better assess patients' health statuses with of-the-moment physiological and pathologic information. Furthermore, innovative neuroimaging-based technologies could transform the brain into an objective target to visualize, measure, diagnose, and localize orofacial pain in real time in the doctor's office. Key genetic and microbiome biomarkers for the early diagnosis and prevention of dental caries and periodontal disease could be analyzed in saliva and blood through laboratory testing, chairside instant tests, or even in vivo planted biosensors.

Technologies will enable the development of preventive- and digital-dentistry-focused personalized oral health care that can be fully integrated with personalized medicine using unified and cybersecure EHRs. Ultimately, these modern technologies will allow care to be accessed in innovative ways, through new clinical service models, teledentistry, mobile dentistry, integrated clinic and home care, and full integration of clinical care with payment and reimbursement systems.

Oral Disease Prevention at Home

Preventive agents and technologies also can be applied outside of professional dental practices. U.S. health care consumers have become more empowered as they seek to gain more control over their personal health, health finances, and health care experiences. Medical solutions and services are swiftly becoming mobile and direct-to-consumer. Smart devices already are monitoring daily blood pressure, glucose and heart rate, physical activity, nutrition patterns, and conditions such as atrial fibrillation. As consumers express desires to improve oral health, more widespread access to and use of technology for oral health solutions are beginning to make their way into the home.

Emerging solutions are focused on better educating consumers and caregivers about oral health, improving self-care through smart connected technologies that measure and track personal oral health data and advancing better at-home oral hygiene. Some examples include the development of educational and caries risk assessment apps, such as Brush Up and My Smile Buddy (Chinn et al. 2013). Several companies have toothbrushes that track brushing data to improve brushing technique, frequency, and efficacy and create a connection to the dental provider. Additional strategies involve using an intraoral biosensor platform to monitor saliva, initially focusing on measuring pH levels (Choi et al. 2017).

In addition, a healthy innovation environment is emerging around personal care and consumable products, such as toothpastes, rinses, floss, gums, mints, and lozenges. These innovations are intended to improve personal oral health by encouraging good oral hygiene, aiding in tooth remineralization, and influencing the composition and behavior of oral biofilms. As the costs of these technologies decrease with greater adoption and production, preventive care at home will have an important role to play across populations for maintaining good health and creating value for consumers, providers, health care sponsors, and communities.

Information and Data Science

Big Data and Electronic Health Records

Big data gleaned from EHRs and other databases should be analyzed electronically to project attributable risk for disease emergencies using data-mining approaches to develop predictive models (Glurich et al. 2017; Hegde et al. 2017). Moreover, integration of oral and craniofacial health with general health through an integrated EHR is critical and will support advances in understanding the physiological interactions between oral and systemic health and disease.

The creation of a collaborative environment across disciplines using EHRs supports high quality health care, research, and education and connects hospitals and health care organizations. Moreover, EHRs have substantial research potential through monitoring health events and evaluating outcomes using data generated from integrated health care systems. This, in turn, can synergistically improve our understanding of the relationships between oral health and overall health and well-being within real-world environments.

Dentists will increasingly help other medical professionals provide primary care to their patients. In many dental offices, recording of vital signs is routine. Screening for diabetes, atrial fibrillation, obesity, vaccinations, mental illness, risk of falls, substance abuse, domestic abuse, and other conditions normally screened for by primary care providers also could be routinely obtained within a dental office environment. The resulting data, residing in an integrated EHR, would be updated and acted upon in a more frequent, regular, and efficient manner. A unified record has a positive impact on population-based research by making it easier to conduct longitudinal studies with greater data fidelity. The study of various oral disease processes will be better understood in the context of the larger whole.

Using EHRs to create a collaborative environment across disciplines contributes to the common goal of providing access to state-of-the-art, high quality, and holistic health care for all segments of the population. One example of an integrated model pairs a large community center (Marshfield Clinic, see Section 4) with a center-dedicated research team. This model expands access to dental care and promotes improved quality of care by generating new knowledge and creating decision support tools that can be quickly translated into practice or used to guide future planning (Acharya et al. 2012). It holds great promise for advancing oral health and integrating oral, medical, and behavioral health in ways that accelerate progress toward improved oral and general health for the patients and communities served. Encouraging national promotion of this model would be beneficial for improving patient outcomes (Acharya 2016; Shimpi et al. 2016; Shimpi et al. 2019a). The Institute for Healthcare Improvement (2003) employs a model for improvement that includes plan-do-study-act cycles for rapid tests of change to emphasize multidisciplinary innovation and learning under an umbrella of improvement science. Such an approach could prove valuable on a platform of an integrated EHR.

Incorporating Social Determinants into Electronic Health Records

Another new direction for EHRs is their use of social determinants of health. Multi-level factors (at the child, family, and community levels) have been described conceptually for influencing oral health (Fisher-Owens et al. 2007; Lee and Divaris 2014). Social determinants of health may include an individual's health knowledge and behaviors, social resources, social support, peer pressure, norms for healthy behaviors, and adherence to treatment plans (Braveman and Gottlieb 2014). The emerging popularity of social media has created virtual communities on the internet that can significantly influence individuals' health behaviors and social determinants. Social determinants may be key contributors to patients' decisions on whether to return to the dental clinic to complete treatment or to adhere to treatment at home.

Incorporation of patients' social determinants into EHRs will improve dentists' understanding and ability to predict challenges related to oral hygiene behaviors. It also will help dentists to identify patients who may need referrals, including for social interventions and personalized oral health care, particularly among vulnerable populations.

Some factors that may not be measured and noted in the EHR and that may affect dental outcomes are referred to as unmeasured confounders. For example, EHR data usually do not include the oral health education individuals receive from schools, communities, the internet, or peers, which influences their sugar consumption and oral hygiene. The instrumental variable method is a way to understand the effects of unmeasured confounders by using a variable that influences which treatment individuals receive but is independent of unmeasured confounders and has no direct effect on the outcome except through its effect on the treatment (Baiocchi et al. 2014). This method can be used with EHR data when there are concerns about both measured and unmeasured confounders.

