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A Healthy Smile Can Last a Lifetime: Exploring the Social Determinants of Oral Health Among Older Adults in the U.S.

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A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Community Health Sciences

by

Jennifer Amanda Archuleta

2024

ABSTRACT OF THE DISSERTATION

A Healthy Smile Can Last a Lifetime:

Exploring the Social Determinants of Oral Health Among Older Adults

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by

Jennifer Amanda Archuleta

Doctor of Philosophy in Community Health Sciences

University of California, Los Angeles, 2024

Professor Hiram Beltrán-Sánchez, Chair

Oral health is an integral component of general health. Still, too many older adults in the U.S. have no access to dental care while also suffering from disproportionate rates of oral diseases. Little has been done to address social determinants of oral health at a national level. The goal of this dissertation was to investigate the link between socioeconomic status (SES) and three indicators of oral health among U.S. older adults: (1) utilization of dental services, (2) untreated dental caries, and (3) permanent tooth loss. These outcomes mark the progression of poor oral health that begins with access to routine dental care, then advances to dental caries, and reaches the terminal outcome of permanent tooth loss. Our theoretical framework drew upon concepts from Elder's (1974) Life Course Framework, Link and Phelan's (1995) Theory of Fundamental Causes. and Cockerham's (2005) Health Lifestyle Theory.

Cross-sectional data from the (2013-2018) National Health and Nutrition Examination Survey (NHANES) were used to assess variations in oral health-related outcomes among adults aged 50 years and older. Key findings revealed that participants with lower levels of education and income were less likely to have regular dental check-ups, had a higher likelihood of untreated dental caries, and faced an elevated risk of permanent tooth loss compared to those with higher SES. These disparities linked to SES were particularly pronounced in adults over 80 years of age with limited educational attainment. Furthermore, escalating levels of food insecurity and having infrequent dental care were both associated with fewer permanent teeth, a higher risk of untreated dental caries, and a greater probability of complete tooth loss.

The consequences of oral diseases are life-altering. Older U.S. adults are especially vulnerable to these challenges, influenced by a combination of social, behavioral, and clinical factors over their lifespan. Unfortunately, research in this area is scarce, while public programs such as Medicare do not even offer basic dental coverage. Thus, understanding critical social drivers of oral health is imperative for enhancing dental outcomes for current and future generations.

The dissertation of Jennifer Amanda Archuleta is approved.

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DEDICATION PAGE

This dissertation is dedicated to *la familia* Archuleta, both living and deceased, my beloved husband, and everyone who has been a guiding light on this personal and academic journey.

And for all those who smile with confidence. May this work help illuminate the path to strong and healthy teeth for people of all ages and backgrounds.

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Melgoza, E., **Archuleta, J**., Tran, E., Abarca, G., Fiastro, A. (2021). The impact of oral health on psychological distress among older adults in California. Innovation in Aging, 5(Supplement_1), 868–868. doi.org/10.1093/geroni/igab046.3139

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Introduction

Oral diseases are chronic and cumulative, resulting in devastating health burdens over time. Although oral health problems can develop throughout all stages of the life course, they usually become most ubiquitous in older age groups. Poor oral health is the leading global cause of disability-adjusted life years among older adults aged 65 and older (Marcenes et al., 2013). Oral health conditions such as untreated dental caries (cavities), gum infections, and permanent tooth loss impact more than 77% of older adults worldwide (Kassebaum et al., 2017). In the U.S., nearly one in five adults over the age of 65 suffers from edentulism, which is defined as complete tooth loss (Dye et al., 2015). The consequences of untreated oral diseases are costly, painful, and diminish overall health and quality of life.

Most oral diseases are preventable and are not distinctively a product of time and aging (Heilmann et al., 2019). A combination of social, environmental, and behavioral factors influences oral health over the life course. Underlying structural factors such as access to dental care, socioeconomic status (SES), and health-related limitations are often disregarded when identifying root causes of oral health issues, especially during older adulthood. Curative approaches are largely used to target oral health problems, while preventive and structural barriers are often overlooked. Socioeconomic gradients in oral health outcomes suggest that behavioral interventions alone do not resolve this public health crisis (Andrade et al., 2020; Dye et al., 2019; Marmot & Bell, 2011). While healthy dental hygiene practices indeed support better oral health, excessive focus on individual behaviors in oral disease prevention places the onus on individual behavioral changes while disregarding significant effects on health by the broader structural factors that include the social and physical environment.

In general, there is a paucity of theory-based research on the oral health status of older U.S. adults that focuses on social determinants of health. Most research on this topic only examines general descriptive data from national surveys, focuses on oral health outcomes in child populations, or relies on longitudinal studies outside of the U.S. (Heilmann et al., 2019). Even though some literature has identified SES as a determinant of oral health, most studies have no explicit application of relevant theoretical frameworks to examine key factors of oral health outcomes. Additionally, few studies consider using a life course perspective to inform how specific mechanisms are unique to the development of oral health in older adulthood. Epidemiologic assessments in the U.S. frequently combine and generalize oral health trends across broad adult populations of individuals aged 18 years and older, while most research does not consider how other health-related factors (i.e., diet, hypertension, and diabetes) compound adverse dental outcomes.

Oral health literature on Latino older adults is even more scarce. Additionally, no recent studies have explored potential differences in the oral health conditions between U.S.-born and foreign-born Latino subgroups of older U.S. adults. Compared to other racial/ethnic groups, Latinos have among the worst outcomes in terms of access to dental services and incidence of oral health diseases (Han et al., 2019). Latinos are also projected to live longer than other racial/ethnic groups, while the population of Latinos over 65 years of age is expected to double from 54.1 million individuals to 94.7 million individuals by the year 2060 (Administration of Community Living [ACL], 2021). Given that Latino older adults currently face disproportionate oral health burdens, while constituting a substantial portion of the U.S. population, there is a likelihood of unprecedented demands for oral health services and emergency treatments in the coming years. Exploring the nativity status of Latino subgroups can shed light on how migration-related factors intersect with racial/ethnic identity to shape oral health outcomes.

Oral health is an integral component of general health. Still, too many older adults have no access to dental care while also suffering from a high prevalence of oral health morbidities. Little has been done to address social determinants of oral health on a national level. Moreover, low-SES older adults and racial/ethnic minorities bear the largest burdens of oral health problems. The dynamic between SES, aging, and key social and behavioral factors is a subject that requires special consideration in the context of oral health.

Project overview and preview of dissertation chapters

The goal of this dissertation was to investigate the relationship between SES and three indicators of oral health status among U.S. older adults. Using concepts from Elder's (1974) Life Course Framework, Link and Phelan's (1995) Theory of Fundamental Causes, and Cockerham's (2005) Health Lifestyle Theory, this work examined three outcomes: (1) utilization of oral health services, (2) untreated dental caries, and (3) permanent tooth loss. These outcomes represented the progression of poor oral health that begins with access to routine oral health care, then advances to dental caries or periodontal diseases, and reaches the terminal outcome of permanent tooth loss. Cross-sectional data from the (2013-14, 2015-16, 2017-18) National Health and Nutrition Examination Survey (NHANES) dataset were used to assess differences and patterns in oral health-related outcomes among adults aged 50 and older.

This dissertation had three aims. The first aim was to investigate how the association between **SES and the use of routine dental health visits** was influenced by age, race/ethnicity, and diabetes diagnosis. Diabetes was expected to be a significant health-related factor in this relationship because medications for diabetes lead to lower saliva production and subsequent oral health issues caused by dry mouth. In addition, a large proportion (about 25%) of adults over age 65 have type II diabetes (CDC, 2020). Thus, low-income older adults with diabetes may find themselves balancing resources between dental care and medical care needs. The second aim investigated how SES impacted **untreated dental caries** among dentate older U.S. adults and determined whether food security and dental visits changed the magnitude of this effect. Last, the third aim examined the extent to which SES influenced **permanent tooth loss** within a larger subpopulation of older U.S. adults (both dentate and edentulous) after accounting for potential mediation by dental visits and food insecurity. Dentate adults were defined as having at least one or more permanent teeth, and edentulism was having complete tooth loss.

The first chapter of this dissertation provides a theoretical background for each aim and its associated research questions. The theoretical background includes definitions and critiques of three life course and social placement theories: Elder's (1974) Life Course Framework, Link and Phelan's (1995) Theory of Fundamental Causes, and Cockerham's (2005) Health Lifestyle Theory. These theoretical approaches served as the basis for a conceptual model that will be described at the end of this chapter. The next three chapters will focus on Studies 1 through 3, which align with each of the three dissertation aims. Each study encompasses a distinct literature review, methodology, review of results, and discussions of the key relationships under investigation. Last, a concluding section will discuss the implications of these findings for oral health policy and identify avenues for improving and expanding this area of research.

Challenges amid the COVID-19 pandemic

The emergence of the COVID-19 pandemic in 2020 has introduced complex barriers to oral health care access and delivery. Unfortunately, national-level oral health data during this timeframe are not currently available to better understand those gaps. Oral health data that were surveyed during 2020 are incomplete and have high response bias due to the disruptions of data collection at the height of the pandemic (Centers for Disease Control and Prevention [CDC] & National Center for Health Statistics [NCHS], n.d.b). Thus, the following analyses will focus on the most recent data from the 2013-14, 2015-16, and 2017-18 NHANES cycles, which do not consider factors that were unique barriers to dental care access at the start of the pandemic. Nonetheless, understanding major factors of oral health status before the COVID-19 pandemic is still relevant to better understand changing trajectories in the oral health landscape. This research paves the way for future studies related to improving oral health care access, delivery, and dental outcomes in the U.S.

Theoretical Background

Chapter summary

Few studies have examined oral health issues within the context of aging and social determinants of health. Most studies on oral health issues focus on connections between clinical oral health indicators and health care access with little attention paid to sociodemographic factors. While some research in oral health accounts for social characteristics, such as SES, these factors tend to be used as controls rather than explanatory indicators of oral health. In addition, little is generally known about the health consequences associated with poor oral health among older adults. Nonetheless, a large body of literature on the social determinants of health suggests the importance of sociodemographic factors in shaping one's health. This dissertation fills a gap in the oral health literature by applying aging and social placement theories to the study of dental care access and dental outcomes in older adult populations.

The framework for this dissertation connects key concepts related to the works of Elder's (1974) life course framework, Link and Phelan's (1995) SES as a Fundamental Cause of Health, and Cockerham's (2005) Health Lifestyle Theory. Under the life course framework, one can posit that oral health issues are shaped by their socio-historical context. From this perspective, the progression of oral diseases is dependent upon different stages of the life course and historical periods. Second, the main tenets of the Fundamental Cause Theory illustrate how socioeconomic stratification gives rise to socioeconomic gradients in particular health outcomes, which are anticipated to include outcomes within the context of oral health. Last, Health Lifestyle Theory explains the interplay between individual autonomy and underlying social structures, which constrain or support one's ability to engage in healthy behaviors. An integrated framework guided by these theories is a novel methodical approach that will add to the current body of oral health research, which largely has no explicit application of theory (Heilmann et al., 2015). This framework aims to inform relevant research questions and identify modifiable factors that influence the oral health status of older U.S. adults.

Elder's (1974) Life Course Framework

Elder's (1974) life course perspective has relevant applications in the field of oral health. Given that oral diseases are cumulative, utilizing a life course framework for this health topic is beneficial for identifying key predictors and points of intervention for oral diseases among older adults. In general, a life course perspective treats age and historical time as contextual factors that shape the trajectory of healthy development and aging (Elder et al., 2003). As a result, health outcomes are often stratified by age gradients. That is, oral health problems that arise earlier in life typically increase in severity over time (Broadbent et al., 2016; Thomson et al., 2004). The key ideas of the life course framework are described by five principles that highlight the temporal nature of health and development (Elder et al., 2003).

Principle of Life Span Development. The first principle of the life course framework describes human development and aging as lifelong processes. Once an individual reaches a specific age marker or milestone (i.e., turning 18 or celebrating retirement), the aging process does not end. Important biological, social, and psychological development continues at all points of the lifespan. For instance, being alive at age 50 does not guarantee one has good or poor dental status. Some oral health outcomes are patterned by age gradients, but depending on certain behavioral, social, and genetic factors, the condition of one's permanent teeth can vary among people of the same age group (Griffin et al., 2019; Wong et al., 2019).

Principle of Agency. According to the principle of agency, people are responsible for constructing their actions, but those choices occur within the bounds and opportunities of history and social circumstances. The ability to make healthy choices depends on the options that exist within one's historical and social context. For instance, sudden unemployment during an economic recession would lead to the loss of employer-sponsored health insurance. As a result of being unemployed in a nation that does not provide affordable or universal dental care, economically disadvantaged groups would have lower access to oral health. Despite having the intention to seek regular dental treatment, many individuals without dental insurance cannot exercise their full agency to engage in important oral health practices.

Principle of Time and Place: The principle of time and place argues that the life course is formed by the historical times and places that people occupy. For instance, Brazil implemented its 2004 universal oral health program, *Brasil Sorridente* (Smiling Brazil), to improve access to oral health services and promote better oral health-seeking behaviors. Ten years after this national program was enacted, the percentage of Brazilians who reported never having a dental appointment decreased across all age groups and income levels (Galvão & Roncalli, 2021). Similarly, the provision of universal dental coverage by Mexico's *Seguro Popular* program in 2003 positively impacted access to dental visits among Mexican older adults. Between 2001 and 2012, the prevalence of dental visits increased among Mexican adults aged 50 years and older; this change was partially explained by greater access to dental insurance and education over the decade and was more robust in more recent cohorts of adults (Archuleta & Beltrán-Sánchez, 2022). Before universal policy changes offered comprehensive dental coverage, a larger segment of the Brazilian and Mexican populations faced greater barriers to receiving dental care.

Principle of Timing: The developmental experiences that precede or follow specific life events, transitions, and behaviors depend on their timing within the life course. Important transitions such as becoming a parent may impact health differently for individuals who experience those transitions earlier in life compared to those who encounter them at a different life stage. For example, hormonal changes during pregnancy are associated with greater susceptibility to periodontal diseases among pregnant women (Figuero et al., 2013; Wu et al., 2015). In addition, the timing of schooling and educational attainment are important factors that relate to SES inequalities, as earlier access to education provides better advantages for accumulating wealth and health-related resources over the life course. In the case of oral health, reinforcement of positive or negative oral health behaviors during youth can have cumulative effects in adulthood, especially as permanent teeth first erupt around age seven (Stanford Children's Health, 2022). Early childhood SES, tooth brushing, and regular dental visits during childhood can influence future oral health-seeking behaviors and the severity of oral health problems in adulthood (Broadbent et al., 2016; Freddo et al., 2018).

Principle of Linked Life: The linked life principle argues that lives are interdependent; they are embedded within a larger network of social relationships and influence the surrounding social environment. This principle is best understood by how interpersonal relationships within a family or community can shape the oral health behaviors of children. In a longitudinal study that followed participants' oral health status from birth to adulthood (age 38), Broadbent et al. (2016) found that the oral health-related beliefs of New Zealander parents predicted their children's future oral hygiene practices, dental service use, and the number of untreated caries and missing teeth in adulthood. Among Hispanic mothers residing in low-income urban neighborhoods, the influence of parental beliefs on children's oral health status was similarly observed (Telleen et al., 2012). Mothers' beliefs on the value of early preventive dental care determined the initiation of dental care. Moreover, the continuation of dental care was positively associated with satisfactory communication with the dental provider, although regular dental visits were restricted by factors such as household income and dental provider availability.

Other related constructs: Age, period, cohort

Age is a social construct that differentiates timed phases of the life course. Although age is typically quantified by the length of time lived, it possesses a meaning beyond its numerical significance. Age is associated with various social meanings such as behavioral expectations, transitions into institutions like school and marriage, and general age categories such as infancy, childhood, and adolescence (Elder et al., 2003). Time could also be understood as a resource, which may be devoted to personal wellness, community engagement, and health-promoting activities. From this perspective, time is privileged and shaped by racial inequities across the life course. Racism accelerates biological aging, while also creating barriers that reduce the availability of free time in marginalized groups (Gee et al., 2019). Time scarcity, in turn, impacts stress, disease management, and healthy aging.

In general, aging is a process that is impacted by social and historical forces. When individuals of all ages are uniformly impacted by a shared historical event, a *period effect* occurs. If historical events have a distinct effect on successive birth cohorts a *cohort effect* takes place. Thus, a cohort effect would show generational differences in oral health outcomes by a particular event, policy, or exposure. For example, water fluoridation has been a major historical advancement in the field of oral health. Evidence has shown that the fluoridation of community water has led to a reduction in tooth decay across various populations worldwide (Crocombe et al., 2015; Rugg-Gunn & Do, 2012; Slade et al., 2018). The widespread availability and oral health benefits of fluoridated water among people of the same community, regardless of age group, illustrated a period effect. However, a cohort effect may be evident when comparing generational differences in dental caries between recent birth cohorts and the birth cohorts who lived before fluoridated water became universally accessible. For example, among participants from Australia born between 1960 and 1990, it was found that higher levels of lifetime fluoridation exposure were associated with fewer dental caries among rural adults born in more recent birth cohorts (Crocombe et al., 2015). Thus, older birth cohorts were differentially vulnerable to tooth decay compared to later generations who benefited from longer exposure to fluoridated water, which was also present at a younger developmental stage.

Critiques of the life course perspective

The life course perspective is a useful framework that explores how age, timing, and social circumstances are intertwined to shape health and development. First, the principle of agency considers how individual health-related actions are restricted by social circumstances and historical placement. One limitation of this assumption is that social structures are only broadly referenced as a major determinant of health. It fails to define the specific attributes of social structures, such as SES. Additionally, the life course framework does not recognize explicit mechanisms in which SES-related factors shape disproportionate outcomes in oral health. To transform the life course perspective into a more practical tool for addressing oral health disparities, it must be integrated with appropriate explanatory theories, such as Link and Phelan's (1995) Theory of Fundamental Causes or Cockerham's (2005) Health Lifestyle Theory. Applying these theories within the broader life course perspective can create a better understanding of the causal pathways that influence oral health status.

A second assumption of the life course framework argues that shared experiences of historical events will similarly impact the health and development of people from the same birth cohort (a cohort effect). Cohort membership is at times used as a proxy for exposure to major historical events, such as large-scale policies (Elder et al., 2003). However, individual experiences are unique; not all cohort members will have an equal response or sensitivity to the shared exposure. Changes in oral health outcomes may also be explained by other influential factors that coincided with the exposure. Thus, cohort studies must include large, nationally representative samples while also controlling for other factors that might explain the association between historical exposure and oral health.

A final assumption of life course theory is that it can be applied to a multitude of chronic health conditions. One problem is that the current life course literature has limited generalizability in the field of oral health. There is a lack of contemporary data across diverse populations and from older adults, as previous findings are based on samples from New Zealand, Brazil, and England (Echeverria et al., 2019; Heilmann et al., 2015; Poulton et al., 2015; Steptoe et al., 2013). In addition, the literature on oral health and the life course focuses primarily on how childhood SES influences oral health outcomes in adulthood (Heilmann et al., 2015). However, little is known about factors unique to older adulthood and how they impact the trajectory of oral health outcomes. As self-sufficiency becomes more difficult in older age prevalent comorbidities such as Parkinson's disease or mobility limitations, inhibit tooth-brushing and other forms of proper oral hygiene among older adults. Chronic illnesses such as diabetes are also most prevalent among older adult populations and are known to increase susceptibility to oral diseases (Huang et al., 2013; Simpson et al., 2015). This dissertation fills a gap by focusing on social and clinical factors relevant to older adult populations.

The changing technological landscape in this current era warrants updated research in this area of study. Changes in policy and technological advancements are experienced differentially by separate cohorts of older adults. In the past two decades, dental treatment and prevention technologies have improved along with the availability of pre-threaded floss, electronic toothbrushes, over-the-counter fluoride rinses, and education on smoking (U.S. Department of Health and Human Services, 2021). Even though the baby boomer generation has had the best oral health outcomes compared to previous cohorts of adults over age 65, people within the 65+ age group remain the most susceptible to developing poor oral health outcomes compared to other age groups (U.S. Department of Health and Human Services, 2021). As an increasing segment of the United States is entering older adulthood with greater projected longevity compared to previous generations, it is expected that there will also be an influx in the demand for preventive oral health care. A life course perspective is required to understand the etiology and trajectories of oral health status throughout various life stages.

Link and Phelan's (1995) Theory of Fundamental Causes

Link and Phelan's (1995) Theory of Fundamental Causes explains how imbalanced power structures can lead to social gradients in health. Socioeconomic status (SES) is an example of a fundamental cause of disease that perpetuates social inequities in oral health outcomes (Phelan, Link, & Tehranifar, 2010). The four main characteristics of a fundamental cause of disease include (1) the ability to influence multiple disease outcomes (2) the capacity to generate multiple risk factors for disease (3) the reproduction of health problems over time by the replacement of intervening mechanisms, and (4) access to resources that can accentuate or minimize adverse health conditions.

Flexible resources

SES determines access to key flexible resources, which include money, knowledge, prestige, power, and beneficial social connections. Inequalities within social, economic, and political systems dictate the unequal distribution of these resources, which produce SES gradients in health. Flexible resources can operate at individual and contextual levels. For instance, individual income and flexible working hours can provide better opportunities for health-conducive behaviors, such as planning dental visits, purchasing denture accessories, or affording restorative dental treatment. At the community level, funding for public dental clinics can increase the number of dental providers, services, and even medical transportation in an area. In general, it has been found that countries with higher spending on national social programs have populations with better oral health status while reducing income-related disparities in oral health (Guarnizo-Herreño et al., 2013; Sanders et al., 2009). Community water fluoridation, a major preventive resource, also has standardized availability, and its use does not depend on individual health behaviors. As a result, equitable and widespread distribution of flexible resources leads to protective effects on population oral health.

Intervening mechanisms

The replacement of intervening mechanisms is a phenomenon that describes how some medical and technological advancements can perpetuate oral health inequities. Once a mechanism no longer produces a health gradient (i.e., all people having access to fluoridated water), another mechanism emerges in its place upon the development of newer health-promoting technologies. Individuals with lower SES groups may benefit most from those innovations; however, higher-SES groups have better access to newer and more costly oral health technologies. Consequently, SES disparities in oral health are widened by the unequal distribution of oral health-related resources and knowledge. For example, oral health technologies over the past two decades have led to general improvements in dental treatment and reductions in permanent tooth loss (Dye et al., 2019). Within this same timeframe, SES disparities in tooth retention have also increased among older adults, since these improvements have largely occurred among more affluent groups. Overall, novel public health interventions or technologies that rely solely on individual health behaviors may generate SES disparities in oral health if these resources are not equitably distributed.

Critiques of Fundamental Cause Theory

Intervening mechanisms point to a key concept in Fundamental Cause Theory, which is that health and social inequities are perpetuated via unequal access to flexible resources among different SES groups. A potential challenge to that assumption is the idea of *countervailing* *mechanisms*. Countervailing mechanisms describe how high-SES groups might instead experience worse health consequences because they have greater access to flexible resources that motivate risky or unhealthful behaviors. High-SES groups might be likely to participate in costly activities such as binge drinking, smoking luxury cigars, or sensitizing teeth with excessive use of tooth-whitening products. However, in most cases, it is assumed that resources will mostly be deployed in a way that is beneficial to health.

Another limitation of Fundamental Cause Theory is that it neglects the importance of timing and its influence on oral health trajectories. Certain factors might supersede or strengthen the influence of SES on oral health, depending on the life stages at which they occur. For example, some findings have shown that having higher SES in adulthood might counteract the negative effects that low SES in childhood has on oral health outcomes (Heilmann et al., 2015; Thomson et al., 2004). Additionally, Fundamental Cause Theory does not explain the dynamic relationship between structural constraints and individual decision-making. Personal beliefs about good oral health practices can create protective effects on oral health outcomes despite experiencing SES-related barriers (Finlayson et al., 2019; Wilson et al., 2017). Among older adults, evidence has shown that higher SES in older adulthood is positively associated with better outcomes for various oral diseases (Dye et al., 2019; Griffin et al., 2019; Tsakos et al., 2011). Although oral health status is socially patterned, factors related to aging and individual behaviors are also needed to help explain causal associations between SES and oral diseases. Applying constructs from the life course perspective and Health Lifestyle Theory would help fill gaps in this framework.

Cockerham's (2005) Health Lifestyle Theory

Health Lifestyle Theory describes the dialectical relationship between personal agency and social structures (Cockerham, 2005). In summary, healthy lifestyles are impacted by both individual choices and external circumstances. Structural factors or *life chances,* such as education, income, and living conditions constrain or encourage specific *life choices*. The temporal aspect of this framework also explains that long-term actions (i.e., regular maintenance of good health behaviors) are reinforced by routine actions and habitus. As oral health diseases are mostly chronic and are regulated by consistent health practices such as tooth brushing, diet, and regular dental visits, Health Lifestyle Theory can help explore the connection between SES and individual behaviors that influence oral health status.

Life choices (structure) and life chances (agency)

Life chances are the *structural factors* that impact routine health behaviors and outcomes. SES is an example of a structural factor. In the context of Health Lifestyle Theory, higher SES determines better access to resources and knowledge, while also shaping norms and preferences that are beneficial for health (Cockerham, 2005; Link & Phelan, 2010). For example, higher SES groups may have greater options for dental services, access to clean water, and closer proximity to fresh produce markets compared to lower SES groups. Convenient access to such amenities can reinforce positive oral health options and subsequent health behaviors. Individual *agency* relates to the life choices that create healthy lifestyles. Agency is directly constrained by structural factors such as SES because having lower SES limits one's options for engaging in positive health behaviors. In addition to SES, agency is also regulated by socialization and experience. Experiences are the regular interactions within one's social environment through which people encounter unique or learned scenarios. Socialization, on the other hand, is the process of absorbing and responding to one's lived environment, including exposure to values, norms, and beliefs. For instance, the decision to make a dental appointment can be influenced by reflections on past experiences and by values adopted (or rejected) from one's social environment. Even though autonomy is part of making healthful decisions, the choices that people make are also impacted by overarching social, economic, and interpersonal forces.

Feedback loop

Health Lifestyle Theory describes how an intrapersonal feedback loop turns individual actions into healthy lifestyles. *Habitus,* or the disposition to act, is the result of the interplay between structure and agency. Habitus is formed by routine perceptions and evaluations of choices; results are not always consciously derived (Bourdieu, 1990). New experiences also continuously revise habitus, which in turn, modifies the structures and environment around it (Bourdieu & Wacquant, 1992). *Practices,* or actions, stem directly from habitus. Practices can be deliberate or automatic. Actions that are closely linked to habitus are routinized and result in minimal calculation or analysis of the action. In this sense, pattered actions are guided largely by automatic routines instead of continuous critical examination. The *reproduction of health lifestyles* is the final phase of the feedback loop. Healthy lifestyles are formed when recurring practices create a feedback loop back to habitus. Those reinforced health behaviors eventually automate in habitus and continue through this cycle, resulting in the maintenance of specific health-related actions.

Critiques of Health Lifestyle Theory

Health Lifestyle Theory explores the link between social structures, interpersonal factors, and individual agency. Unlike behavioral theories that offer little attention to the role of SES on health, Health Lifestyle Theory describes how the interplay between agency and external social conditions shapes health-related behaviors. Individual actions are influenced by social systems that encourage or impede the adoption of healthy behaviors, including social norms and beliefs. This aspect of Health Lifestyle Theory is useful for identifying mechanisms that promote positive oral health behaviors while also recognizing barriers caused by SES disparities. For example, engaging in healthful practices may not be feasible for individuals who do not have sufficient time, resources, or knowledge to invest in oral health care. At the interpersonal level, past stressful encounters with a dentist may discourage people from seeking any dental care. A limitation of this theory is that it only broadly describes the link between social structures, individual behaviors, and health outcomes. It does not explicitly define SES as a structural factor or explain how resources are disproportionately allocated to create and amplify SES gradients in oral health. A secondary explanatory theory, such as Fundamental Cause Theory, is required to overcome this gap.

The second assumption of Health Lifestyle Theory proposes how behaviors are structured by an intrapersonal feedback loop (via habitus, practices, and reproduction of healthy lifestyles). This feedback loop illustrates that routine, and generally, long-term adherence to health behaviors leads to sustainable behavioral changes as opposed to infrequent and sporadic actions. For instance, consistent dental hygiene practices, such as daily flossing, may lead to better prevention of gum disease than irregular adherence to those activities. However, Health Lifestyle Theory does not contextualize health-promoting routines by any specific timeframe or life stage. Risk factors for oral diseases may have greater prevalence at certain life stages, and consequently, decrease engagement in healthy lifestyles (i.e., less frequent tooth-brushing among older age groups due to mobility limitations). Principles from Fundamental Cause Theory and the life course perspective add important insights to this discourse. Integrating relevant constructs from each of these theoretical approaches offers important guidance for determining the generational differences in oral health needs and effective points of intervention.