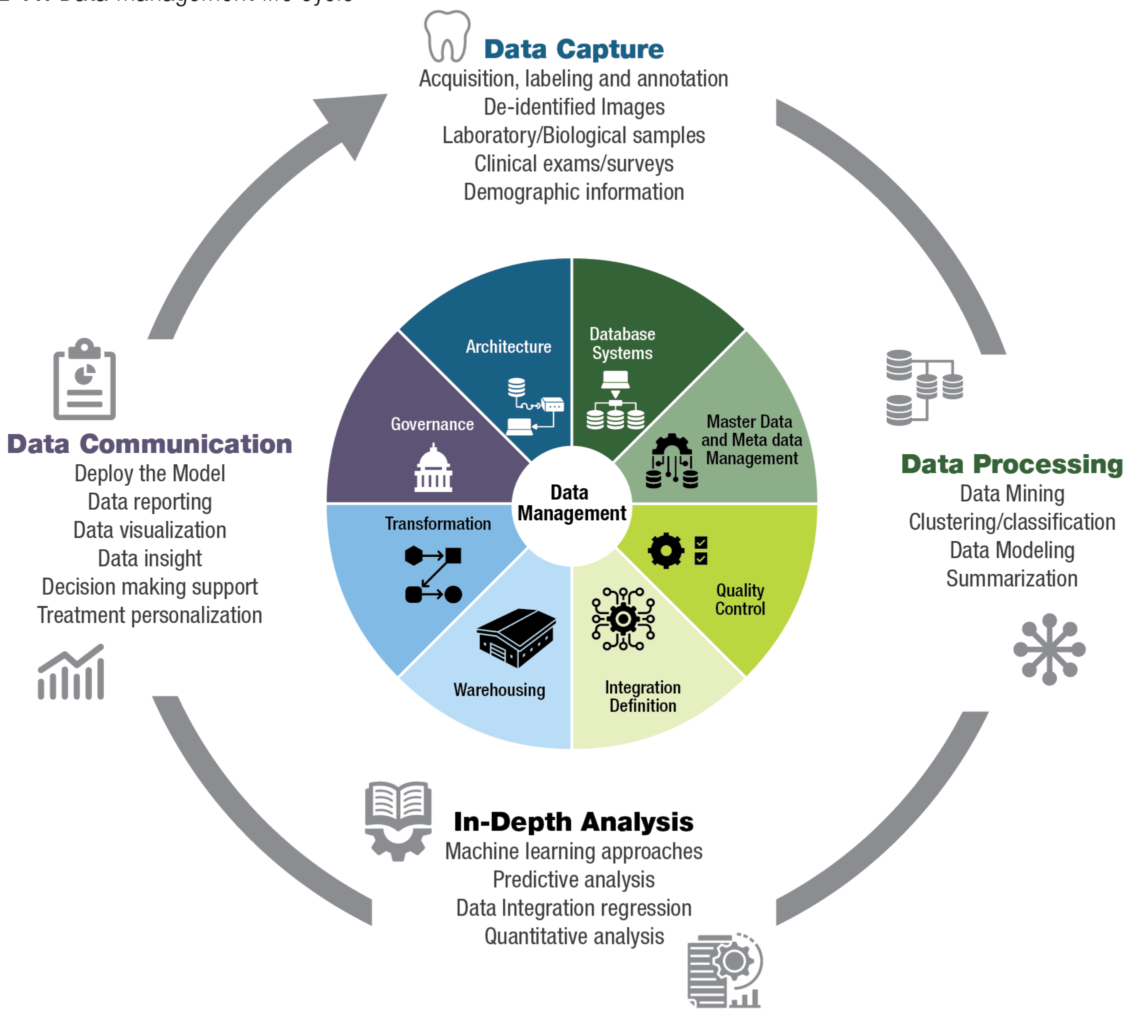
In the context of research, investigators need to be cognizant of the multifaceted nature of health disparities, including levels of influence (individual, interpersonal, community, societal) and domains of influence (biological, behavioral, physical, sociocultural, and health care system) that are critical to understanding minority health as outlined by the National Institute on Minority Health and Health Disparities at the National Institutes of Health (NIH) (National Institute on Minority Health and Health Disparities 2018).

Data Science

Oral health data science continues to evolve as an integral contributor to emerging technologies that advance treatment for oral diseases and disorders. However, few institutions have explored the potential for utilizing EHR data to study oral health problems that may cause or co-occur with other medical conditions.

Applying mathematical and computational approaches to complex and multidimensional data can lead to a deeper understanding of dental, oral, and craniofacial health and ultimately transform how oral health care is delivered. This outcome will involve a more comprehensive integration of basic, clinical, and population science to devise new tools and approaches. Understanding the spectrum of information and data science requires that oral health data scientists be skilled in applying advanced data-mining approaches for analyses of large amounts of data (Figure 11).

FIGURE 11. Data management life cycle



Data Modeling

Predictive computational modeling offers a tool that can enhance research capacity, contribute to better management of health care systems, and support patient-clinician shared decision-making. Current projections suggest that the United States will spend US$6 trillion on health care in 2027, with the vast majority of those dollars spent on treatment (Keehan et al. 2020). Predictive computational modeling is critically important to making health care more efficient and less expensive because it emphasizes risk assessment and prevention of disease progression. Rigorous statistical modeling and machine learning approaches in predictive modeling offer an opportunity to make scientific advances relevant to all ages and to reduce health disparities.

Predictive computer modeling approaches offer a way to understand the relationships among genotype, phenotype, environmental factors, and the patterns of craniofacial, oral, and dental diseases and disorders (Pendergrass et al. 2011). Predictive models from larger samples are more likely to include diverse population features (Cremers et al. 2017). Prediction of individual differences using Machine learning approaches for data analytics of phenotypes from clinical, imaging, and omics data (Scheinost et al. 2019) improves the ability to uncover novel oral health associations. However, predictive modeling may explain disappointingly little of the variance in predicted variables, particularly when compared to results derived from descriptive models (Whelan and Garavan 2014; Yarkoni and Westfall 2017).

Increased predictive computer modeling and machine learning research efforts can be combined for research on dental caries, periodontal diseases, oral and pharyngeal cancers, chronic facial pain, temporomandibular joint dysfunction, Sjögren's syndrome, and other craniofacial, oral, and dental autoimmune diseases. In addition, salivary biomarkers may allow oral health professionals to screen for risk for many systemic diseases and disorders, such as Alzheimer's disease, cancer, and diabetes (Băbţan et al. 2019; Díez López et al. 2019; Hrubešová et al. 2019; Liu et al. 2019; Wang et al. 2019; Wunsch et al. 2019).

Future work focused on creating easy to use and understand results to support shared decision-making by clinicians and patients bears promise for improving oral health. The development of guidelines to monitor these models' performance will be essential to improving process and patient outcomes.

Data Integration and Interoperability

The interoperability and sharing of health and health-related data are critical to improving care quality and efficiency. New information is generated during every patient encounter in a hospital, dental practice, physician's office, pharmacy, laboratory, and public health and human services agency, or with emergency medical services. This information currently is stored in separate databases, and no single unique identifier exists to link disparate information into a single comprehensive patient record. Whether in large dental academic institutions, health maintenance organizations (HMOs), or small dental practices, the use of stand-alone systems with different patient identifiers—such as internal billing systems, electronic dental records, laboratory orders, and digital images—may result in treatment delays and prevents data aggregation for clinical decision support. This also severely limits the utility of electronic data for clinical research.

Integrating traditional data such as insurance claims, clinical research, and electronic health and dental record data with the data from these new resources has the potential to deliver precise and personalized assessment of a population's or person's risk for a disease and recommended treatment. To achieve this goal, it is necessary to continue developing and evaluating patient-matching algorithms to integrate data from disparate sources.

Because there is no unique patient identifier used in the United States as there is in countries with nationalized health care, U.S. health care organizations must rely on patient-matching algorithms using demographics and other identifiers. Regional health information exchanges, such as the Indiana Health Information Exchange, have been successful in transmitting messages across more than 100 hospital systems annually by using patient-matching algorithms to match patient records. However, no information exchange is occurring between electronic health and dental record systems except in HMO settings that have integrated medical and dental record systems. Future research should enhance the accuracy of patient-matching algorithms to integrate electronic health and dental record data and to facilitate exchange of information between these systems.

Establishing a common vocabulary and mapping the terminologies used in different settings to the common vocabulary can enable divergent systems to communicate. The American Dental Association (ADA) Standards Committee on Dental Informatics is a standard-setting organization accredited by the American National Standards Institute that involves researchers and public health policymakers in developing standard terminologies and a conceptual framework to promote interoperability and seamless data exchange across different health information technology systems. Expanded work to include electronic health and dental record system vendors, dental and health care organization leadership, public health and federal government officials, and oral health informatics and data science researchers will provide greater breadth and depth for effective patient care.

In addition to informatics, future work also should build on existing work in medicine, dentistry, and related fields, such as information and data science and computer science, to develop approaches that enable continuous monitoring and improvement of the quality of data gathered during provider-patient encounters. Furthermore, research is needed to develop and validate metrics for evaluating the quality of different data types from diverse data sources. It also is important to characterize patient profiles by carefully phenotyping the electronic health and dental record data using advanced data-mining approaches that leverage all data types, such as structured, unstructured, images, and data recorded in various different formats.

Data Capture

Advances in raw data capture from laboratory, fieldwork, surveys, clinical examinations, volumetric and surface imaging and sensor devices, online service companies, and simulations require emerging technologies for data management infrastructure. Both quantitative and qualitative patient-related data can arise from epidemiology, genomic analyses, clinical care processes, imaging assessments, patient-reported outcomes, and environmental exposure records, as well as a host of social indicators, such as educational records, employment history, and genealogical records. For example, the automated de-identification of images is addressed today by open-source tools such as 3D Slicer and the Medical Imaging Resource Center Clinical Trial Processor, which receive Digital Imaging and Communications in Medicine images and replace protected health information with de-identified data. Large amounts of data that do not originate from health-related activities, such as data originating from social media platforms, are currently captured for a variety of purposes. However, there could be some potential for public health use through this digital data source.