Integrated conceptual model

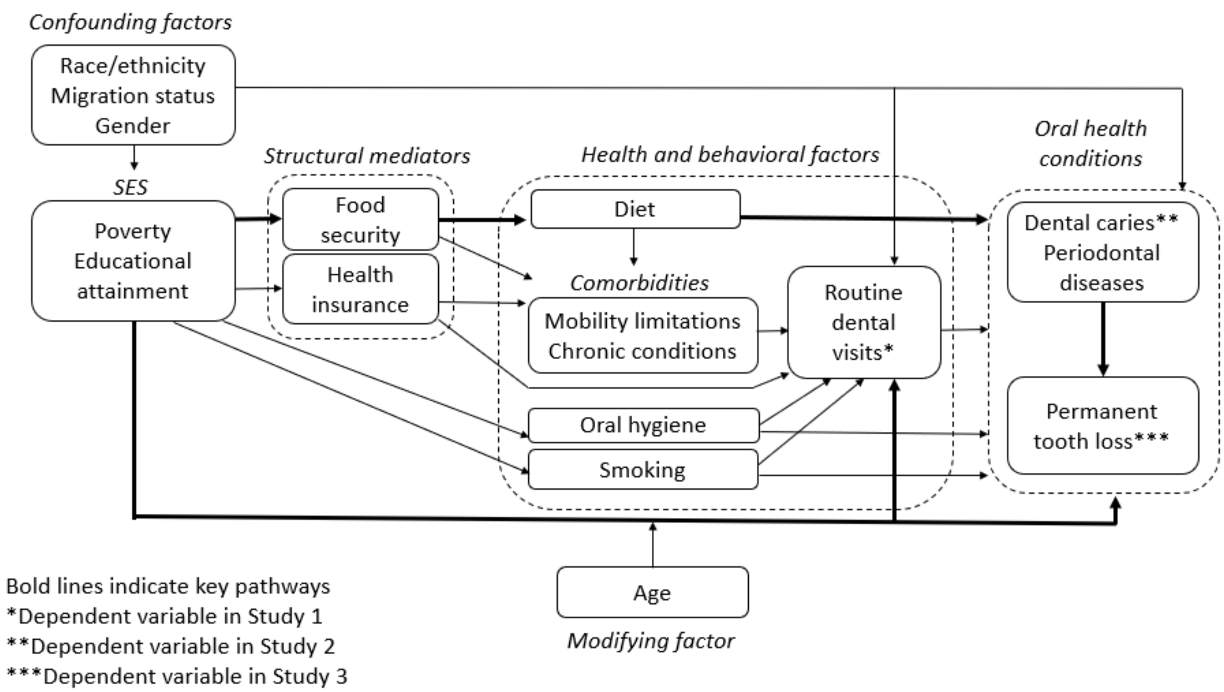
Figure 1A illustrates an integrated conceptual model that examines oral health outcomes among U.S. older adults. This model was informed by relevant constructs from the life course perspective, SES as a fundamental cause of disease, and Health Lifestyle Theory. Three key relationships are represented by pathways (designated by the boldened arrows) between SES and three separate oral health-related outcomes. These outcomes represent the progression of poor oral health: beginning with having regular dental visits, then advancing to dental caries or periodontal diseases, and then culminating to permanent tooth loss. The first variable domain under the box labeled “SES” shows key structural factors that have been known to cause disproportionate outcomes in oral health access and outcomes (Griffin et al., 2019; Tsakos et al., 2011). These factors include poverty and educational attainment, which are the key independent variables in the model. The second domain is a subset of structural mediating factors (health insurance and food security) that are directly influenced by the variables in the first domain. According to Fundamental Cause Theory, SES can limit access to flexible resources such as health insurance and nutritious food. Past research has also shown that these factors are essential determinants of oral health, but few findings are specific to older adults with food insecurities (McMaughan et al., 2020; Wiener et al., 2018). Food security is indicated by the bold print arrow as the first key mediator along the pathway to oral health conditions.

The third domain includes health and behavioral factors, which consist of diet, oral hygiene, smoking, and comorbidities. These factors are regulated by social structures from the previous domains, as suggested by Health Lifestyle Theory and Fundamental Cause Theory. Following the pathway of interest, food security directly influences diet, which in turn, impacts outcomes for comorbidities. Comorbidities of interest include those with high prevalence in older adulthood such as diabetes, heart disease, and mobility limitations, due to their associations with adverse oral health outcomes (Halter et al., 2014; Musich et al., 2018). Health insurance also has a direct impact on the treatment and prevention of chronic conditions, such as diabetes and hypertension (Casagrande & Cowie, 2018; Rivera-Hernandez et al., 2016).

The last variable in this domain is routine dental care, which is the first key outcome of interest in Study 1. The diagram shows that the frequency of dental visits among older adults is directly impacted by health insurance, smoking, oral hygiene practices, and factors related to SES (Blasi et al., 2018; Casagrande & Cowie, 2018; Lee et al., 2014). Comorbidities are also expected to dictate regular utilization of dental health services, as managing other comorbidities may consume time and financial resources, taking precedence over routine oral health care. The main association between SES and dental visits is confounded by gender, race/ethnicity, and migration status (nativity and length of stay in the U.S.), since differences in those characteristics have been found to independently impact both oral health utilization and SES (Assari & Bazargan, 2019; Dye et al., 2019; Huang & Park, 2015; Wilson et al., 2016). Age is also depicted as a modifying factor for this association, because SES disparities in dental care utilization tend to widen in older age groups (Dye et al, 2019; Harber-Aschan et al., 2020).

Last, oral health conditions represent variables in the ultimate domain of the conceptual model. The first category of oral health conditions includes dental caries and periodontal diseases. These factors are directly impacted by diet, routine dental visits, oral hygiene, and smoking (Hujoel & Lingström, 2017; Lutfiyya et al., 2019; U.S. Department of Health and Human Services, 2021). SES also has a direct effect on oral health conditions, with moderation by age and confounding by the same factors previously listed (gender, race/ethnicity, and migration status). Dental caries and periodontal diseases are intermediary outcomes that ultimately lead to permanent tooth loss, the most distal oral health condition in this model. Permanent tooth loss shares a nearly identical mechanism as the previous oral health conditions. The only difference is that dental caries and periodontal diseases are preliminary dental conditions leading to permanent tooth loss.

Figure 1A. Conceptual framework of the key relationships between SES, food insecurity, and three oral health-related outcomes among older U.S. adults



This integrative conceptual model adds to a limited body of knowledge on oral health and the life course; it offers useful perspectives on the relationship between SES and various indicators of oral health while considering the interactions of important social and physical barriers in older adulthood. The life course perspective justifies the selection of specific age-related factors, like mobility issues or diabetes. In addition, it brings attention to the changing trends in the oral health landscape. Within the past few decades, notable improvements in oral health have been observed in older U.S. adults (U.S. Department of Health and Human Services, 2021). These changes in oral health status alongside worsening SES disparities might be explained by how risk or protective factors among recent cohorts differ in type and severity from factors that were already explored in previous generations. For instance, poverty is a well-documented determinant of health; it creates many barriers to receiving oral health services and leads to worse dental conditions compared to non-poor older adults (Dye et al., 2019; Lee et al., 2014). However, due to periods of economic recession or restrictive oral health policies, some generations might experience worse poverty-related burdens and subsequent health outcomes than others.

In addition, the changing demographic of U.S. older adults reflects an increase in the proportion of older Latinos, with a projected growth of 19.9 million Latinos aged 65 and older in the next 40 years (an increase from 6% of the 2019 U.S. population to 21% in the year 2060) (ACL, 2021). Factors such as nativity status, language barriers, and racial discrimination among older U.S. Latinos are social determinants of health that might be stronger predictors of poor oral health than poverty status alone. This is an understudied area in oral health, even as older Latinos have both the highest life expectancy and the highest rates of disability and chronic health issues compared to the rest of the U.S. population (ACL, 2021). Examining the intersection between oral health, poverty, and migration status among Latinos would help refine the current understanding of oral health equity, that is, the provision of quality dental care and the availability of culturally sensitive public health policies and interventions.

Overall, testing the pathways in this current model may reveal new trajectories in the oral health literature ─ first, by shedding light on new influential drivers of health in recent cohorts of older adults, and second, by capturing how familiar and pervasive determinants of oral health have changed in severity over time. With this approach, we are better equipped to examine less-explored mechanisms such as the impact of food security on the oral health of older adults or differences in oral health by U.S.-born and foreign-born Latino subgroups. In conclusion, the proposed conceptual model offers a useful framework for identifying key points of intervention and drivers of SES disparities among older U.S. adults. Using the theoretical and conceptual framework shown in Figure 1A, the aims of this dissertation are:

Aim 1: To explore patterns of routine dental visits among older U.S. adults and whether the association between SES and dental visits is explained by differences in nativity status among older U.S. Latinos or by diabetes diagnosis.

Aim 2: To examine the association between SES and untreated dental caries among dentate older U.S. adults and the potential mediating role of food insecurity.

Aim 3: To examine the association between SES and permanent tooth loss among older U.S. adults and the extent to which food insecurity and routine dental visits partially explain this association.

Study 1: The impact of socioeconomic status on routine dental visits in older adulthood

Abstract

The proportion of older U.S. adults receiving routine dental care has declined in the past two decades. High socioeconomic status (SES) has been known to improve access to dental care, but little is known about how social placement, age-related factors, and individual behaviors intertwine to shape dental care use among older U.S. adults. The purpose of Study 1 was to examine differences in the relationship between SES and routine dental visits across different subpopulations of older adults. Education and income were the main independent variables and having a dental visit in the past 12 months was the dependent variable. Insurance and occupational status were control factors due to their impact on dental care access.

The study sample included adults ages 50 years and older from the 2013-14, 2015-16, and 2017-18 NHANES cycles, a bi-annual survey of health, social, and demographic characteristics from a representative sample of 5,000 non-institutionalized members of the U.S. population. The final sample size was 8,674 adults. Multiple logistic regression and imputations of missing data were used to examine SES disparities in dental visits by age category (50-59 years, 60-69 years, 70-79 years, and 80+ years). Results showed that higher SES was associated with receiving past-year dental care in all age groups but had gradually stronger effect sizes at older age. Adults who were non-Hispanic Black, some older groups of non-Hispanic Asian and U.S.-born Hispanic adults, and adults ages 80+ years with diabetes were least likely to receive dental care. Results for individual health behaviors (daily flossing and non-smokers) were also significantly associated with receiving past-year dental care net of other factors. Monitoring oral health becomes increasingly important with older age. Thus, addressing persistent and modifiable gaps in dental care access is essential for the prevention of oral diseases.

Introduction

Regular dental care visits are an integral component of maintaining good oral health. For the past 20 years, visits to the dentist have declined among U.S. adults aged 65 and older (Kramarow, 2019; Wall et al., 2012). Between 1997 and 2010, the proportion of past-year dental visits among adults aged 65 and older decreased from 73.1% to 69.6% and stagnated near 66% throughout the 2010s (Kailembo et al., 2018; Kramarow, 2019; Wall et al., 2012). These figures show that for a decade, about 35% of older adults did not receive any dental care within the past year. Age disparities in oral health access are persistent within this population. Rates of dental care utilization were lowest among adults aged 85 years and older (57.9%) followed by adults aged 75-84 years (64.1%) and adults aged 65-74 years (67.7%) (Kramarow, 2019). As the severity of oral health problems becomes more common with older age, access to preventive and restorative oral health care for older adult populations requires greater attention.

Having a low socioeconomic status (SES) can create additional barriers to dental care access in older adulthood. Older U.S. adults with the worst access to oral health services include those with low income, less educational attainment, no medical or dental insurance, and those residing near or below the poverty line (Kailembo et al., 2018; Kramarow, 2019; Lee et al., 2014; Vujicic et al., 2016). Despite the importance of regular dental visits and the increasing need for dental care in older adulthood, Medicare insurance only covers the cost of emergency room dental visits for beneficiaries aged 65 years and older (U.S. Centers for Medicare and Medicaid Services, n.d.). This barrier exacerbates the economic strain of dental care since the affordability of dental services is the most common reason for not receiving dental treatment of any type, particularly among older adults with a lower income (Bhoopathi et al., 2021; Vujicic et al., 2016). Although current evidence points to a strong causal effect between social placement and access to oral health care, the relationship between SES and oral health access is poorly understood within the context of older U.S. adults and in relation to other social and behavioral drivers of oral health.

Social determinants of health such as racial discrimination and migration status have been known to increase barriers to oral health care utilization in older adult populations (Bhoopathi et al., 2021; Kramarow, 2019; Wilson et al., 2016). Few studies have examined how these other factors dictate the relationship between SES and oral health utilization, especially in older Latino subgroups that differ by nativity status. Additionally, older adults with physical impairments or chronic diseases such as diabetes might not have sufficient time, funds, or energy to invest in oral health, which compounds the cumulative damage of untreated oral health problems. Alternatively, protective behaviors such as daily oral hygiene practices could correspond with better oral health-seeking behaviors. However, it is unclear whether SES influences the strength of those protective effects on routine access to those services.

The purpose of Study 1 was to examine how SES and individual behaviors influence access to dental care among older U.S. adults. SES (represented as income level and educational attainment) was the main predictor of oral health utilization. Occupation and insurance status were also examined to identify how they might mediate the role of access in these relationships. Controlling for differences by race/ethnicity and nativity of U.S. Hispanic older adults also determined whether subpopulations of racial/ethnic minorities were more vulnerable to experiencing gaps in dental care particularly if they were born outside of the U.S. In addition, key health behaviors such as daily flossing were included as protective factors, while diabetes and smoking status were included as potential mediating risk factors. In the following literature review, we will discuss these key relationships and then illustrate a conceptual model that represents the major pathways, research questions, and related hypotheses for this chapter. Next, the methods and results section will outline the analytic approaches and findings for Study 1. Last, the discussion section will review these findings and offer recommendations for future oral health research and oral health policy reform for older U.S. adults.

Literature review

Why are regular dental visits important?

The American Dental Association recommends having a routine preventive dental visit every six months, or at minimum, once per year, to ensure the regular examination, cleaning, and maintenance of healthy teeth (American Dental Association, 2013). Routine dental visits are an important component of basic oral hygiene. At preventive dental screenings, providers can detect early signs of tooth decay or oral infections that can later develop into more severe, painful, and permanent health problems. Dental visits also allow dental practitioners to reinforce teeth-cleaning techniques, remove plaque build-up on tooth surfaces, provide oral health education, and distribute referrals for specialty and follow-up treatment. Past longitudinal research has found that long-term and routine oral health visits can mitigate the onset and progression of oral health illnesses (Listl et al., 2014; Thomson et al., 2010). A study across 13 different countries by Listl et al. (2014) found a positive association between regular dental attendance since childhood and better chewing ability at age 50. Longitudinal data from the New Zealand Dunedin Study similarly found that regular dental check-ups were associated with better oral health status from childhood to adulthood (Thomson et al., 2010). Furthermore, receiving an annual dental visit (as opposed to one-time emergency visits) strengthened this effect. Although recent studies in the U.S. older adult population are limited, the consistency of these findings across various geographic regions and age groups likely point to a causal relationship between routine dental visits and better oral health status through older adulthood.

SES and oral health access

Socioeconomic hardship in older adulthood creates challenges for equitable access to dental care. In 2017, the official poverty rate of adults 65 and older was 9.2%, which represents 4.7 million older adults who had a net worth lower than the U.S. Census Bureau's threshold for poverty (the threshold was $11,756 that same year for adults aged 65 and older) (Cubanski et al., 2018). About 14% of older adults who lived below the U.S. federal poverty level (FPL) reported having an unmet dental care need due to cost compared to 8% of the general U.S. population over age 65 (Kramarow, 2019). Income disparities in dental care are also found in graded patterns. For example, fewer than 5% of older adults within the highest income bracket (above 400% of the FPL) did not visit a dentist because of the cost of dental care compared to 7% of older adults who made between 200% to 399% of the FPL and 15% of older adults who made less than 200% of the FPL (Vujicic et al., 2016).