Clinical images produced by imaging devices and optical scanners are reconstructed from raw, or source, data produced by detectors. The optimal conversion of source data from these sensors into reconstructed tomographic images suitable for human interpretation or radiomics is an emerging area of value. The successes of AI techniques in analyzing the ImageNet database of more than 14 million annotated nonmedical images have led to explosive growth in the use of deep learning to analyze clinical images and other health data. These promising computer vision systems, which perform clinical image interpretation tasks at the level of expert clinicians, have the potential to transform medical and dental imaging and reduce diagnostic errors, improve patient outcomes, enhance efficiency, and reduce costs (Gulshan et al. 2016; de Dumast et al. 2018).

A picture archiving and communication system is a medical imaging technology that provides economical storage and convenient access to images from multiple types of source machines and imaging modalities. Such a system can combine all of a patient's information, including 3D data, into one universal file to homogenize the process of image reconstruction within the different systems. It offers the potential to export data to external third parties such as dental laboratories, medical specialists, and referring practitioners, subject to regional data-protection issues. Appropriate security procedures (including establishing permissions for access to data identifiers) and novel algorithms for statistical analyses and interpretation of generated data need to be developed and implemented. In this context, legal regulations must define clear standards for the security of patient data.

Data Linkages

During the past decade, efforts at linking large data sources have been accelerating. Data linkage is simply connecting information from different sources that relate to the same person or the same construct that results in a more robust dataset. At the federal level, the National Center for Health Statistics (NCHS) has been working to provide a rich, protected set of linked data files using some NCHS health survey datasets with administrative data from other agencies to promote research (National Center for Health Statistics 2020). Using linked datasets for surveillance and assessing the effectiveness of policy interventions holds great promise. However, new data partnerships are needed not only to better capture and assess overall health and well-being, but also to facilitate the incorporation of relevant oral and craniofacial health data (Secretary's Advisory Committee for Healthy People 2030 2019). Encouraging these data linkage activities will be a source of new information to help guide planning of oral health programs, policy, and research well into the next decade.

Artificial Intelligence and Related Information Technologies

AI takes computing beyond automation, computation, and storage and enables digital systems to analyze and make decisions resembling human thought. AI entered the lexicon in 1956 as more of an aspirational vision than a reality. Since 2000, that vision has evolved substantially and now promises the realization of exciting technologic advances for dental practice. This evolution has become possible because of enormous increases in computing power and communications coupled with miniaturization, big data aggregation and analytics, neural networks, and machine and deep learning. This ever evolving explosion in computing power, along with enormous improvements in the algorithms driving hardware and software design, are enabling huge advances in digital thinking that allow these systems to rapidly learn from experience.

AI has several potential future applications in the dental office. In the short term, AI may be used to enable patients to self-schedule and to optimize a practice's calendar, taking into consideration such variables as the requirements for various procedures. This capacity could be coupled with ride services (e.g., Uber, Lyft) to automate the transportation of patients to and from the practice. Further out, AI software algorithms will be able to study standard dental photographs and radiographs to "see" disease—dental caries, periodontal disease, abscesses, cancers, and other hard- and soft-tissue diseases—at a very early stage, often much earlier and more reliably than a provider's eyes alone. Another emerging application for AI is its use in the identification and interpretation of biomarkers to diagnose serious, often life-threatening, oral and systemic cancers and other diseases. Salivary diagnostics approaches are becoming more common and an expansion of their use at home is inevitable. As these new solutions achieve regulatory approval, dentistry also will be able to conduct inexpensive and easy-to-perform, noninvasive liquid biopsies on saliva samples to intercept serious local or systemic disease, often before appearance of definitive lesions and before symptoms are reportable. Finally, there are many opportunities to use AI and machine learning techniques for tracking and assessing educational outcomes.

Teledentistry

Teledentistry offers substantial potential for improving the oral health of underserved populations. The application of telehealth and teledentistry also creates opportunities for distance learning that improve dental science and oral health literacy. Similarly, mobile health care services and the use of mobile technology, such as smartphone apps and text messages to manage and track dental health conditions or promote healthy behaviors, have substantial promise for further expanding the effective utilization of teledentistry in both the private and public health sectors. Clearly, teledentistry provides a feasible choice for remote screening, diagnosis, consultation, treatment planning, and education in dentistry (Irving et al. 2018). One successful application of teledentistry to improve access to oral health specialty care for high risk rural children is the partnership among the Eastman Institute for Oral Health, the Finger Lakes Migrant HealthCare Project, the Community Health Center of the North Country, and others (Box 1).

Box 1. How does a rural community ensure that high-risk children receive oral health specialty care?

Sometimes a child has such severe dental problems that treatment under anesthesia is required. Getting to a medical center that can provide this kind of treatment can be difficult for families who live far from it. The Teledentistry Initiative at the Eastman Institute for Oral Health, University of Rochester, NY, facilitates access to specialty care for these children and their families. When a community dentist in a rural setting refers a child for treatment under anesthesia, an audio and video meeting is arranged with the child's family and a pediatric dentist at the Eastman Institute. This remote meeting serves as the initial dental examination, allows the dentist to determine whether the child needs treatment under anesthesia or other special treatment, gives the parents the chance to have their questions answered, and builds rapport between the child, family, and dentist. Since 2004, more than 1,500 children and their families have participated in this pediatric teledentistry program. In a 2014 published review of the first 251 patients needing treatment under anesthesia, the program achieved a 93% treatment completion rate. Partners with the Eastman Institute for Oral Health include the Finger Lakes Community and Migrant Health Center, North Country Federally Qualified Health Center, community dentists, the American Teledentistry Association, and the Monroe Country Department of Health.

Promising partnerships and programs such as these can serve as models for others to improve the oral health of underserved populations living in rural areas. Another example of a promising new direction in teledentistry is use of the Institute for Healthcare Improvement's plan-do-study-act cycle to rapidly institute a teledentistry helpline at the start of the COVID-19 pandemic (Weintraub et al. 2020).

Learning Health Systems

Recognition of the roles learning health systems (LHSs) can play in eliminating health disparities, including oral health disparities, has been growing. Organizations and networks working to improve the health of underserved individuals and communities have embraced the concept and are advancing it in ways that are broadly inclusive and participant-driven.

For example, an LHS approach could be employed to address gaps in evidence and evidence-based practice by forming a multi-stakeholder learning community with shared interest in learning about and improving treatments for chronic periodontal disease. A key first step would be to capture relevant data from real-world patient care and experiences to study the problem of interest (e.g., assessing what adjuncts to supplement scaling and root planing work best for different types of patients). This could include patients' observations of symptoms and self-reports of health-related behaviors as well. Next, analytics could be used to generate new knowledge from the data (e.g., an algorithm to predict which adjuncts are most likely to benefit different types of patients). The knowledge could then be mobilized in actionable forms to clinicians (as well as patients) and implemented into clinical practice, perhaps in the form of user-friendly applications built into clinical decision support and subsequently integrated into EHR systems. In turn, successive cycles of data capture, analyses to generate knowledge, and implementation would begin to enable continuous learning and improvement. The knowledge would be refined, optimized, and updated. Such an approach holds the potential to transform how treatment decisions are made.

Implementation Science

Implementation science holds tremendous promise for improving oral health for all, including reducing health disparities, by addressing factors at the individual, clinician, health care system, community, and societal levels that may limit the accessibility or effectiveness of evidence-based practices for disadvantaged and underserved populations (Chinman et al. 2017).

Rigorous clinical trials are necessary to test the efficacy and effectiveness of new interventions. The existence of customizable digital platforms that cover the entire spectrum of a clinical trial, including informed consent, recruiting, enrollment, adverse event monitoring, study balance and randomization, remote data portals, and validated methods for data collection (such as questionnaires) are a boon. Remote telehealth and telemedicine (e-visits) and real-time study monitoring are becoming realities. The ability to leverage more targeted recruitment tools, including social media and real-time links to patient advocacy groups, will streamline the recruitment process and save time and research costs while ensuring that the right population is used to answer the research question.

Large datasets collected during these trials and overlaid with advanced algorithms and data science capabilities allow for deeper insights and personalized prevention and treatment approaches. Opportunities to access and leverage data from multiple investigators to amplify learning and fill in knowledge gaps will create faster and ultimately better-targeted research programs. Given the need to increase the pace of innovation for oral health, clinical trials with enhanced technology for administrative activities and data collection and analysis will be even more important, especially when specialized patient populations are required.

Scientific advances in dental research are promoting dental technology development. The success of some dental product companies is encouraging more investment in dental technology. Furthermore, the U.S. Food and Drug Administration (FDA) is making a strong effort to accelerate product approval at the direction of the 21st Century Cures Act, passed in 2016, which enhances the agency's ability to modernize clinical trial designs and clinical outcome assessments and speed the development and review of novel medical products. In addition, the Act directs the FDA to coordinate activities among the drug, biologics, and device centers. It also improves the regulation of combination products, which are products composed of any combination of a drug, biologic product, and device.

The 21st Century Cures Act also directs the FDA to include the patient's voice in drug development and review by developing a regulatory framework to evaluate how real-world evidence (RWE)—data regarding the use, or the potential benefits or risks, of a drug derived from sources other than traditional clinical trials—can potentially be used to support approval of new indications for approved drugs or to support or satisfy post-approval study requirements. The FDA approach to incorporating patient-reported outcomes into the approval process is highly effective for measuring meaningful treatment benefits (Patrick et al. 2007).

A variety of sources relating to the delivery of health care and its outcomes can provide RWE, including EHRs, claims and billing data, and product and disease registries. Use of such evidence has the potential to allow researchers to answer questions about treatment effects and outcomes efficiently, saving time and money while yielding answers relevant to broader populations of patients than would be possible in a specialized research environment. This approach can help to streamline clinical development and inform products' safe and effective use.

The FDA also is tasked with facilitating more efficient product development by helping sponsors incorporate complex, adaptive, and novel trial designs into proposed clinical protocols and applications for new drugs and biologic products.

Research Workforce, Education, and Training

Status of Research in Dental Educational Programs

Within the last 5–7 years, much study and discussion have addressed science, technology, engineering, and mathematics workforce needs and doctoral education (Human Microbiome Project Consortium 2012a; 2012b; National Academies of Sciences, Engineering, and Medicine 2018a). By placing increased emphasis on skills needed for working both within and beyond academic institutions, graduate education will benefit from increased focus on interdisciplinary science, collaborative team science, and technology and data science.

Comprehensive research universities, including member institutions within the Association of American Universities (AAU), prepare 70–80% of all Doctor of Philosophy graduates. Schools of dentistry are represented in about one-third of AAU member institutions. At the same time, new schools of dentistry have emerged without visible, productive research programs and lack the collaborative strengths of medical and public health sciences found in comprehensive research universities. Reports and research represented in the Bailit and Formicola (2017) project, "Advancing Dental Education in the 21st Century," address needed changes to ensure sustainable commitments to contemporary research .

How the profession comes together to realize the future for graduate and professional education is key to sustaining these advances and making improvements in clinical care accessible. The students admitted to dental schools today, whether pursuing science or clinical care, will be working well into the second half of the 21st century. Most of this future work could very well be related to advancing science in oral-systemic connections and discovering appropriate interventions to improve oral and craniofacial health. Such work will require collaborations across medicine, engineering, and dentistry in multidisciplinary areas of precision health care, big data, systems biology, stem cell biology, biomaterials, and tissue engineering (Polverini and Krebsbach 2017).

Supporting Oral Health Science Training

Dental institutions have shared the vision of shaping dentistry's future leaders to sustain the mission of advancing health through education, service, research, and discovery. It is time to focus on the early stages of the pipeline, with enhanced training and constant stewardship to sustain an optimal support system for young scientists and clinician-scientists.

Academia is a major pathway for oral health scientists, but recruitment alone without increasing the pool of candidates will have limited impact on solving the dental faculty workforce shortage. Evidence suggests that formal training programs that provide students with necessary skills and basic knowledge about academia enhance awareness and facilitate the development of an academic career after graduation (Roger 2008; Gironda et al. 2013; Horvath et al. 2016). Dental institutions and professional organizations have developed programs to actively promote the recruitment and retention of future faculty. ADA, the American Dental Education Association (ADEA), and the American Association for Dental, Oral, and Craniofacial Research (AADOCR) (formerly the American Association for Dental Research) offer dental careers and professional development fellowships to dental students and educators that include structured mentoring, career insights, and hands-on experiences in research, teaching, and other aspects of an academic career. ADEA's Academic Dental Careers Fellowship Program recommends that institutions improve the climate for academic careers, promote academia's value, and increase robust interactions among students, faculty, and the institution (Palatta 2016).

Mentoring programs in dental schools and professional organizations also will help strengthen grant-writing skills, improve young faculty retention and advancement in academic careers, and enhance workforce diversity. A national mentoring program involving many institutions will be essential to diminishing disparities among institutions and to enhancing diversity in the faculty workforce (Jones et al. 2017). Cultivating partnerships and collaborations with NIH and professional dental organizations such as ADA, ADEA, and AADOCR; enhanced utilization of the NIH Loan Repayment Program to address educational debt; and developing research training programs targeted to the unique needs and challenges of dentist-scientists would enhance their abilities to successfully compete for research funding from NIH and other federal and nonfederal sources to sustain their research careers.

Several organizational efforts are attempting to increase and diversify the oral health scientific workforce. These include the National Institute of Dental and Craniofacial Research (NIDCR) Award for Sustaining Outstanding Achievement in Research, the NIH Scientific Workforce Diversity Office, and the NIH Policy Supporting the Next Generation Researchers Initiative. NIDCR funds such programs as the Director's Postdoctoral Fellowship to Enhance Diversity in Dental, Oral, and Craniofacial Research; the Summer Dental Student Award; the Dentist Scientist Career Transition Award for Intramural Investigators (K22); and the Dual Degree Dentist Scientist Pathway to Independence Award (K99/R00), created in 2008. These programs, along with all research training, should be monitored in partnership with the community of stakeholders to assess their effectiveness.

Chapter 4: Summary

Remarkable changes have occurred in research and technology during the last 20 years that hold promise to improve the orchestration of patient care and elevate oral and systemic health for all Americans. A concerted effort to optimize these discoveries while delving deeper into mechanisms of disease, engineering strategies, data science, and implementation science is essential to continue the momentum and translate discoveries into realities (See Box 2 for Key Summary Messages and Call to Action).

New findings about the human genome, oral microbiome, virome, and other omics are essential to transforming health care practices. Such discoveries are pivotal for improved oral and overall health. New scientific tools enable finer-detailed analyses of the underpinnings of diseases that have an impact on the oral and craniofacial region. Such approaches facilitate the ability to dig deeper in the pursuit of effective prevention and treatment strategies. Scientific advances encourage the unfurling of new discoveries, challenge present dogma, and enrich health care's future. The emergence of novel pathogens, such as severe acute respiratory syndrome coronavirus 2 (CoV-2), which causes COVID-19, and other as-yet-unknown agents, requires ongoing efforts to strengthen the scientific base and swiftly incorporate scientific advances in technology to optimize clinicians' abilities to provide oral health care safely and effectively.

The exciting advances regarding the microbiome's interaction with humans provide many opportunities for a better understanding of human oral diseases and development of new therapeutic directions. The oral microbiome has huge targeting potential and offers a strategic opportunity for microbial gene editing alongside human genome editing.