Similar patterns are found within different levels of educational attainment, which is another commonly used indicator of SES. Previous research has found that higher levels of education are associated with a higher likelihood of receiving regular dental visits (Andrade et al., 2020; Chamut et al., 2021; Wilson et al., 2017). A study of adults aged 50 and older across 23 upper-middle- and high-income countries, which included Brazil, China, South Korea, Mexico, United States, encountered educational disparities in oral health utilization in all 23 nations (Andrade et al., 2020). In the U.S., older adults who did not complete high school were two to five times more likely to lack regular dental care compared to older adults with a high school degree or higher level of education (Chamut et al., 2021). This effect might be explained by the influence that education has on acquiring oral health-related resources, knowledge, and beneficial social connections. Some evidence also suggests that educational attainment, including that of childhood caregivers, also shapes the beliefs, habits, and knowledge of health care systems that positively impact oral health behaviors into adulthood (Wilson et al., 2017). Even though education and income help offset the burden of financing oral health care and navigating complex health systems, the extent of the effect of SES on oral health care access is unclear within the context of other social and political forces.

Dental coverage for older U.S. adults

Lack of dental insurance is a substantial barrier to receiving affordable and necessary oral health services, especially for older adults with low SES. Older adults who are retired no longer receive dental coverage through an employer, while those with low wages or who are actively searching for work cannot afford to retire, let alone, pay for dental care. Medicare, the government-sponsored healthcare program for adults aged 65 years and older, covers the cost of emergency dental visits, but it currently does not offer benefits for basic and preventive dental services (U.S. Centers for Medicare and Medicaid Services, n.d.). In 2017, approximately 70% of older adults in the U.S. lacked access to basic dental insurance (Kramarow, 2019). Even among Medicare beneficiaries, about 47%, or 24 million individuals, lacked any basic dental coverage in 2019 (Freed et al., 2021). Medicare recipients with private insurance (16%), state Medicaid (8%), or other paid supplementary plans such as Medicare Advantage (26%) were able to access some form of basic or premium dental coverage. Still, about one in five Medicare beneficiaries who received a past-year dental service had over $1,000 in out-of-pocket expenditures. In 2015, the mean out-of-pocket spending on dental care was $586 among retired adults aged 65 years and older, while working adults aged 21 to 64 years and children or adolescents younger than 21 years of age paid $264 and $200 respectively in out-of-pocket dental expenditures (Manski & Rohde, 2017). Furthermore, about 7.2% of older adults compared to 4.3% of children reported that they missed dental appointments because of cost (Vujicic et al., 2016). Lacking dental insurance is a significant challenge to receiving dental care, particularly among older adults.

In the United States, programs such as Medicaid cater to low-income populations by offering basic dental services at minimal to no cost. However, since the 2010 Affordable Care Act (ACA), dental services have been offered as an essential health benefit for children but not for adults (Vujicic & Fosse, 2022). Federal laws do not mandate dental coverage for older adults with Medicaid; instead, each state determines the scope of dental benefits for Medicaid-eligible adults (Center for Health Care Strategies [CHCS], 2019). In 2019, only 18 states plus Washington D.C. offered extensive dental coverage for adult Medicaid recipients; 15 states offered limited dental services, 12 states provided emergency-only dental services, and three states offered no dental benefits through Medicaid (CHCS, 2019). As of 2021, these figures shifted slightly: three more states (21 total) provided comprehensive dental benefits, while one more state (16 total) provided limited benefits (Vujicic et al., 2021). The remaining nine states offered only emergency dental benefits and three states continue to provide no dental coverage for adults under Medicaid.

Optional Medicaid programs leave older adults vulnerable to the unexpected costs of dental care. In times of recession, many states respond to budget constraints by removing dental services from Medicaid coverage (Medicaid and CHIP Payment and Access Commission, 2015). The uncertainty and volatility of these decisions have a detrimental impact on dental care access and oral health outcomes. In 2003, the elimination of Medicaid dental benefits from Oregon's state Medicaid program, Oregon Health Plan, led to an increase in unmet dental care needs, a reduction in preventive dental care visits, and an increase in oral health-related emergency department visits among Medicaid recipients (Wallace et al., 2011). Consequently, low-income older adults without full dental coverage are expected to pay high out-of-pocket fees or wait until dental issues escalate to receive dental care.

Social and economic costs of limited oral health access

These financial barriers to oral health care have lasting social and physical consequences. Older adults with low SES are less likely to receive dental care, including basic preventive services, compared to those with dental insurance and higher SES (Lutfiyaa et al., 2019; Manski et al., 2016; Vujicic et al., 2016). These same groups that are less likely to access dental care are concurrently more likely to experience dental pain, report a poor condition of mouth and teeth, and have lower life satisfaction due to problems with their mouth and teeth (American Dental Health Association, 2015). Furthermore, poor oral health among adults with low SES leads to economic consequences. About one-third of low-income adults in the U.S. reported that the condition of their mouth and teeth affected their ability to interview for a job (American Dental Health Association, 2015). This statistic increased to 60% among adults without any public dental care insurance from Medicare or Medicaid (Vujicic et al., 2021). In summary, the absence of universal dental care programs for older adults fails to address SES disparities in oral health care access and dental outcomes.

Race/ethnicity and migration status

SES disparities in oral health care access are compounded by racial and ethnic differences in access to dental care. Compared to non-Hispanic White U.S. older adults, non-Hispanic Black and Hispanic older adults are more likely to face cost barriers to dental services

(Vujicic et al., 2021). In addition, non-Hispanic White older adults had the highest prevalence of past-year dental visits (69.1%) compared with Hispanic and non-Hispanic Black older adults (54.7% and 52.6% respectively) (Kramarow, 2019). Gaps in dental care by race/ethnicity have similar patterns as racial/ethnic differences in income. In 2018, 18.9% of non-Hispanic Black older adults and 19.5% of Hispanic older adults had incomes below the U.S. poverty threshold compared to 7.3% of non-Hispanic White older adults (Administration on Aging, Administration for Community Living, & U.S. Department of Health and Human Services, 2020). Dental insurance status also varied by race/ethnicity. Older Hispanic adults had lower rates of dental insurance (17.5%) than non-Hispanic White older adults (30.6%) and non-Hispanic Black older adults (28.6%) (Kramarow, 2019).

Racial discrimination and mistrust of health care systems were found to play a role in low oral health utilization among non-Hispanic Black and Hispanic patients (Singhal & Jackson, 2022). Non-Hispanic Black and Hispanic older adults were more likely than other racial/ethnic groups to have irregular dental visits and poorer dental health outcomes (Kelley et al., 2018). Additionally, dental provider shortages are major concerns in low-resourced neighborhoods, many of which have higher proportions of Black and Hispanic residents (Liu et al., 2022; Pourat et al., 2021). The low representation of minorities in the oral health care workforce is another barrier to oral health care, particularly if English fluency is a barrier to receiving quality oral health care. A study in California found that while most low-income adults were Latino (53%), only 6% of practicing dentists identified as Latino (Pourat et al., 2021). As a result of these challenges, Latino older adults were more likely to have an unmet dental care need compared to other racial/ethnic groups (Bhoopathi et al., 2021; Kramarow, 2018).

Barriers related to migration status might explain some gaps in oral health access. For example, eligibility criteria for medical and dental insurance programs often exclude recent immigrants (non-continuous residence within the past five years) or undocumented immigrants, while Medicaid programs in some states only offer restricted dental benefits (State of California, 2022). Medicare is not available to immigrants who do not meet specific residency requirements, while only recently (as of May 1, 2022), California became the first state to expand Medicaid eligibility to adults aged 50 years or older, regardless of immigration status (State of California, 2022; Kaiser Family Foundation, 2022). In addition, language barriers and anti-immigrant discourse and legislation may instill fears and mistrust against health care institutions and government-sponsored services. A study by Kelley et al. (2018) found that foreign-born Mexican American older adults were less likely to have regular dental visits compared to their U.S.-born counterparts. Other findings by Wilson et al. (2016) revealed that foreign-born U.S. residents, including both noncitizen and naturalized citizens, had lower rates of dental service use (39.5% and 23.1% respectively) compared with U.S.-born citizens (43.6%).

Length of stay in the U.S. might also play a role in shaping oral health access in the United States. Cultural assimilation and familiarity with the U.S. health and dental care systems might create segmented advantages in dental visits across immigrant populations. For example, U.S.-born Hispanic adults and foreign-born adults who have lived in the U.S. for most of their lives might have better access to and knowledge of navigating dental care services within the U.S. compared to foreign-born Hispanic adults who recently immigrated to the U.S. Alternatively, some recent migrants, and even U.S. citizens, might receive more affordable dental care from countries, such as Mexico, if they have consistent access to dental providers across the border (Robbins, 2014). Despite the U.S.'s proximity to several dental tourism destinations in Mexico, very few studies have examined this topic, including the possible health and structural implications of dental tourism (Adams et al., 2018). Overall, many older adults residing in the U.S. with low SES face multiple barriers to receiving dental care. This type of financial strain is further complicated by discriminatory practices, policies, and other systemic barriers related to race/ethnicity and migration status.

Medicaid expansions since the 2012 Affordable Care Act have helped decrease racial and ethnic disparities in dental care coverage and service utilization in the past decade. Wehby et al. (2022) examined these changes using Medical Expenditure Panel Survey data from 2011 to 2018. After comparing those two periods, the study found that the provision of extensive dental benefits by some state Medicaid programs improved access to both preventive oral health services and specialized dental treatment. The likelihood of having a past-year dental visit increased by eight percentage points among non-Hispanic Black and Hispanic adults. Overall, racial/ethnic disparities in oral health utilization decreased by 75% for non-Hispanic Black adults and 50% for Hispanic adults.

The decline in these racial/ethnic disparities was driven because of two reasons: First, dental service utilization increased among non-Hispanic Black and Hispanic adults. Second, dental visits changed very little among non-Hispanic White adults. Moreover, in states without extensive dental benefits, no reduction in racial disparities was found (Wehby et al., 2022). Despite the overall positive impact of universal oral health care, dental care access remains lowest among non-Hispanic Black and Hispanic adults and populations with lower incomes. In addition, non-Hispanic White populations experienced relatively little changes in oral care utilization even after Medicaid expansions, which suggests that other factors, such as oral health literacy, beliefs, and potential issues with navigating Medicaid enrollment or health care systems, might still be barriers to receiving routine dental care. These findings provide helpful insights into patterns of racial inequities in oral health care. However, these data only apply to the general U.S. adult population. Thus, future research on racial and ethnic disparities in oral health care must focus on older adults to address a critical gap in the current literature.

Prioritizing dental care with comorbidities in older age

Having one or more chronic conditions could create significant barriers to oral health care, especially in older age groups who have the highest prevalence of multiple morbidities (Boersma et al., 2020). In 2015, about 80% of older adults with Medicare were treated for one chronic condition, while 68% received treatment for two or more chronic conditions (National Council on Aging, 2021b). Diabetes was among the top five most common chronic conditions, with over one-quarter of older adults receiving diabetes treatment that same year (National Council on Aging, 2021b). Chronic morbidities could impact access to oral health care for several reasons. First, time and expenses for multiple health concerns leave older adults with fewer resources to invest in oral health visits, especially if they lack extensive dental coverage. In these situations, older adults may prioritize other health concerns over routine oral health visits until their dental problems escalate to requiring emergency care. Second, older adults who have mobility limitations and few transportation options cannot access oral health services without appropriate social or physical support. Studies have found that older adults who lived alone were more likely to miss dental appointments than those who lived with relatives or those who received home dental visits (Lexomboon et al., 2021). Finally, the rising prevalence of cognitive illnesses, such as dementia and Alzheimer's disease, in the older adult population also creates issues for at-home dental hygiene and receiving timely dental care. A longitudinal study of older adults in Sweden found that having a diagnosis of dementia was associated with discontinued dental care appointments (Lexomboon et al., 2021).

The need for dental care among older adults with diabetes

Few studies have explored the relationship between oral health access and chronic conditions in the U.S. older adult population. In particular, diabetes is a major concern among U.S. adults, which has increased in prevalence with age and impacts over one-quarter of the population over age 65 (about 14.3 million adults) (CDC, 2020). Diabetes has a critical role in predicting both access and outcomes in oral health care. A study by Patel et al. (2021) found that adults ages 50 years and older had fewer past-year dental visits if they had a diagnosis of diabetes, heart disease or stroke, and chronic obstructive pulmonary disease (COPD), even after adjusting for income, education, and insurance. These results are concerning, as these same individuals, particularly those with diabetes, are also known to have a higher risk of developing gum disease compared to individuals without these conditions (Patel et al., 2021).

There are several possible explanations for these oral health disparities among patients with diabetes. First, older adults with diabetes are likely to take prescription and over-the-counter medications that reduce salivary flow, which increases the risk of dental caries (National Institute of Health, 2022). Second, dry mouth is a common symptom among adults with diabetes who have high blood sugar (National Institute of Health, 2022). Without knowledge of those side effects, the oral cavity might inadvertently become vulnerable to dental diseases via diabetes symptoms and the management of those symptoms. Alternatively, regular oral health visits could support the general health of older adults with diabetes, especially Hispanic adults who experience the highest incidence of diabetes compared to other racial/ethnic groups in the U.S. (CDC, 2020). Some evidence suggests that treatment for periodontitis improved glycemic control for people with a type 2 diabetes diagnosis (Simpson et al., 2015). Nevertheless, compared to the general U.S. adult population without diabetes, the rate of annual dental visits is lower and has declined more quickly among adults with diabetes and pre-diabetes (Luo et al., 2018). Despite the cumulative health risks of diabetes on oral health, little is known about how the added burden of diabetes in older patients might create barriers to accessing oral health services.

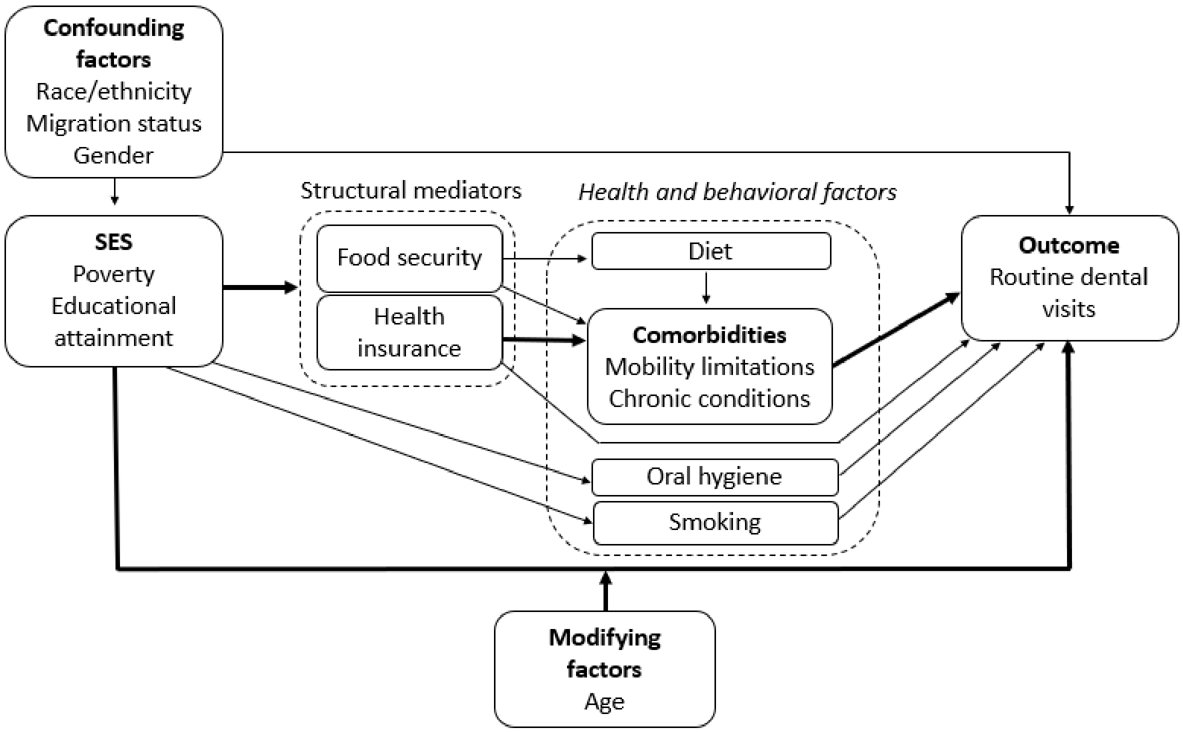
Other risk/protective factors of oral health access

Certain risk factors for oral diseases and health-related behaviors correlate with a lower likelihood of receiving dental services. Older adults who are current smokers or have a history of smoking are less likely to receive dental visits than those who do not smoke (Wu et al., 2007). Alternatively, protective factors such as maintaining proper oral hygiene like brushing and flossing are associated with better oral health practices including receiving regular dental care, having better oral health education, and maintaining positive beliefs about the importance of visiting a dentist; however, available data are only representative of maternal-child populations (Boggess et al., 2010; Wilson et al., 2017). Whether preventive habits reduce the negative impact of low SES on oral health visits is poorly understood in older adults. Still, the positive impact of good oral behaviors on oral health utilization is promising. Understanding key behavioral and health-related factors may provide additional insight into how they may amplify or reduce the effect of SES on dental care access in older adults.