The development of health data comprising microbial and clinical information, coupled with robust bioinformatics approaches, has great potential to put big data to work in new approaches to health services research and also to realize the potential of personalized oral health care. Several pieces of the oral health–disease puzzle are amenable to analysis and incorporation into valuable models, including metabolomics, proteomics, phenomics, and genomics. Ongoing efforts in biotechnology and digital and information technology are generating large datasets that can be mined to promote personalized care. The aggregation of many individuals' data will inform clinical decision-making. These datasets will identify profiles of patients at risk for advancing dental diseases, communities at greatest risk for oral diseases, such as dental caries or oral cancer, and links with comorbid systemic diseases. Learning health systems at various levels of scale promise to transform human health by delivering knowledge to the right person, at the right time, in the right dose, through the right route, and in the right form. These innovations provide an opportunity to rethink oral health prevention and care delivery for the entire public and, most importantly, for underserved populations.

Whether science focuses on diagnostics, therapeutics, or technology, it also must address the steps needed to assist providers in adopting these new technologies and scientific approaches. The intersection of science and technologic advances presents unique opportunities for the dental profession. Science drives the need for innovative technologies, and the testing of new devices and platforms informs the gathering of evidence that can drive the best oral health practices. Dental care is constantly changing; new treatments are introduced, and old treatments are phased out. Preventive measures need to be constantly considered and new approaches adopted to address dental, oral, and craniofacial diseases and disorders. Implementation science strategies will translate the most effective preventive and interventional approaches to help providers achieve optimal standards of care.

Restorative materials that go beyond simple replacement, with bioinspired foundations to form new mineral and prevent future disease, are rapidly evolving.

BOX 2. Key Summary Messages for Emerging Science and Promising Technologies to Transform Oral Health

1. Science and technology provide the essential foundation for preventing and treating oral disease, and research breakthroughs during the past 20 years offer exciting opportunities to improve oral health.
2. Tremendous advances have occurred in the technology supporting dental practice, including new, bio-inspired dental materials, innovative chairside diagnostic strategies, 3-D bioprinting, improved digital imaging, and artificial intelligence-based models.
3. Discoveries related to the microbiome, genomics, and other omics offer promise for individualizing oral health care and revealing relationships among systemic diseases, suggesting possibilities for new treatments.
4. Discoveries in cellular analyses and regenerative medicine are leading to new treatments to improve oral health, including techniques and products created for bone and soft tissue regeneration that currently are being used in clinical settings.
5. The field of data science has grown considerably in the past 20 years, offering improved opportunities in "big" data analytics using integrated electronic health records and other large health databases for analyses as computing power has become more robust and efficient.
6. Implementation science holds promise for more effective adoption of evidence-based oral health practices, reduction of oral health disparities, and improvement of oral health equity.
7. The emergence of novel pathogens, such as COVID-19 and other as yet unknown agents, underscores the need to strengthen the scientific base and ensure the flexibility of the scientific enterprise to swiftly incorporate advances and technology necessary for addressing new health challenges.

Call to Action:

- Training, support, and mentorship of more oral health scientists and academics are needed to ensure a robust workforce who can extend and effectively use the advances in science that are so critical for delivering care in the changing landscape of oral health.

The field would benefit from robust clinical testing of oral ecosystems to better assess microbial, biochemical, and biomechanical challenges. The development of dental materials that are simpler to use, more durable, aesthetic, and effective against the attachment of plaque biofilms in the oral cavity is critical.

Advances in data science are having an impact on many facets of daily living, with promising aspects for dental care that still, however, lag in their translation to dental practice. Data capture has grown at an unprecedented rate, with collateral requirements for data management that include data warehousing, cleansing, governance, security, architecture, quality monitoring, and documentation. Data processing and in-depth analysis are needed to validate and test models before deployment and to demonstrate progress toward personalized oral health care. Health informatics, a rapidly growing area of interest in health care and public health, is driven by data science to inform timely decision-making. The conversion of dental records into a connected electronic health record framework with medical, pharmacy, and behavioral health is absolutely crucial for the integration of oral health with overall health to be fully realized.

Future work should focus on developing guidelines to monitor the performance of these models to improve process and patient outcomes. When implementing these data science approaches, it is critical to ensure that modeling and other artificial intelligence diagnostic developments using large datasets are done in an ethical way that does not discriminate against individuals based on characteristics including race, ethnicity, and gender.

There have been tremendous advances in the technology supporting dental practice, notably digital approaches, chairside diagnostic strategies, and imaging. Translational/clinical and scientific/mechanistic frontiers must converge in order for saliva-based, personalized, and precision medicine applications to be used in clinical practice. The existing clinical workforce needs to be kept abreast of new, evidence-based approaches for improving oral health care. The scientific workforce also needs to be kept aware of the scientific underpinnings of new approaches that challenge previously held tenets. New technologies should be strategized to reduce health disparities and expand the ability to provide care to a broader population. The profession needs to carefully strategize best practices for optimizing teledentistry to improve oral health care.

In the therapeutic arena, robotics will assist traditional dental surgical procedures, such as implants, in making treatment more precise and freer from side effects. Innovative new drugs, such as microbiome-modulating compounds or proresolving and anti-inflammation reagents with novel drug delivery systems, will be developed to treat and prevent major dental diseases, such as dental caries and periodontitis. Stem cell based tissue regeneration bears potential for repairing tooth, bone, and soft tissue damage, and new bioinspired dental materials will replace traditional dental materials. Most important, preventive dentistry could take center stage with the increased and improved identification of at-risk patients and those who experience disparities in care.

In the digital and information technology arena, dentistry will routinely employ digital scanning and three-dimensional bioprinting-based dental therapies. Artificial intelligence and machine learning will improve software construction of personalized, multidimensional, virtual models representing mucosa, teeth, bone, and cartilage. Multidimensional recording and the mixture of virtual reality and augmented reality will enable remote diagnostics, presurgical lifelike simulation, enhanced treatment planning, and the execution of therapy using guidance or navigation. Big data generated through nationwide datasets and integrated, pooled electronic medical records will be mined and analyzed with artificial intelligence-based data technologies to identify trends, associations, and clinical outcomes to create new types of evidence-based dentistry. Active ongoing and future studies and close partnerships among federal regulatory agencies, states, institutions, industry stakeholders, and patient advocates will optimize regenerative therapies in the next decades.

To realize optimal health in the population, the scientific workforce requires continual attention and direction. Programs should be complemented, expanded, and partnered with academic institutions to support the education of the future oral sciences workforce. Although the development of the scientific workforce has plateaued, the need for well-trained faculty members has grown. An ideal dental school graduate would be a highly skilled clinician with a deep understanding of the scientific foundation of dentistry, an appreciation of population health issues, and the compassion to serve. A necessary subset of those individuals should be cultivated to continue to focus scientific training on aspects of oral health science that are critical for the nation's future care needs. Programs and research training of the oral health research workforce should be expanded and monitored in partnership with the stakeholder community to assess effectiveness and outcomes of ongoing and new programs, ensure diversity at all levels, embrace team science, and course-correct to achieve intended goals. Stakeholders should identify shared priorities and leverage resources to achieve common goals for developing a robust and diverse oral health research workforce that is well prepared and capable of meeting future oral health research needs.

During the past 20 years, basic scientific discoveries in such areas as the microbiome, genomics, and regenerative medicine provided potential to improve population and individual oral health. Data science and other technologies have substantially advanced, providing opportunities to help individuals access care, making dental care more patient-centered, and presenting opportunities to improve health informatics that guide decision-making. Oral health research has an important role in facilitating new knowledge that can be used not only to improve the nation's oral health, but also to advance public health in a way that improves overall health and well-being.

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Oral Health in America: Advances and Challenges
Conclusion

Conclusion

In 2000, the landmark report, *Oral Health in America: A Report of the Surgeon General* (U.S. Department of Health and Human Services 2000), emphasized that oral health is integral to the health and well-being of all Americans. That conclusion remains crucially important today. Over the last 2 decades, mounting evidence has demonstrated the essential role of oral health in a long and healthy life. Good oral health represents not only the ability to eat, speak, and smile, but also freedom from pain that can interfere with normal functioning—including sleep, work, and learning. Oral health problems can occur at any point across the lifespan, but more often than not, they are preventable through individual, family, and community efforts. Social and commercial determinants of health can support or interfere with these efforts to achieve better oral health, and we are just beginning to understand what is needed to support positive outcomes in this regard. Many individuals and families continue to struggle with accessing oral health care. If there is one overarching challenge for oral health that has persisted over the last 20 years, it would certainly be the inadequate access to dental care that tens of millions of Americans experience. This lack of access to oral health care leads inevitably to untreated disease and, by association, to pain. Even so, the future for oral health in America is promising. Steps taken over the last 2 decades have revealed the promise and potential of a variety of innovative strategies. Consequently, the collective actions we take today can ensure that everyone in this country will have the opportunity to enjoy the benefits of good oral health tomorrow.

Reflections on the 2000 Surgeon General's Report on Oral Health

One of the closing sections of the 2000 Surgeon General's Report on Oral Health in America was titled "Facing the Future." It summarized briefly what were believed to be the major themes—or six "cultural movements"—that would influence the course of oral health over the coming years; it also described a basic framework for oral health that would be driven by those themes. Our first impression on rereading that section after completion of one of the later drafts of the current report was that it had truly been prescient. The "future" challenges and opportunities embodied in the six themes identified in 2000 reflect the same major influences and challenges that are described in this report. While those themes may have changed their shape slightly in some cases, there is no question that they continue to represent major factors provoking us, energizing us, and directing us toward new approaches and new efforts to improve oral health for all. It is worthwhile to look back now to that 2000 report and consider the six major influences they described and how those are reflected in various sections of the current report.

To recapitulate, the 2000 report stated that we were facing the promise of a new era for health that would be shaped by the convergence of the following six cultural movements, which could be expected to have "profound implications for the future of the oral health and general health and well-being of all people":

1. The biological and biotechnology revolutions;
2. A redistribution of the world's people by rapid and sizable migrations within countries and across borders;

3. Changing demographics in industrialized as well as developing nations;
4. Changing patterns of disease, including the emergence and reemergence of infectious diseases, and changes in the organization of health care;
5. Instant worldwide communication through the internet, cable, satellite, and wireless technology; and
6. A continuing exponential rate of growth in information technology, specifically in computer speed, memory, and complexity.

Although the current report was not written with the intention of addressing these influences, it is now easy to see that each section herein has, indeed, reflected at least one or two of these influences in the descriptions of the advances, challenges, and promising new directions around which the report's content has been organized. It seems quite correct, therefore, to say that these six influences represent important patterns of change that have shaped oral health over the last 20 years. Because the six influences overlapped in a number of ways, we will discuss them here in just three groupings: (1) Advances in Biology, Technology, and Computing Capacity (Influences 1 and 6); (2) Changing Population Patterns and Demographics (Influences 2 and 3); and (3) Instant Communication and Contagion (Influences 4 and 5).

Advances in Biology, Technology, and Computing Capacity

The biological and technological revolution that was heralded in the Surgeon General's Report on Oral Health 20 years ago has unquestionably transformed our thinking about what is possible for oral health. Section 6 of this report focuses on "Emerging Technologies and Promising Science" and describes some of the discoveries related to genomics and the microbiome that have begun to reveal relationships among diseases and suggest possibilities for personalized treatment. Research on the oral microbiome has led to a far better understanding of the processes underlying periodontal disease and its consequences as well as its relationship to systemic disease. The "big data" thinking that was necessary to pave the way for identifying and mapping the human genetic structure, as realized through the Human Genome Project, required improvements in analytic techniques, as well as expanded knowledge in cellular and genomic biology. These advances, in turn, have facilitated new discoveries related to oral health and every other field of medicine. Although new and exciting areas of scientific discovery were underway in 2000, much of what we now are seeing—in regenerative techniques, for example—had not yet been imagined. The laboratory development of living materials for use in restoring bone structure, for example, is becoming a reality in the practice of implant dentistry, and three-dimensional printing techniques are now being used in the production of several different types of dental prostheses and restorations. Other advances that have made an impact on the delivery of dental care during the last 20 years include digital radiographs, intraoral cameras, and other technological devices used in diagnostic applications.

The continuing explosion of scientific knowledge, as reflected in this report, also is related to the sixth and last bullet in the list of influences above, "exponential growth in … computer speed, memory, and complexity." Today, we take for granted this exponential growth in computing and sometimes struggle to make use of the capacity it reflects. Electronic health records (EHRs) present a very simple example of this. The integration of dental and medical records could result in moving more quickly toward the use of individual health information to inform treatment and prevention of oral diseases, although this potential has not yet been fully realized. Section 4, which addresses "Oral Health Integration, Workforce, and Practice," provides descriptions of some excellent early efforts to do this. These initiatives also recognize the benefits that integrated records can bring to health care providers responsible for patient care related to systemic diseases, such as diabetes, that have known oral health implications. Section 6 also reminds us of the need and ongoing efforts to improve our EHR infrastructure and how truly integrated health information can advance individual and public health. The biological and computer technological revolutions are challenging—not only because they continue to transform what we know but also because they continually create both new goals and new obstacles to surmount on the way to achieving those goals.

Changing Population Patterns and Demographics

The second and third major influences listed in the 2000 report referred to redistribution of people by migration and changing demographics in both industrialized and developing nations. These changes, indeed, have come to pass and, in all likelihood, they will continue to reshape the racial and ethnic profile of our country as well as those of many other nations. These influences reflected the major role that population-based disparities were beginning to have on strategies to improve oral health across our country in 2000. Today, however, these disparities represent an overarching challenge that can be seen throughout the current report. As we confront the urgency of addressing disparities in patterns of oral disease that reflect our population's profile, we are compelled to seek a greater understanding of the factors underlying disparities and to develop skills for tailoring treatments to address these factors. Moreover, we cannot escape the importance of building a health care workforce that mirrors the people for whose oral health care they are responsible. Various aspects of these challenges are described in all six sections of this report.

In Section 1, the concept of upstream variables that create disparities in oral health status and also in access to regular dental care was introduced, and the manifestations of these differences were explored in terms of their impact on health care systems and on our national economy. The complex relationships among social, cultural, commercial, and other influences on individuals and families underscore the fact that oral health depends on more than the availability of dental care. Social determinants of health play a vital role in influencing oral health outcomes; these determinants represent not only a variety of factors reflecting where people live, learn, and work, but also the economic and social systems within society that affect all of us. Social determinants for some are associated with insufficient resources and opportunities to maintain health, leading to persistent health inequities that impact both individuals and the communities where they live. Observing these inequities compels us also to confront the ways in which perceptions of group differences have created and built unconscious bias and structural racism into our social and health care systems. These systemic biases play out in many ways—for example, in the differential availability and marketing of a variety of products that can harm or support oral health. Because of the disparate associations of financial and other social determinants with various population groups, commercial motivations may exacerbate oral health disparities and inequities. Policy implications are important in this discussion, and issues such as taxation of health-harming products and other governmental and community-level actions that have been suggested also are discussed.

In Sections 2 and 3, which focus on oral health across the lifespan, the data related to changing population patterns were central for virtually every topic. This focus on population-based social and environmental disparities is perhaps most obvious in the presentation of data related to childhood caries. Income and race are among the most powerful predictors of dental disease in young children, and this continues to occur despite tremendous strides in the overall reduction of dental caries. The same is true for access to dental care, where minority racial identification and lower incomes are clearly associated with unmet oral health needs in children. New research in social determinants of oral health is suggesting that, among recent immigrant populations, acculturation may be an important, albeit complex, factor in determining oral health.