Conceptual Model

Figure 1.1 illustrates a conceptual model of the mechanisms for the proposed research questions in Study 1. The boldened arrow shows a direct relationship between SES variables (educational attainment and poverty status) and the dependent variable, routine dental visits. This primary relationship is modified by age and shows possible confounding by race/ethnicity, migration status, and gender. The mediating variables are divided into two domains: (1) structural mediators and (2) health and behavioral factors. The structural mediators directly stem from the SES domain. These variables include food security and health insurance, with insurance depicted in bold as part of the main mediating pathway analyzed in Study 1 (food security will be the main predictor in Study 2). These structural mediators directly influence the next set of mediators, which include health and behavioral factors such as diet, mobility limitations, chronic conditions (focusing on diabetes as the main pathway, particularly for Hispanics), oral hygiene, and smoking. These factors have a direct association with routine dental visits.

Figure 1.1. Conceptual model of Study 1 that depicts the association between SES and receiving dental care among older U.S. adults.



Research questions

The following research questions and hypotheses for Study 1 are:

1.1. Do the observed SES disparities in routine dental visits increase with older age (across the following age groups: 50-59 years, 60-69 years, 70-79 years, and 80+ years)?

1.2. Does nativity among older Hispanic adults explain differences in dental visits by SES?

1.3. Is the association between SES and dental visits attenuated by diabetes, particularly in older age groups (80+ years) who are likely to experience higher rates of diabetes?

Hypotheses

1.1. Lower SES is associated with fewer routine dental visits, such that the magnitude of the SES-dental visits association will increase in older age groups.

1.2. Older Hispanic adults born outside the U.S. are predicted to have fewer dental visits compared to older U.S.-born Hispanic adults, independent of SES.

1.3. Diabetes has an inverse association with receiving past-year dental care (diabetes partially mediates the SES-dental visits association).

Methods

Data collection and measures

Data were obtained from the 2013-14, 2015-16, and 2017-18 NHANES, a cross-sectional study administered by the National Center of Health Statistics. NHANES collects demographic, health, and nutritional information from a nationally representative sample of approximately 5,000 people in the United States every two years. Self-reported data were obtained by trained interviewers at participants' homes while medical personnel conducted physical and dental examinations at NHANES mobile examination clinics (MEC). All variables used in the final analysis for Study 1 were collected from the public access NHANES demographic and health-related questionnaire data. The study sample consisted of adults ages 50 years and older pooled across the three NHANES waves (n= 8,674). This study for this dissertation was approved by the UCLA Institutional Review Boards (IRBs).

Having a past-year dental visit was the primary dependent variable for this analysis. It was collected as a self-reported ordinal variable from the questionnaire item, "About how long has it been since you last visited a dentist? Include all types of dentists, such as orthodontists, oral surgeons, and all other dental specialists, as well as dental hygienists." Response options were 6 months or less, more than 6 months but no more than 1 year, more than 1 year but no more than 2 years, more than 2 years but no more than 3 years, more than 3 years but no more than 5 years, more than 5 years ago, and never have been to the dentist. These categories were consolidated into a binary variable in the final logistic regression analysis to reflect whether participants have visited a dentist in the past year ("yes" or "no/never been"). The construction of this variable followed a similar operationalization as detailed in previous studies and was based on the Healthy People 2020 and Healthy People 2030 initiatives for adults to receive at least one oral examination per year (Adunola et al., 2019; U.S. Department of Health and Human Services, n.d.). A 3-category measure of this variable was originally considered for the final analysis (“within the past 12 months," "between 1-5 years," and "more than 5 years, or never visited a dentist”) (Bidinotto et al., 2021). After assessing model fit with ordinal logistic regression results, a Brant test indicated that this model violated the proportional odds assumption (see Appendix 1.1). Although the 3-category dental visits variable was not used in the final regression model, Table 1.1 provides the percentages of each response from the original variable for dental visits frequency. The number of missing observations among adults ages 50 years and older for this variable was 25 (0.3% of the study sample).

SES was the main independent variable that was represented by educational attainment and income level. Educational attainment was collected from the self-reported demographic questionnaire as an ordinal variable. The questionnaire item asked, “What is the highest grade or level of school you have completed or the highest degree you have received?” Responses were grouped into the following categories of educational attainment: Less than 9th grade, 9th-11th grade, high school/GED, some college or associate degree, and college degree and higher. Responses for “refused” or “don’t know” were coded as missing (n=18). The final operationalization of education used three categories (high school or less, some college, and college graduate) based on Fryar et al.’s (2020) study of an older adult population that used NHANES data.

Income level was collected from the demographic questionnaire as an ordinal variable reported from the following dollar ranges of family income: $0 to $4,999, $5,000 to $9,999, $10,000 to $14,999, $15,000 to $19,999, $20,000 to $24,999, $25,000, to $34,999, $35,000 to $44, 999, $45,000 to $54,999, $55,000 to $64,999, $65,000 to $74,999, $20,000 and over, under

$20,000, $75,000 to $99,999, and $100,000 and over. NHANES top-coded values at $100,000 or greater and provided broader ranges of income categories to maintain the privacy of respondents in smaller categories and to account for uncertain responses (CDC & NCHS, 2017). This variable was recoded into the following 4-categories based on Zhang et al.'s (2021) definition of the variable: less than $20,000, $20,000 to $74,999, $75,000 to $99,999, and $100,000 or more. This selection was also informed by sensitivity analyses (see Appendix 1.2) that compared this operationalization of income with a 3-category income variable (less than $20,000, $20,000 to $74,999, and $75,000+) and a variable for the poverty income ratio (PIR) (Dye et al., 2019). PIR had a greater number of missing observations than family income with over 100 more missing respondents. The income variable had 915 missing values, which constituted 10.6% of the sample population.

Additional covariates that were collected from the NHANES demographic database included gender, age, race/ethnicity, and migration status. Variables from the health questionnaire database included smoking, flossing, diabetes, health insurance, and occupation. All covariates were self-reported via in-person interviews at the participants' homes. Gender was operationalized as a dichotomous categorical variable (male or female) with no missing responses. Age in years was collected as a continuous variable, and individuals over age 80 were top-coded at 80 years. For our analysis, age was converted into four categories of age groups (50 to 59 years, 60 to 69 years, 70 to 79 years, and 80+ years) based on prior studies that compared oral health outcomes from middle adulthood to the beginning of older adulthood and more advanced stages of older adulthood; these age ranges showed a gradual decline of oral health for adults in older age (Dye et al., 2019, Griffin et al., 2012). The age variable had no missing values.

Race/ethnicity was a categorical variable that was collected as a six-item variable. Categories were “Mexican American,” “other Hispanic,” “non-Hispanic White,” “non-Hispanic Black,” “non-Hispanic Asian,” and “other race, including multiracial.” The “Mexican American” (n=1,149) and “other Hispanic” (n=934) categories were consolidated into a single group (Dye et al., 2018). Next, the Hispanic category was subdivided into either a “U.S.-born” or “foreign-born” category (Sanders, 2010). This was done to examine differences in nativity status within the Hispanic racial/ethnic group. Foreign-born Hispanics also comprised the largest proportion (52% or n=1,383) of the total foreign-born population (n=2,655). Information on nativity status was collected with the following questionnaire item: “In what country were you born?” Response options included “Born in 50 US states or Washington, DC,” “others,” “refused,” and “don’t know.” Answers with “refused” and “don’t know” were combined with missing responses, and the resulting measure was a dichotomous variable (born in the U.S. vs. born outside of the U.S.). The number of missing responses for this item was four. When combined with the Hispanic category, the final operationalization for the race/ethnicity variable included six categories: “U.S.-born Hispanic,” “foreign-born Hispanic,” “non-Hispanic White,” “non-Hispanic Black,” “non-Hispanic Asian,” and “other race, including multiracial.”

An alternate measure for migration status was considered that separated foreign-born respondents by their length of stay in the U.S. The survey question asked, “What is the length of time the participant has been in the U.S?” with response options of less than 1 year, 1 to 4 years, 5 to 9 years, 10 to 14 years, 15 to 19 years, 20 to 29 years, 30 to 39 years, 40 to 49 years, and 50+ years. Respondents were then placed into one of the three following groups: U.S.-born, non-U.S.-born with <15 years length of stay in the U.S., and non-U.S.-born with ≥15 years length of stay in the U.S. (Fryar et al., 2019). The number of missing responses for this variable was 94.

This variable was not used in the final analyses because of the small cell size of foreign-born participants who lived fewer than 15 years in the U.S. (they represented about 3% of the total sample vs. 27% of foreign-born participants who lived more than 15 years in the U.S. and 69% of participants who were born in the U.S.).

Information on smoking status was derived from two questionnaire items on smoking behaviors. Respondents provided yes or no answers to the following questions: “Have you smoked at least 100 cigarettes in your entire life” and “Do you now smoke cigarettes?” These responses were used to create a 3-category variable for smoking status, which included “never smoker,” “former smoker,” and “current smoker” as smoking categories (Bidinotto et al., 2021; Fryar et al., 2019). There were 10 missing responses for smoking status within the sample of respondents aged 50 and older. Self-reported diabetes diagnosis was collected with the following question: “Other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?” Possible response options were “yes,” “no,” and “borderline.” Diabetes was dichotomized as a “yes” or “no” variable by omitting respondents who reported “don’t know” (n=7) or “borderline” (n=355) (Zhang et al., 2021). A total of n=362, or 4% of the original sample, had missing responses for the diabetes variable.

Daily flossing was self-reported as a range of 0-7 days based on the following question: “Aside from brushing your teeth with a toothbrush, in the last seven days, how many days did you use dental floss or any other device to clean between your teeth?” Responses for this variable were grouped into three categories based on a prior study on preventive oral health care among older adults (Zhang et al., 2021). The categories were “7 days (every day),” “1 to 6 days per week,” and “0 days (never).” This grouping was also selected to equalize the distribution of responses. There were 13 missing responses for this variable.

Insurance was collected with the following "yes" or "no" questionnaire items: (1) "Are you covered by health insurance or some other kind of health care plan?" and (2) "Are you covered by private insurance?" A series of additional "yes" or "no" questions also asked whether participants were covered by other types of insurance such as Medicare, Medi-gap, Medicaid, other state-sponsored health plans, other government insurance, military health care, and a single service plan. Responses to each category were not mutually exclusive. I originally explored a having cutoff for Medicaid-only patients. However, most people had a mix of several types of insurance (public and private). The sample size for Medicaid-only patients in the entire 50+ sample was also very small (n=141). Ultimately, a 3-category variable was constructed to identify respondents with either "no health insurance," "private/other insurance only," or "public insurance only." Medicare, Medicaid, and state- or government-sponsored health insurance were considered "public insurance," while other forms of insurance were grouped as "other." Overall, almost all respondents under "public" had either Medicaid or Medicare. The health insurance variable had 20 missing responses.

Last, a variable for occupation status was constructed from questionnaire items on employment status in the past week. This variable was utilized to better understand the likelihood of having dental insurance in older adulthood since having dental insurance is expected to improve access to dental care. Respondents were grouped into one of the following three categories: (1) employed (if individuals reported "working at a job or business" or "with a job or business but not at work" in the past week), (2) not employed (those who responded "not working at a job or business" due to reasons other than retirement, or "looking for work" in the past week), or (3) retired (Ussery et al., 2021). The variable for occupation status had seven missing responses in the sample.

Statistical Analyses

The sample population included respondents ages 50 and older across six years of pooled NHANES participants from 2013 to 2018. These eligible observations resulted in a sample size of 8,674 participants. About 15% (n=1,288) of the sample population had at least one missing variable of interest. The missing data had no evident biases or outstanding patterns and were not dependent on the missingness of other variables (see Appendix 1.3). Income-related questions accounted for the highest number of missing responses, which accounted for 10% of the sample population, followed by diabetes (4% of the sample).

Prior to imputing the data, T-tests and chi-square tests were used to identify statistically significant differences in the variable distributions between the missing and complete case subsamples (see Appendix 1.4). Compared to the missing sample, the complete case sample had a greater proportion of non-Hispanic White adults (73.2% vs 64.1%) and U.S.-born older adults (85.6% vs 79.5%). Given those significant differences between the subsamples and that about 10% of adults had missing income information, a complete case analysis was not selected over multiple imputation. All missing observations (n=1,288) from the sample population were then imputed in the final descriptive and multivariate analyses (Rubin, 1996). Per NHANES recommendations, this study also utilized appropriate sampling weights in the univariate and multivariate models to account for the NHANES sampling design and to reduce nonresponse bias (CDC & NCHS, n.d.a).

Sensitivity analyses also investigated whether an interaction term between age and the main SES variables (income and education) had a significant effect on past-year dental visits (see Appendix 1.5). An interaction between gender and age was also included in case any associations between gender identity and dental visits were driven by age differentials. A simple model (Model 1) included the covariates, income, education, and gender. This simple model was compared with other models that had either: an interaction term between age and education (Model 2), an interaction term between age and income (Model 3), or an interaction term between age and gender (Model 4).

Log-likelihood ratio tests found that the inclusion of the interaction terms in all models improved the goodness of fit relative to the simple model (see Appendix 1.5). No age interactions were present for gender, while only a few income and education subgroups had a significant interaction effect with age. The final sets of results were stratified by age to further examine SES-related differences in dental visits within subpopulations of older adults. This analytic approach also examined whether other predictor variables explained differences in dental visits that appeared only in specific stages of older adulthood.