Population data also demonstrate notable disparities in the oral health of adults. Throughout the adult years, the ability to pay for oral health care is likely to determine the status of oral health—especially for those who are members of minority racial groups. Although important initiatives of the past 20 years have supported improved oral health for most young children, the outcomes of this progress diminish as those children move through adolescence and into adulthood. As a group, working-age adults have seen little change in oral health; this is clearly related to the ongoing challenges of financing and accessing dental care, as well as to the dearth of oral health promotion initiatives aimed at preventing the initiation of dental caries in adolescents and young adults.

Changing demographics also help to explain the increased numbers of rural-dwelling individuals who have little access to dental care and who may lack access to such preventive oral health measures as water fluoridation. Finally, because our population is aging rapidly, we see new patterns of disease and growing demand for oral health care for those in institutional settings. Older Americans now have far lower rates of edentulism and fewer problems of maintaining functional dentition, but those rates do not apply to all groups within the population. The fact that our population is aging may represent the single most important change that we will see during the next 20 years. The number of people who will be 65 or older by 2035 will be greater than those who are 18 or younger. Preparing for this shift in the composition of our society demands greater attention and new strategies for addressing the changing needs of the older population.

Section 4 focuses on oral health integration, workforce, and practice—all important topics when considering changing population demographics. Most compelling from that section are the recommendations for innovative models of care that include new types of providers; expanded responsibilities across medicine and dentistry; and the introduction of oral health care and preventive services into new settings where people live, work, and learn. These innovations in care delivery notwithstanding, our ability to respond to oral health care needs is hindered by cost factors related to pursuing dental education or, later, to practicing in high need areas. When dentists graduate with education debt at unprecedented levels, they may feel pressured to practice only in higher-demand and higher-income areas, and the maldistribution of essential oral health services is simply exacerbated. The content of professional training, too, must be adapted to address a changing population's needs and to emphasize prevention, rather than treatment. Finally, in Section 4, we benefited from an in-depth look at the problems of financing oral health care and the ways in which the separation of this aspect of health has created particular burdens for the underserved within our new population demographics. For instance, dental coverage is not as widespread as medical insurance because it is treated as an add-on to health insurance, rather than an essential part of it. The demand for oral health care, and with it, the oral health status of the nation, would be elevated if oral health services were considered an essential health benefit for individuals of all ages.

Although the focus of Section 5 might appear at first glance to represent a topic apart, the issues of pain, mental health, and substance use are inextricably tied to a variety of issues and concerns for oral health and the practice of oral health care. The same barriers encountered by those who are disadvantaged by social and environmental determinants of oral health also are experienced by individuals who live with mental illness or cope with substance use disorders. Section 5 represents an unprecedented attempt to coalesce and synthesize information on pain, mental illness, and substance misuse in the context of oral health. This section explicates patterns of substance use and the relationship of various substances and use patterns to oral disease; in doing so, it informs oral health research, as well as patient care issues and provider behaviors related to these problems.

Even with respect to emerging science and technology, which is the focus of Section 6, issues of health disparities in relation to population demographics are a salient topic. The development and evaluation of evidence-based oral health practices depend on the testing of those practices in a manner that addresses our changing population demographics. Only with this approach will advances in research help to address, rather than exacerbate, existing disparities in oral health. The contributors to Section 6 also underscore the need for increasing the numbers of oral health scientists and academics who reflect the many racial backgrounds, cultures, and other characteristics of the population at large.

The impact of rapid changes in population demographics and associated health disparities and inequities—both within our country and around the world—as well as greater reliance on technology to deliver dental care, represent a growing concern. Recently, global oral health was described in a *Lancet* editorial as being at a "tipping point," where technological changes and consumer demands for esthetic dentistry were changing the perception of dental care and accelerating oral health disparities as more people face increasing barriers to receiving essential care for oral health (*The Lancet* 2019). If our idea of what oral health should be continues to move toward these newer expectations and trends, then the risk is high for many to remain disenfranchised from the benefits of good oral health as care becomes more unaffordable. This will result in many Americans continuing to live with untreated disease, to have poor access to prevention and care, and to experience a lower quality of life.

Communication and Contagion

As we observe the tremendous impact of population-related and socially driven health disparities that was predicted in 2000, we are acutely aware that patterns of disease must be understood globally as well as nationally. We are not isolated, and in fact, it is not possible for us to be isolated as a country with respect to oral health, any more than to any other aspect of the human condition. The fourth and fifth major influences predicted in the first Surgeon General's Report on Oral Health—changing patterns of disease, including the emergence and reemergence of infectious diseases, and instant worldwide communication—are even more salient at this particular moment in time.

As this report was in development, our world was unexpectedly gripped by the COVID-19 pandemic, a vivid illustration of universal human vulnerability to a viral disease that does not respect national or social boundaries. We have learned that it does not matter where such a disease originates; we will ultimately experience it as citizens of the world. Furthermore, it will cease to affect us only when and if it no longer infects anyone, anywhere in the world. This was the lesson of smallpox, as well as the efforts to eradicate polio, and we are learning these lessons again today. Although vaccines now provide individual protection from the virus, the emergence of variants of the original COVID-19 coronavirus remind us that the disease will not instantly be eradicated, nor will we have seen the last of such pandemics. We simply cannot exist as an island on this globe, and our health fate is inevitably shared with all the earth's inhabitants. This is true for oral health as well as for every other aspect of health.

In response to COVID-19, this report's contributors have attempted to describe in real time the impact of the pandemic on oral health specifically, and on the delivery of oral health care services—from the postponement of dental care during the pandemic to the modification of treatment procedures by eliminating or adapting aerosolizing techniques and adding protective equipment. That effort to understand the impact of the pandemic can be viewed in some way in each of the Sections of this report, yet it also was clear that we were writing only the early chapters of this history, that we were only beginning to imagine the longer-term consequences on oral health of this virus, and perhaps of other infectious diseases in the future. A very cogent lesson of the COVID-19 pandemic is that managing such events will necessitate partnerships among all nations. Just as it is a fact that viral diseases have no boundaries, it is an imperative that science must have no boundaries. In this regard, of course, instant worldwide communication is our best friend.

Of course, there have been other changes in disease patterns as well, and this monograph has described those with respect to oral diseases. We are seeing unprecedented levels of human papillomavirus–related oropharyngeal cancer, and the ongoing epidemic of opioid misuse represents another pattern that was not a part of the picture in 2000. Across the board, we see improvements in our ability to control and to treat the most common oral diseases—but not for all of the people all of the time. Substantial challenges remain for achieving the goal of integrating new technologies, such as EHR and telehealth. Those who live with poverty, those who have medically compromising conditions—including mental illness and substance use disorders—and those who differ by virtue of race or ethnicity, are undeniably bearing the brunt of these new patterns of disease. It is important to acknowledge that these same groups stand to gain the most if we are able to fully apply new science and technology in ways that will be available to them. Again, our challenge is less whether we can prevent or treat a particular disease than it is whether we can do that for everyone.

Reconsidering a Framework for Oral Health

The 2000 report closed its discussion of important influences by identifying two major drivers for the advancement of oral and craniofacial health over the coming years. Those were stated as: (1) the need and demand for dental, oral, and craniofacial health services; and (2) the role, functions, and mix of health professionals. These two themes are certainly salient in the topics covered in this report. Rather than drivers for the future, however, these two themes now appear to represent major facets of the oral health landscape that are, themselves, being driven by the changing patterns described in the report. Based on the work in this volume, the key determinants of the need for services and types of providers are changing population patterns and changing disease patterns. These two factors ultimately will require changes in the services that are needed and also in the roles, functions, and mix of health care professionals who will provide those services. The entry of new kinds of providers—such as dental therapists—and the provision of some oral health services by medical providers are demonstrating the recognition that oral health is inseparable from overall health. Integrated electronic health records and the extension of health services to new settings are additional steps that will extend care options and thereby enhance the capacity to prevent oral disease. The advantages of these strategies ultimately accrue to patients, and especially to the growing number of individuals who have not been well served by traditional approaches to care.

This monograph has provided numerous examples of ways in which consumers/patients, health care providers, and health policy makers can engage to improve oral health and strengthen an oral health framework that benefits all Americans. For parents, encouraging twice-a-day toothbrushing, providing a healthy diet, and ensuring regular dental care—including seeing a dentist by a child's first birthday—are behaviors that will set children on the right course for sustained oral health. Pregnant women are learning that it is both safe and smart to receive preventive dental care and seek treatment for dental problems. Safe and effective measures to prevent oral diseases are available for everyone, regardless of age. Smoking is a major risk factor for gum diseases and oral-related cancers, and early research on e-cigarette use shows that it may have harmful effects in the mouth and throat that are similar to those of other tobacco use. State and national quitlines are a valuable resource for users of tobacco products who want to quit. Dental providers as well as physicians are increasingly taking the initiative in offering these and other resources.

Dental care has been moving away from extensive treatment and restorative procedures to the use of minimally invasive techniques—for example, with nonsurgical approaches to dental caries management. The effective use of this approach requires a documented assessment of risk and the ability to track small changes in demineralization and other surface conditions. Dental practice has become increasingly reliant on advanced applied technology, such as digital imaging, dental implants, and materials used to prevent, arrest, and restore disease-affected orofacial areas. The effective management of orofacial pain is an essential part of dental practice, and the profession has been active in promulgating improved practices for more judicious prescription of controlled substances and more effective strategies for the appropriate use of nonprescription analgesics.

Interprofessional education and care are changing the way dental services are provided, and there is a growing emphasis on collaborative health care, especially for those with special health needs and those with limitations due to functional dependency. The integration of dental services with medical care is occurring in both directions, with physicians increasingly engaging in oral health prevention activities; dentists now providing diabetic screenings, counseling for tobacco cessation and HPV prevention, or substance use screening. Several states have authorized vaccinations as a part of dentists' health services as well. Although more Americans than ever are receiving dental care away from a conventional dental office, more are also receiving some primary health care services from oral health professionals.

This monograph also has highlighted society's structural influences on oral health. Although actions taken by individuals and providers are essential for good oral health, ensuring better oral health for all requires actions at the level of public policy. Only through policy can access to oral health services be assured for all. Unfortunately, that access to care is the most persistent challenge to the goal of oral health for all. It is not enough to articulate that oral health is important, or that it is clearly related to general health. Access to oral health care must be declared an essential health benefit—one to which all Americans have a right, regardless of age or any other characteristic of our lives. From a simple declaration such as this, it could be expected that many other structural changes would flow—from addressing the scope of practice or improving educational competencies, to expanding dental insurance coverage, among others. If America is to make a significant step toward improved oral health for all, it is clear that individuals, providers, and policy makers will all have important roles to play.

Creating Optimal Oral Health for All

This report, *Oral Health in America: Advances and Challenges*, reflects the interconnectedness among a wide variety of factors and determinants that influence oral health and overall health. Although the report has been presented in six broad sections that appear at first glance to be more independent than related, a closer inspection will prove otherwise. The six sections can be conceptualized as a complex cluster of puzzle pieces (see Introduction, Figure 1) that, when assembled, can bring our nation much closer to optimal oral health for all. For example, in the figure, three puzzle pieces (reflecting Sections 1, 4, and 5) are shown as unconnected to the assembled puzzle, suggesting that connecting them in position will improve oral health in America. These pieces focus on several major issues that influence access to care, such as the workforce, care integration, financing care, and health systems. Other equally important issues from these three sections include inequities and disparities, pain management, substance misuse, and behavioral health issues. In considering the meaning of this puzzle, it also needs to be understood that the three pieces that are shown as connected within the assembled puzzle should not be perceived as representing completed work. For example, from implementing effective strategies to address adolescent oral health to identifying interventions that provide proper oral health services for older adults, many tasks have not yet been addressed.

The current report is far-ranging and describes the many ways in which the major social or cultural influences foreseen by the 2000 report have buoyed new discoveries and encouraged creative approaches in oral health care. Unfortunately, those same influences also have limited our progress. We have the problems of too much data and not enough applicable information, producing a paradox that affects our health care system and challenges our decision-making efforts. New knowledge and novel technology create enormous potential and also raise additional questions about what is feasible financially, operationally, or culturally. New opportunities for pain management create the potential for misuse of the same medications that can solve a problem. Better understanding of the behaviors that support oral health create demands for greater understanding of the educational, social, cultural, and financial obstacles to achieving those behaviors. Better health care means longer lives, and longer lives inevitably result in additional health care challenges, including those of oral diseases and disorders.

In 2000, the Surgeon General's Report on Oral Health in America demonstrated that oral health is integral to overall health. Twenty years later, this report has both reaffirmed those findings and provided a greater understanding of that relationship. The true value of this report, however, will be in the extent to which it provides a plan for securing the same benefits of good oral health for every individual. Given the multiple and often complex influences on oral health, we have attempted to identify some key findings of the current report that reflect these forces (Box). Just as each section of this report has identified a call to action, we will close this report with three more calls to action that suggest promising directions for achieving better oral health for all: (1) policy changes are needed to reduce or eliminate social, economic, and other systemic inequities that affect oral health behaviors and access to care to significantly improve the nation's oral health; (2) dental and other health care professionals must work together to provide integrated oral, medical, and behavioral health care in schools, community health centers, nursing homes, and medical care settings, as well as dental clinics to improve oral health for more people; and (3) we need to diversify the composition of the nation's oral health professionals, address the costs of educating and training the next generation, and ensure a strong research enterprise dedicated to improving oral health to strengthen the oral health workforce.

These calls to action are not simple decisions that can be made and implemented easily. Each requires the development of a still stronger scientific evidence base, a commitment to recruiting and sustaining human resources to accomplish the task, and a focus on implementation and evaluation—all within the context of our changing demographics. We must test both the new models that we envision and our approaches to disseminating those models, and we must prove their results, both in terms of economic and social impact as well as the health impact for individuals. The charge is daunting, but we are better positioned than ever to undertake work that will create the opportunity for optimal oral health and ensure oral health equity across all communities and for every individual within those communities.

Box. Key summary messages for *Oral Health in America: Advances and Challenges*

- Good oral health is important for the overall health and well-being of individuals of all ages, their families, communities, and the nation.
- Through research and policy changes over the past 20 years, we have made substantial advances in the understanding and treatment of oral diseases and conditions, yet many people of all ages and demographic backgrounds still have chronic oral health problems and lack access to care.
- Healthy behaviors can improve and maintain individuals' oral health; these behaviors are shaped by social and economic conditions in which people are born, grow, work, and live.
- Oral and medical conditions often share common risk factors, and just as medical conditions and their treatments can influence oral health, so can oral conditions and their treatments affect other health issues.
- Substance misuse and mental health conditions negatively affect the oral health of many, and oral health providers are an integral part of the interprofessional team caring for these individuals. Professional schools have been challenged in preparing dental providers with the knowledge and skills needed for these new roles.
- Oral health services are evolving rapidly towards interprofessional models of delivery that integrate services across the health professions and expand access to care through new practice settings and new professional roles.
- The COVID-19 public health crisis has challenged the nation's health care system, including oral health care providers as never before, and with those challenges came new ways of ensuring safety during provision of dental care, of treating disease, and recognizing that oral health cannot be separated from overall health.

Call to Action:

- To significantly improve the nation's oral health, policy changes are needed to reduce or eliminate social, economic, and other systemic inequities that affect oral health behaviors and access to care.
- To improve oral health for more people, dental and other health care professionals must work together to provide integrated oral, medical, and behavioral health care in schools, community health centers, nursing homes, and medical care settings, as well as dental clinics.
- To strengthen the oral health workforce, we need to diversify the composition of the nation's oral health professionals, address the costs of educating and training the next generation, and ensure a strong research enterprise dedicated to improving oral health.

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