Descriptive analyses were conducted with the total analytic sample of adults aged 50+ years then were stratified by the following age groups: 50 to 59 years, 60 to 69 years, 70 to 79 years, and 80+ years. This stratified approach was used in similar studies that compared dental outcomes across various age groups of older U.S. adults (Dye et al., 2018; Griffin et al., 2012). Participants younger than 65 years were included in the sample to better understand age disparities in past-year dental visits from middle adulthood to the beginning and more advanced stages of older adulthood. Baseline data for each key variable were examined across the total sample and then stratified by the four age groups (see Table 1.1).

Bivariate analyses were conducted between the outcome variable and indicators that were central to the main hypotheses (see Figure 1.2). These variables included education, income, race/ethnicity of Hispanic adults, and diabetes. No covariates in the full model exhibited patterns of collinearity. All variance inflation factors had values less than 2.5, which is a standard cutoff used to identify collinear associations.

Next, multiple logistic regression models examined the associations between key predictors and the outcome variable, past-year dental visits. Reference groups were selected based on large cell counts and advantageous socioeconomic position. Reference groups were also represented by the lowest level of ordinal variables to demonstrate improving gradients in oral health outcomes. Covariates in the logistic regression models were added sequentially, based on the conceptual model in Figure 1.1. Model 1 represents the main relationship between dental visits, income, and educational attainment. Model 2 incorporates the confounding variables (gender, race/ethnicity, and nativity status of Hispanic participants). Model 3 adds insurance and occupation status to the variables from Model 2. Last, Model 4 includes variables from the health and behavioral domain (diabetes, smoking status, and flossing), which were mediators that were the most proximal to the outcome variable.

Log likelihood-ratio tests, Akaike information criterion (AIC), and Bayesian information criterion (BIC) were compared across each stepwise logistic regression model to assess goodness-of-fit in the unweighted model (see Appendix 1.6). The full model had the best model fit. These sequential models were then re-calculated with imputed and weighted data for the total sample population and stratified by each age subgroup (see Appendices 1.7-1.11). From these data, the covariates related to each hypothesis (income, education, race/ethnicity, Hispanic nativity, and diabetes) were extracted and compiled into the final set of results (see Table 2.2 and Table 2.3). All analyses were conducted using STATA version SE/15.1 statistical software.

Results

Descriptive results

Table 1.1 shows the weighted distribution of key characteristics for the total sample and each age group. In the total sample, we found that about 64% of adults ages 50 years and older had a dental visit in the past year. The prevalence of past-year dental visits slightly increased among younger older adults and then decreased among the oldest groups. The oldest age group had the fewest dental visits (60.9%) whereas participants between 60 to 69 years of age had the highest proportion of dental visits (67.3%). The largest proportions of adults in the total sample had a high school education or less (38.8%), had an income between $20,000 and $74,999 (45.8%), had private insurance (69.2%), were born in the U.S. (84.9%), and identified as female (53.3%) or non-Hispanic White (72.1%). Most of the sample also had no diagnosis of diabetes (80.5%) and never smoked (51.9%). Even though 37% of adults ages 50 years and older flossed daily, still about one-third (30.5%) did not floss at all in the past seven days.

Some characteristics varied across the age categories. Male participants, racial/ethnic minorities, and foreign-born older adults had successively lower proportions in older age groups. Private insurance status was similar across all age categories. However, participants in older age groups relied more on public health insurance and were less likely to be uninsured than the younger age groups. In addition, older age groups were successively less likely than their younger counterparts to have had any college education. In the 80+ year age group, about half of the participants reported having a high school diploma or fewer years of education compared to only 36% of respondents between ages 50 and 59 years. Age gradients were also present in the prevalence of diabetes, flossing, and current smoking status: The proportion of respondents with diabetes and zero days of flossing were highest in the oldest age groups, while younger respondents were more likely to floss daily and be current smokers.

Table 1.1. Baseline characteristics from 2013-2018 NHANES participants stratified by age (in years)*

	Total		Age 50-59		Age 60-69		Age 70-79		Age 80+	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*
One or more dental visits in the past year (Dependent variable)	64.4	*1.3*	62.0	*1.7*	67.3	*1.8*	66.2	*1.9*	60.9	*1.8*
Frequency of dental visits										
6 months or less	50.9	*1.3*	46.9	*1.6*	53.9	*2.0*	55.2	*2.1*	48.9	*1.7*
6 to 12 months	13.4	*0.6*	15.0	*1.2*	13.3	*0.9*	10.9	*1.2*	11.6	*1.2*
1 to 2 years	9.1	*0.4*	11.6	*0.8*	7.7	*0.6*	6.7	*0.8*	8.2	*0.9*
2 to 3 years	5.9	*0.4*	5.6	*0.6*	5.9	*0.5*	6.3	*0.7*	6.2	*0.9*
3 to 5 years	6.0	*0.4*	6.8	*0.6*	5.5	*0.7*	5.2	*0.5*	5.3	*0.7*
5+ years	14.0	*0.8*	13.1	*1.0*	13.0	*1.2*	15.1	*1.2*	18.5	*1.5*
Never have been to the dentist	0.6	*0.1*	0.8	*0.2*	0.5	*0.1*	0.4	*0.1*	0.4	*0.2*
Had an unmet dental care need in past year	15.0	*0.8*	19.2	*1.3*	14.5	*1.2*	10.7	*0.7*	7.1	*0.9*
Level of education										
High school or less	38.8	*1.4*	36.5	*2.0*	37.4	*1.7*	40.7	*1.6*	48.9	*2.1*
Some college	30.4	*0.9*	31.4	*1.5*	30.8	*1.7*	29.8	*1.5*	26.2	*1.6*
College graduate	30.8	*1.5*	32.1	*2.2*	31.7	*1.9*	29.4	*2.0*	24.8	*1.8*
Income level										
<$20,000	17.7	*1.0*	16.2	*1.4*	16.7	*1.2*	19.0	*1.7*	24.6	*1.8*
$20,000-$74,999	45.8	*1.1*	39.5	*1.5*	47.1	*1.8*	51.2	*2.3*	56.9	*2.3*
$75,000-99,999	11.0	*0.7*	12.4	*1.0*	10.9	*1.6*	10.6	*1.7*	6.4	*1.1*
$100,000+	25.5	*1.5*	31.9	*2.0*	25.2	*1.9*	19.2	*2.0*	12.1	*1.8*
Gender										
Female	53.3	*0.6*	51.2	*1.0*	52.6	*1.0*	55.2	*1.4*	60.6	*1.2*
Male	46.7	*0.6*	48.8	*2.0*	47.4	*1.0*	44.8	*1.4*	39.4	*1.2*
Race/ethnicity & nativity										
U.S.-born Hispanic	3.7	*0.5*	4.6	*0.6*	3.4	*0.5*	3.1	*0.5*	2.0	*0.5*
Foreign-born Hispanic	6.5	*0.6*	8.1	*0.9*	6.2	*0.7*	5.1	*0.7*	2.9	*0.5*
Non-Hispanic White	72.1	*1.8*	67.3	*2.0*	72.8	*2.0*	75.6	*1.9*	82.2	*1.8*
Non-Hispanic Black	10.0	*1.0*	11.3	*1.1*	10.0	*1.1*	8.5	*1.0*	7.5	*1.1*
Non-Hispanic Asian	4.6	*0.6*	4.9	*0.7*	4.7	*0.6*	4.6	*0.7*	3.3	*0.7*
Other race or multiracial	3.2	*0.4*	3.7	*0.6*	2.9	*0.6*	3.1	*0.6*	2.0	*0.5*
Length of stay in the U.S.										
U.S.-born	84.9	*1.0*	82.4	*1.2*	86.2	*1.2*	85.5	*1.3*	89.2	*1.3*
non-U.S. born, <15 yrs	1.5	*0.2*	2.0	*0.4*	1.2	*0.2*	1.4	*0.3*	0.7	*0.2*
non-U.S. born, 15+ yrs	13.6	*0.9*	15.6	*1.1*	12.7	*1.0*	13.0	*1.1*	10.0	*1.3*
Occupation status										
Employed	45.6	*1.0*	71.9	*1.7*	43.0	*1.2*	14.0	*0.9*	6.0	*0.8*
Not employed	18.6	*0.9*	24.5	*1.6*	19.2	*1.3*	10.0	*1.1*	9.1	*0.8*
Retired	35.8	*0.8*	3.6	*0.5*	37.8	*1.5*	76.1	*1.3*	84.9	*1.1*

Table 1.1 continued

Health insurance status										
Private	69.2	*1.2*	69.6	*1.6*	68.8	*1.8*	68.8	*1.8*	69.4	*1.8*
Public	22.9	*1.0*	17.4	*1.0*	24.1	*1.6*	29.3	*1.8*	29.4	*1.7*
No insurance	7.9	*0.6*	13.1	*1.2*	7.1	*0.8*	1.9	*0.4*	1.3	*0.4*
Has diabetes	19.5	*0.7*	14.3	*1.1*	21.6	*1.2*	25.8	*1.2*	21.7	*1.2*
Daily flossing										
0 days	30.5	*0.9*	25.3	*1.1*	29.8	*1.5*	35.0	*1.3*	45.4	*2.1*
1 to 6 days	32.1	*0.8*	37.7	*1.3*	32.4	*1.5*	26.3	*1.7*	19.7	*1.3*
7 days	37.4	*1.0*	37.0	*1.3*	37.8	*1.9*	38.6	*1.8*	34.9	*2.1*
Smoking status										
Never smoked	51.9	*1.0*	54.2	*1.7*	47.6	*1.7*	51.7	*1.7*	56.8	*2.2*
Former smoker	32.7	*0.8*	24.2	*1.0*	37.2	*1.6*	39.3	*1.7*	39.9	*1.9*
Current smoker	15.5	*0.8*	21.7	*1.3*	15.2	*0.9*	9.0	*0.9*	3.3	*0.6*
N	8,674		2,782		2,993		1,744		1,155	

*Percentages for analytic sample were imputed and calculated with NHANES sampling weights to reflect the national U.S. adult population.

Bivariate results

Figure 1.2 represents bivariate associations that correspond with each of the three hypotheses in Study 1. The first two panels show the bivariate associations between the dependent variable (past-year dental visits) and the main SES predictors (income and educational attainment). Panel 1 depicted a steady gradient between income and dental visits, in which greater levels of income were associated with a greater likelihood of visiting a dentist in the past 12 months. In the lowest income bracket, only about 41% of respondents had a dental visit in the past year compared to 59.6% and 78.2% of respective respondents in the following two income brackets, and 83.1% in the highest income bracket. Panel 2 shows a similar pattern between having higher levels of educational attainment and higher proportions of past-year dental visits. About half of the respondents with a high school diploma or less had a dental visit in the past 12 months compared to 64% of participants with some college and 83% of those with a college degree.

In Panel 3, we noted differences in dental care access between foreign-born Hispanics and U.S.-born Hispanics. Overall, U.S.-born Hispanics were more likely to have a dental visit than foreign-born Hispanics (58.0 % vs. 51.7%). This panel also shows that non-Hispanic Whites had the highest likelihood of receiving dental care (68.5%) and non-Hispanic Blacks had the lowest likelihood (48.2%) compared to all other racial/ethnic categories. In the fourth and final panel, participants with diabetes were less likely than those without diabetes to receive dental care in the past year (56.6% vs 66.2%). The observed relationships for each bivariate association were in the same direction as their corresponding hypotheses and were explored further in a multiple logistic regression model.

Figure 1.2 Bivariate associations between dental visits and 4 different covariates (income, education, nativity of Hispanic adults, and diabetes) *

Panel 1: Dental visits increase with higher income levels

Income level	Had a past-year dental visit		
	No	Yes	Total (%)
<$20,000	59.0	41.0	100
$20,000-$74,999	40.4	59.6	100
$75,000-99,999	21.8	78.2	100
$100,000+	16.9	83.1	100
Total (%)	**35.6**	**64.4**	**100**

Panel 2: Dental visits increase with higher educational attainment

Educational attainment	Had a past-year dental visit		
	No	Yes	Total (%)
High school or less	50.2	49.8	100
Some college	35.7	64.3	100
College graduate	17.3	82.7	100
Total (%)	**35.6**	**64.4**	**100**

Panel 3: Dental visits are higher among U.S-born Hispanic adults than foreign-born Hispanic adults

Race/ethnicity	Had a past-year dental visit		
	No	Yes	Total (%)
U.S.-born Hispanic	42.0	58.0	100
Foreign-born Hispanic	48.3	51.7	100
NH White	31.5	68.5	100
NH Black	51.8	48.2	100
NH Asian	36.4	63.6	100
Other race	45.4	54.6	100
Total (%)	**35.6**	**64.4**	**100**

Panel 4: Participants with diabetes have fewer dental visits compared to those without diabetes

Has diabetes	Had a past-year dental visit		
	No	Yes	Total (%)
No	33.8	66.2	100
Yes	43.4	56.6	100
Total (%)	**35.6**	**64.4**	**100**

Source: NHANES, 2013-2018

*n=8,674; Survey weights and imputed data were used in the above calculations.

Multiple logistic regression results: SES and dental visits

Table 1.2 shows the odds ratios for past-year dental visits from four sequential models. These models include estimates for the main SES predictors (income and education) described in Hypothesis 1.1. The purpose of this table was to show how the relationship changed between SES variables (income and education) and past-year dental visits upon the addition of the other covariates from the conceptual model. These results were also stratified by age to observe any changes within subpopulations of older adults. The full logistic regression model (Model 4) included all key predictors (education, income, gender, race/ethnicity, nativity of Hispanic adults, occupation status, health insurance, diabetes, flossing, and smoking).

Education

Model 1 (with only income and education as predictors) for the total population showed that higher levels of education were associated with greater odds ratios (ORs) of having a past-year dental visit. Compared to participants ages 50+ years with a high school diploma or less, participants with some college had 1.6 times greater odds of having a past-year dental visit, and those with a college degree had 3.1 greater odds of visiting a dentist. When the covariates in Model 2 (gender, race/ethnicity, and Hispanic nativity) and Model 3 (health insurance and occupation status) were successively added to Model 1, the coefficients for education remained unchanged. However, the odds ratios declined for participants with some college (from 1.6 to 1.3) and those with a college degree (from 3.1 to 2.3) when the health mediators (flossing, smoking, and diabetes) were added to Model 4. Despite the reduction in magnitudes of the education coefficients, the estimates for education in the full model had the same directions of association and were statistically significant as in the preceding sequential models for the total population.

Similar to the findings from the total population, the changes in the education coefficients across the sequential models for each age group only appeared once Model 4 variables were added. In all age subcategories, higher education had a generally positive association with receiving a past-year dental visit. Not all point estimates for education in the final models were significant in every age group, though they all had the same directions of association. The inclusion of the Model 4 variables resulted in non-significant associations between dental visits and having “some college” within the 70 to 79-year and 80 years or older age groups. While having a college degree made a significant impact on improving dental visits across all age categories (between OR: 1.7 and OR: 3.4), having some college education was only beneficial in the full model within the 60- to 69-year age group (OR: 1.4).

Income

Income had a graded effect on dental visits within the total population and most age subgroups, in which the odds of having a dental visit increased over higher levels of income. For example, Model 1 from Table 1.2 shows that compared to individuals in the lowest income category (less than $20,000), participants in the total population who earned between $20,000 to $74,999 had 1.8 greater odds of receiving a past-year dental visit. Participants in the next income level (between $75,000 to $99,999) had 3.8 times greater odds of visiting a dentist compared to the lowest income group, while individuals who made over $100,000 had 4.5 times greater odds of receiving a past-year dental visit compared to the same reference group.

The estimates for each income category remained similar between Model 1 and Model 2 in the total population. However, the estimates decreased slightly after controlling for health insurance and occupation in Model 3 and reduced again to a greater degree after the inclusion of the health mediators in Model 4 suggesting that health insurance and occupation partly accounted for the association between income and past dental visits (i.e. within the $100,000+ category, Model 1 OR: 4.5, Model 2 OR: 4.4, Model 3 OR: 3.8, and Model 4 OR: 2.9). While these mediating effects were present across the other income levels in the total population, all estimates for income were still significant in the full model and had the same graded pattern as in the simple model. When stratified by age, the effect sizes for income in most age groups decreased with the addition of Model 3 and Model 4 variables. In general, the income coefficients in the full model had a statistically significant impact on dental visits in all age categories.

Differences in effect sizes between age categories

The subgroup analysis by age showed that the SES gap in dental visits was worse among the oldest adults compared to the SES disparities present within other age categories. The estimates from the stratified data did not use the same comparison groups, but these results did suggest that larger SES disparities were observed within populations of the oldest age groups than when focusing on only younger subsets of older adults or the combined population of adults over age 50 years. For example, in Model 4, adults between the ages of 50 and 59 years in the highest income bracket had 2.7 times greater odds of receiving a past-year dental visit than adults in the same age group who made below $20,000. These odds increased across older age groups, with adults over 80 years of age in the $100,000 income bracket having 3.6 times greater odds of receiving a past-year dental visit than the lowest income bracket of their respective age category. Overall, income had a particularly large impact on dental visits, with widening SES disparities in older age groups.

Table 1.2. Sequential logistic regression models for income and education: Odds ratios for past-year dental visits by age group

	Total Sample				Age 50-59 years				Age 60-69 years				Age 70-79 years				Age 80+ years			
Models	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
<u>Variables</u>																				
Level of education																				
High school or less (reference)																				
Some college	1.6 **	1.5 **	1.5 **	1.3 *	1.3	1.3	1.2	1.1	1.9 **	1.8 **	1.7 *	1.4 +	1.8 **	1.7 *	1.6 *	1.4	1.8 *	1.8 *	1.7 +	1.5
College graduate	3.1 **	3.1 **	2.9 **	2.3 **	2.3 **	2.2 **	2.1 **	1.7 *	4.0 **	3.9 **	3.7 **	2.9 **	4.7 **	4.8 **	4.5 **	3.4 **	2.9 **	3.0 **	2.9 **	2.5 **
Income level <$20,000 (reference)																				
$20,000-74,999	1.8 **	1.8 **	1.6 **	1.5 **	1.4 +	1.4 +	1.2	1.1	1.9 **	1.9 **	1.7 *	1.5 +	2.3 **	2.3 **	2.1 **	1.7 +	2.3 **	2.1 **	2.0 **	2.1 *
$75,000-99,999	3.8 **	3.8 **	3.3 **	2.8 **	3.7 **	3.8 **	2.8 **	2.4 *	4.1 **	3.9 **	3.3 **	3.0 **	3.0 *	3.0 *	2.8 *	1.9	6.5 *	6.8 *	6.5 *	7.2 *
$100,000+	4.5 **	4.4 **	3.8 **	2.9 **	4.7 **	4.8 **	3.2 **	2.7 **	4.8 **	4.6 **	3.9 **	2.9 **	4.6 **	4.4 **	4.0 **	2.7 *	3.9 **	4.0 **	3.8 **	3.6 *
Constant	0.6 **	0.7 *	0.9	0.5 **	0.6 **	0.7 +	1.1	0.8	0.5 **	0.8	0.9	0.5 +	0.5 **	0.8	0.8	0.5 +	0.5 **	0.7 +	0.9	0.5
N	8,674				2,782				2,993				1,744				1,155			

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, gender, race/ethnicity, Hispanic nativity

Model (3): education, income, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (4): education, income, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

Multiple logistic regression results: Nativity of Hispanic subgroups

Table 1.3 shows the odds ratios for past-year dental visits by race/ethnicity and diabetes status across a series of the same four sequential models described in the previous section. In the total sample, the estimates for race/ethnicity in the Model 2 showed no significant differences in having a past-year dental visit between foreign-born Hispanic adults and non-Hispanic White adults. The same results were observed between U.S.-born Hispanic adults and non-Hispanic White adults. With the addition of the Model 3 and Model 4 covariates, the coefficients for both Hispanic subgroups were mostly the same and remained non-significant.

Similar outcomes were observed in all age groups, except for U.S.-born Hispanic adults between ages 70 and 79 years. Compared to White adults between ages 70-79 years, U.S.-born Hispanic adults in that same age group had 60% lower odds of receiving a past-year dental visit (with the same odds ratios in Models 2, 3, and 4). Other patterns by race/ethnicity illustrated that non-Hispanic Black adults above age 60 had about half the odds of receiving a past-year dental visit compared to non-Hispanic White adults in all sequential models. In the oldest age group (80 years and older), non-Hispanic Black adults had up to 60% lower odds of visiting a dentist compared to non-Hispanic Whites in the full model, while non-Hispanic Asian adults of the same age category had 70% lower odds than non-Hispanic White adults across all sequential models.

Multiple logistic regression results: Diabetes

Diabetes was incorporated in the full model only (Model 4) as part of the health variables domain from the Study 1 conceptual model. In the total population of adults ages 50+ years, participants with diabetes had 20% lower odds of receiving a dental visit in the past year compared to adults without a reported diagnosis of diabetes. Interestingly, the age-stratified coefficients showed that diabetes had no significant associations with past-year dental visits except within the subpopulation of adults ages 80 years and older. In this age group, participants with diabetes had 30% lower odds of seeing a dental visit in the past 12 months compared to participants without diabetes.

Table 1.3. Sequential logistic regression models for race/ethnicity, Hispanic nativity, and diabetes: Odds ratios for past-year dental visits by age group

	Total Sample				Age 50-59 years				Age 60-69 years				Age 70-79 years				Age 80+ years			
Models	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Variables																				
Race/ethnicity	-				-				-				-				-			
U.S.-born Hispanic		0.8	0.9	0.8		1.1	1.1	0.9		1.1	1.1	0.9		0.4 *	0.4 *	0.4 **		0.7	0.7	0.7
Foreign-born Hispanic		0.9	1.1	1.0		1.0	1.3	1.0		0.9	1.1	0.9		0.8	1.0	1.0		0.7	0.8	0.8
Non-Hispanic White (reference)																				
Non-Hispanic Black		0.6 **	0.6 **	0.7 **		1.0	1.0	0.9		0.5 **	0.5 **	0.5 **		0.4 **	0.5 **	0.5 *		0.3 **	0.3 **	0.4 **
Non-Hispanic Asian		0.8 +	0.9	0.8 +		1.1	1.2	1.0		0.7 +	0.7	0.7		0.7	0.8	0.8		0.3 **	0.3 **	0.3 *
Other race or multiracial		0.7	0.7	0.8		1.0	0.9	1.0		0.6	0.6	0.6		0.7	0.7	0.8		0.6	0.7	0.6
Diabetes	-				-				-				-				-			
No (reference)																				
Yes				0.8 +				0.8				0.7				1.0				0.7 +
Constant		0.7 *	0.9	0.5 **		0.7 +	1.1	0.8		0.8	0.9	0.5 +		0.8	0.8	0.5 +		0.7 +	0.9	0.5
N	8,674				2,782				2,993				1,744				1,155			

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, gender, race/ethnicity, Hispanic nativity

Model (3): education, income, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (4): education, income, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

Discussion

The purpose of Study 1 was to improve understanding of the relationship between SES and past-year dental visits within different subpopulations of older U.S. adults. Three hypotheses were tested within a conceptual framework that tied perspectives from social determinants of health and the life course approach. First, Hypothesis 1.1 posited that having lower SES decreased the probability of having a routine dental visit; this association was also expected to have a larger impact on older subpopulations of U.S. adults. In Hypothesis 1.2, foreign-born Hispanic adults were predicted to have fewer routine dental visits than U.S.-born Hispanic adults. Last, Hypothesis 1.3 focused on whether participants with diabetes were less likely to receive past-year dental care compared to participants without diabetes.

In summary, lower levels of both education and income were associated with lower odds of dental visits in all age groups, with declining effect sizes after the inclusion of the health mediators (diabetes, flossing, and smoking). After controlling for all key covariates in the full model, adults within the highest income bracket ($100,000+) had between 2.7 and 3.6 times greater odds of receiving dental care than adults with incomes below $20,000. Adults in the 80+ year age group represented the largest value in this range. Adults with a college degree were also more likely to receive dental care in the past 12 months compared to adults with a high school degree or less (OR between 2.7 and 3.6), whereas adults with some college or an associate degree had no difference in the likelihood of visiting a dentist, except among adults in the 60- to 69-year age range (OR: 1.4). In concordance with previous studies, our results supported that individuals with lower SES were less likely to visit a dentist than higher-SES groups (Vujicic et al., 2016). In addition, the results from Study 1 demonstrated that income disparities in dental visits were most evident within older subpopulations. Widening SES disparities in dental visits suggest that financial strain is an increasing barrier to accessing dental care, particularly with older age.

Contrary to the results expected for Hypothesis 1.2, U.S. nativity did not provide significant advantages in dental care utilization among U.S.-born Hispanic adults compared to foreign-born Hispanic adults. There were also few differences in dental visits when comparing both subgroups of Hispanic participants to non-Hispanic White participants. Only U.S.-born Hispanic adults between ages 70 and 79 years had about 64% lower odds of receiving dental services in the past year than non-Hispanic White adults (OR: 0.36). Racial/ethnic disparities in dental visits were also evident among some groups of non-Hispanic Black and non-Hispanic Asian adults. For instance, the odds of receiving dental care among non-Hispanic Black adults were nearly half of the odds of non-Hispanic Whites in all age groups. Non-Hispanic Asian adults above 80 years of age also had 70% lower odds of dental care visits compared to non-Hispanic White adults.

The disparities in dental visits found among both Hispanic and non-Hispanic Black adults resembled recent patterns in oral health utilization found in the population of U.S. adults over 65 years of age, while the low likelihood of dental visits among the oldest subpopulation of non-Hispanic Asian adults was an unexpected finding that warrants attention in future research (Kramarow, 2019; Vujicic et al., 2021). With respect to the non-significant results for foreign-born Hispanic adults, other studies alternatively, have observed lower rates of dental service utilization among foreign-born U.S. adults versus U.S.-born adults (Wilson et al., 2016). However, those other findings were examined within a more general population of U.S adults (ages 18 years and older and consolidated age groups above 65 years) and did not focus on examining dental visits by Hispanic subgroups or older categories of adults. Furthermore, recent studies have discussed the gradual narrowing of racial/ethnic disparities in oral health access, but those trends were too analyzed across the general U.S. adult population (Wehby et al., 2022). To add to this body of research, our findings from Study 1 revealed that racial/ethnic gaps in dental care persisted within different stages of older adulthood. Barriers to oral health care that differentially impact older adults based on nationality or racial background require better understanding and appropriate intervention to realize equitable outcomes in dental care access.

Last, the role of diabetes in Hypothesis 1.3 was expected to mediate the relationship between SES and dental visits. This outcome was partially supported while testing Hypothesis 1.1 after the addition of the health variables (including diabetes) in the full model decreased the point estimates for SES. Ultimately, the effect of diabetes on past-year dental visits was found to only impact adults in the oldest subpopulation in the sample. Adults with diabetes who were 80 years and older had 30% lower odds of receiving a dental visit in the past year compared to adults without diabetes of the same age group. Alternatively, diabetes appeared to have no impact on dental visits across the younger age groups.

The outcomes within the 80+-year subpopulation were similar to the findings from prior literature, which suggested that diabetes has an inverse association with dental care visits (Luo et al., 2018; Patel et al., 2021). The self-reported aspect of the diabetes variable might impact the accuracy of our results by underestimating the true number of individuals experiencing symptoms of diabetes. About 4% of respondents who had “borderline” diabetes were also marked as having missing responses for that variable. Future research might examine other clinical measures from the MEC assessment to ascertain diabetes diagnosis. Furthermore, diabetes might be a more influential predictor of dental outcomes than only dental health utilization. Nonetheless, diabetes increased in prevalence across older age groups and impacted over one-fifth of the adult population above age 60. Thus, exploring the relationship between diabetes and clinical outcomes for oral health might provide a direct biological link between diabetes and susceptibility to certain oral diseases.

This study had several limitations. First, the sample sizes were small for specific subpopulations of older adults, such as foreign-born and Hispanic older adults. To account for low response rates in some populations, NHANES oversampled for racial/ethnic minorities, low-income, and older adults aged 80+ years beginning in the 2011 NHANES cycle (Johnson et al., 2014). This study also mitigated the issue of small sample sizes by pooling data from six years of NHANES waves from 2013 to 2018. Furthermore, this study utilized survey weights and imputation techniques to decrease bias and improve the precision of model estimates (CDC & NCHS, n.d.a; Rubin, 1996).

Second, specific information on dental characteristics such as dental insurance was not available in the NHANES questionnaire. Medical insurance was used instead as an indicator of financial assistance for general health care services, including dental care. Similarly, the questionnaire item for past-year dental visits did not specify whether the type of visit involved routine dental care or specialty oral health services. Nevertheless, a majority of the sample with a past-year dental visit indicated that the reason for their most recent dental visit was for a check-up, examination, or cleaning (about 63%), while 13% stated that their recent visit entailed dental treatment that was recommended directly after a preventive visit. Even though 22% of respondents visited the dentist in the past year because of oral pain, some of those respondents could have had a preventive dental visit that took place earlier within that same year. Thus, we expect that most of the sample who visited a dentist in the past 12 months regularly attend dental appointments for preventive care. Furthermore, some older adults may have received dental visits outside the U.S. Although data on this topic are limited, this issue is unlikely to create serious limitations in undercounting attendance to dental appointments since the NHANES survey asked about general experience with visiting a dentist and did not require that the dental visit had to occur within the U.S.

Overall, this study contributes to a limited body of research on dental care outcomes by age-specific and modifiable factors. These findings have important implications for oral health policy and practice. Currently, oral health care produces the greatest level of financial burden in the U.S., compared to other types of health care services. (Vujicic et al., 2016). Older U.S. adults also reported cost as the primary barrier to receiving oral health services (Bhoopathi et al., 2021; Kramarow, 2019). Consequently, access to dental care declines significantly among older adults with low SES and no health insurance (Vujicic & Nasseh, 2014).

Obtaining necessary dental care becomes increasingly important in older adulthood. Yet, current dental policies under Medicare and Medicaid are insufficient and require immediate revision. Interventions that are accessible, are culturally relevant to racial/ethnic minorities, and that cater to the specific needs of low-resourced older populations are important for removing social disparities in dental care access. Universal dental coverage is an important investment for public health, especially since more than one-third of U.S. adults over age 50 were unable to receive any type of dental care in the past year. The future prevention of oral diseases depends on eliminating the persistent and modifiable gaps in dental care access across all life stages.

Study 2: Investigating the effects of food insecurity and socioeconomic status on untreated dental caries among older U.S. adults

Abstract

Dental caries, or cavities, constitute the largest burden of noncommunicable diseases in the world. They are experienced almost universally by older adults. In general, having an advantageous socioeconomic status (SES) is associated with better outcomes for oral health. Few studies have focused on food insecurity as a social determinant of oral health in older adult populations. The purpose of Study 2 was to examine the SES-caries relationship among older U.S. adults and the extent to which food insecurity explained this association. The mediating role of routine dental visits was also explored. The dependent variable was the presence of untreated dental caries, and independent variables were education and income. Key mediating variables included the level of food insecurity and frequency of dental visits.

Data came from a subset of dentate adults ages 50 years and older from the 2015-16 and 2017-18 National Health and Nutrition Examination Survey (NHANES). This study did not include NHANES participants prior to 2015 because earlier survey waves did not request information about untreated dental caries, only general experiences of caries. The final sample size was 4,639 adults. Binary logistic regression, multiple imputation of missing variables, and sampling weights were used in the final set of results. No significant interactions between age and SES were present, but because outcomes had varying effects on untreated dental caries by income, food security, and dental visits within some age groups, results were stratified by age category (50-59 years, 60-69 years, 70-79 years, and 80+ years). Findings revealed that lower levels of SES increased the odds of untreated dental caries within the youngest and oldest age groups. Next, adults with "marginal" or "very low" food security had more than twice the odds

of untreated dental caries compared to those with full food security within the 60- to 69-year age group, even after accounting for SES. Longer delays in routine dental visits were also associated with the presence of untreated dental caries in all age groups. Oral health issues are largely overlooked across older adult populations, especially with respect to the social determinants of oral health. Addressing this gap requires a deeper understanding of the social and age-related factors that perpetuate inequities in preventable oral diseases, such as untreated dental caries.

Introduction

Dental caries, also known as cavities, are a type of oral disease in which the hard surfaces of the teeth are permanently damaged by decay (Mayo Clinic, 2022). Dental caries is one of the most common, yet overlooked, non-communicable diseases in the world (Vos et al., 2017). In an assessment of 328 health-related conditions by the Global Burden of Disease Study, untreated dental caries in permanent teeth was the most prevalent health burden among children and adults (Vos et al., 2017). Older adults experience dental caries almost universally. In the U.S., nearly all adults aged 65 years or older (97%) have had a cavity while 20% have untreated tooth decay (Dye et al., 2015; NIH, 2021). Disparities by SES also show that in some countries, adults with lower income and education are more likely than those with higher levels of income and education to have dental caries (Costa et al., 2012; Wang et al., 2017). No recent explanatory studies for this relationship have been conducted specifically among older U.S. adults.

Food security, which is also closely tied to having an advantaged SES, might also play a mediating role in the relationship between SES and untreated dental caries. Food insecurity influences diet quality, which in turn, directly impacts oral health status. In 2018, about 10% of adults aged 60 years and older (7.3 million individuals) experienced food insecurity in the U.S. (National Council on Aging, 2021a). Among older U.S. adults, the likelihood of having food insecurity is highest among adults ages 60 to 70 years, Hispanic and non-Hispanic Black adults, individuals who live with disabilities, and adults who reside below the U.S. poverty line (National Council on Aging, 2021a; Ziliak & Gunderson, 2020). Little is known about the extent to which food insecurity impacts dental caries in older adulthood. Most studies on this topic have focused on childhood and middle adulthood, while only one other study has explored this topic in older adults (Chi et al., 2020). Although those findings did not explore the role of food security as a mediator of SES and dental caries, results from prior research suggest a possible link between food insecurity and a higher likelihood of dental caries with older age (Chi et al., 2020; Hill, 2020).

Outcomes for dental caries also vary by race and ethnicity (CDC, 2019a; Hybels et al., 2016). Older adults who identified as non-Hispanic Black, Mexican American, and had low income were more likely to have untreated dental caries than other racial/ethnic and income groups (CDC, 2019a; U.S. Department of Health and Human Services, 2021). Some findings suggest the presence of a Hispanic Health Paradox for oral health, a phenomenon in which immigrant groups from Latin America exhibit better health outcomes compared to their U.S.-born Hispanic and non-Hispanic White counterparts, despite experiencing greater disadvantages related to SES and migration (Sanders, 2010). Studies that have explored this topic produced mixed results, while no current studies have focused on older adult populations (Horton & Barker, 2010; Sanders, 2010; Spolsky et al., 2012; Wilson et al., 2016).

One explanation involves the disproportionate access to and utilization of regular oral health services among specific income and racial/ethnic groups. Regular dental visits play a crucial role in preventing and mitigating oral diseases, including dental caries. Hispanic older adults, non-Hispanic Black older adults, and older adults with low SES are the groups least likely to access dental care services (Andrade et al., 2020; Wehby et al., 2022). Previous research has shown that high dental care expenses and infrequent dental visits predicted untreated root caries in older adults (Badr & Sabbah, 2020). However, the degree to which dental visits impacts untreated dental caries in older adults, while accounting for the influence of other social determinants of health, remains unexplored.

The purpose of Study 2 was to examine the association between SES and untreated dental caries among dentate older U.S. adults. Secondary aims modeled food security as a key mediator in this association. The third aim explored the effect of dental health visits on untreated dental caries, while controlling for race/ethnicity and nativity of Hispanic adults. The following sections provide a literature review for Study 2 that discusses the current landscape of food security and oral health in older U.S. adults. After examining evidence that points to a potential link between food security and oral health outcomes in older adults, a conceptual model will be presented on this topic. The conceptual model outlines several mechanisms that will describe the main research questions and hypotheses for this study. Next, the methods and results will explain the statistical analyses and summarize key findings for Study 2. At the end of this chapter, a discussion of those key results will explore their implications for public health and provide recommendations for future research.

Review of literature

Dental caries in older adults

Dental caries, or cavities, are a type of decay that causes permanent damage and small holes in the roots or surfaces of teeth (Mayo Clinic, 2022). Clinical risk factors for dental caries include consumption of sugary food and beverages, poor oral hygiene, lack of preventive dental care, smoking and alcohol use, diabetes, dry mouth, taking medications that decrease salivary flow, and low fluoride exposure (Huang et al., 2013; Mayo Clinic, 2022; NIH, 2022). These factors contribute to plaque build-up and cultivate environments for bacterial infections in the oral cavity. If left untreated, dental caries can lead to oral pain, tooth sensitivity, infection, and even tooth loss (Mayo Clinic, 2022). Harmful exposures to the oral cavity are cumulative. Because many dental concerns are not addressed in their early innocuous stages, minor dental issues can worsen over time.

Older adults experience the greatest burden of dental problems. In 2016, the prevalence of dental caries in older adults was 97% (NIH, 2021). This figure has remained mostly unchanged since the year 2000 when 96% of older adults had reported experiences of dental caries. However, within those 16 years, the rate of untreated dental caries in older adults declined by six percentage points, from 28% to 22% (NIH, 2021). Despite this small improvement, untreated tooth decay still increases in prevalence with older age (CDC, 2019a; U.S. Department of Health and Human Services, 2021). The proportion of older adults with dental caries is alarmingly high; however, disparities by SES show that this risk is greatest among older adults with the fewest resources.

Older adults with low SES are the most vulnerable to having untreated dental caries. Older adults living in poverty were three times more likely to have untreated tooth decay than older adults with higher incomes (CDC, 2019a). Even though the rate of untreated dental caries in older adults has slowly declined in the U.S., SES disparities for this outcome have widened in the last 20 years (NIH, 2021). Between 2000 and 2016, untreated dental caries decreased more rapidly among older adults with high SES (21% to 14%) compared with older adults living in poverty (48% to 43%). One explanation for these differences is that dental care is less accessible to older adults with lower incomes (Kailembo et al., 2018). Lacking appropriate and timely dental care can translate to an elevated risk of dental caries. Previous studies have found that the inability to afford dental care was associated with worse outcomes for untreated root caries (Badr & Sabbah, 2019). Although economic hardship is a strong predictor of oral diseases, few studies have examined the role of food security, which is an important indicator of both diet and oral health.

Food insecurity and oral health

Food security is defined as having consistent and safe access to nutritious meals (U.S. Department of Agriculture [USDA], 2022b). In 1995, the U.S. Department of Agriculture developed the first guidelines that assess the extent and severity of food insecurity in the U.S. (USDA, 2022a). Food security is captured by a series of standardized questionnaire items that ask individuals about the availability of food-related resources and their concerns about acquiring consistent meals for their households (USDA, 2022a). The spectrum of food security groups people into one of four categories: (1) high food security (no problem or limitations with food access), (2) marginal food security (households sometimes had anxieties or issues with accessing food but with no substantial reductions in food quality and intake), (3) low food security (quality, variety, and desirability of diets diminished, but food intake, quantity, and normal eating patterns had no substantial disruptions), and (4) very low food security (at times, normal eating patterns were disrupted and food intake was reduced because of the lack of money and other food-related resources) (USDA, 2022b). In 2018, about 10% or 7.3 million adults ages 60 and older experienced low or very low food security in the U.S. (National Council on Aging, 2021a). From 2001 to 2018, the proportion of older adults with low food security rose by 38% and the proportion of older adults with very low insecurity increased by 94% (Ziliak & Gunderson, 2020). During that same period, the population of older adults also increased by 129% and 222% for each category. The demographic shift in the past two decades combined with increasing SES disparities in dental outcomes highlights a growing concern for meeting the nutritional needs of older U.S. adults.

Older adults with the highest risk of having food insecurity include Hispanic and non-Hispanic Black adults, adults with lower household incomes, individuals who rent vs. own their homes, and older adults between ages 60 to 69 years (Ziliak & Gunderson, 2020). SES influences food security in graded patterns (Ziliak & Gunderson, 2020). Among older adults with "low" food security, about 29.5% resided below the official poverty threshold, 17.3% resided between 100% and 200% of the poverty threshold, and 2.7% had an income above 200% of the poverty threshold. Similarly, older adults were most likely to have "very low" food security if they resided below 100% of the poverty threshold (14.2%) followed by residing between 100% and 200% of the poverty line (6.1%) and greater than 200% of the poverty time (0.8%). Periods of recessions have been shown to amplify food insecurity rates. For instance, the Great Recession of 2007 to 2009 corresponded with accelerated rates of food insecurity in the entire U.S. population, including older adults (Ziliak & Gunderson, 2020). Since that period, levels of food insecurity in older adult populations have not fallen below pre-recession rates (Ziliak & Gunderson, 2020). These trends are unsurprising, as national recessions contribute to unemployment and greater economic hardship. Financial instability during times of recession has a lasting impact on food security. In effect, prolonged inaccessibility of nutritional food sources may lead to diet-related health problems.

Diet and oral health are closely intertwined. Previous literature shows diets that are high in added sugar and artificial sweeteners increase the risk of developing dental caries (Moynihan, 2016). Given that many low-cost food sources are processed and have high contents of added sugar, food insecurity can contribute to a poor-quality diet, which has a direct effect on oral health. Both food security and quality of diet might also depend on the SES of one's geographical residence. Individuals with food insecurity may be more likely to reside in food deserts, which are environments that offer few affordable options for nutritious meals because of low economic resources in the community and geographic isolation (Osorio et al., 2013; Whitley, 2013). Individuals with low SES may also rely on inexpensive meals from food swamps, which are areas that contain a high concentration of fast-food restaurants and processed snack-food vendors (Osorio et al., 2013).

Some government programs in the U.S. have been designed to support families with food insecurity. For instance, the Supplemental Nutrition Assistance Program (SNAP) provides low-income older adults with supplementary funds for meals. However, only about 48% of older adults who qualify for SNAP are enrolled in the program (National Council on Aging, 2021a). Moreover, some low-income older adults do not meet eligibility requirements based on citizenship and documentation status (USDA, 2021). Many gaps contribute to poor diet, especially among older adults with low food security. Older adults with worse access to quality food sources may also be in the same groups that experience the highest burden of dental problems and among those with worse rates of diabetes, which has been known to contribute to higher risks of tooth decay (Huang et al., 2013). Although the literature on food security and untreated dental caries in older adults is scarce, some findings in middle-aged adults and child populations suggest that food security and untreated dental caries have an inverse association (Chi et al., 2020; Hill, 2020; Lee et al., 2022b). A similar effect is expected in the U.S. older adult population, given the robust association between nutritional intake and oral health.

Untreated tooth decay in racial/ethnic minorities and access to dental care services

Hispanic and non-Hispanic Black adults have the highest rates of untreated dental caries compared to other racial and ethnic groups (CDC, 2019a). Compared to non-Hispanic White older adults (14%), non-Hispanic Black (29%) and Hispanic (36%) older adults ages 65 years and older had more than double the prevalence of untreated dental caries (CDC, 2019a; U.S. Department of Health and Human Services, 2021). These same racial/ethnic groups also have disproportionate barriers to resources that promote better outcomes for oral health. For example, non-Hispanic Black and Hispanic older adults have lower SES and fewer regular dental visits than their non-Hispanic White counterparts (Bhoopathi et al., 2021; Wehby et al., 2022). Additionally, rates of food insecurity were highest among non-Hispanic Black (18.4%) and Hispanic (17.5%) older adults compared to the general older adult population in 2015 (8.8%) (Administration on Aging, Administration for Community Living, & U.S. Department of Health and Human Services, 2016). Racially targeted marketing practices in low-resourced neighborhoods also widen disparities in poor diet and subsequent oral health outcomes. Several studies have found that advertisements for unhealthy food products and fast-food restaurants are disproportionately allocated in non-Hispanic Black and Hispanic neighborhoods with low SES (Bailey et al., 2017; Grier & Kumanyika, 2010). Racial discrimination, a lack of regular oral health care, and limited access to quality food sources contribute to disproportionately worse oral health outcomes for racial/ethnic minorities.

Differences in nativity and migration might also play a role in furthering disparities in dental caries among older adults. Language barriers, discrimination, low social and economic ties, anti-immigration laws and discourse, and documentation status, are some barriers that might lead to worse oral health outcomes among older adults who were not born in the U.S. Limited studies have produced mixed findings about oral health status among immigrant populations (Sanders, 2010; Spolsky et al., 2012; Wilson et al., 2016). Even fewer studies have focused on the oral health of older adults born in Latin America. Some speculation points to a Hispanic Oral Health Paradox. This paradox suggests that foreign-born Hispanic adults may exhibit better outcomes for oral health than Hispanic adults born in the U.S., even though some immigrants are more likely to face additional burdens that lead to worse oral health, such as having lower SES and less access to dental care (Sanders, 2010). So far, the paradox has only been examined in small populations of Hispanic immigrants, has not studied dental caries as a key outcome, and has not specifically focused on older adults. Even though foreign-born Hispanic adults have lower access to dental care, little is known about how U.S. nativity impacts the main relationship between SES and oral health outcomes in older Hispanic adult populations (Wilson et al., 2016).

Untreated dental caries versus general experiences of caries

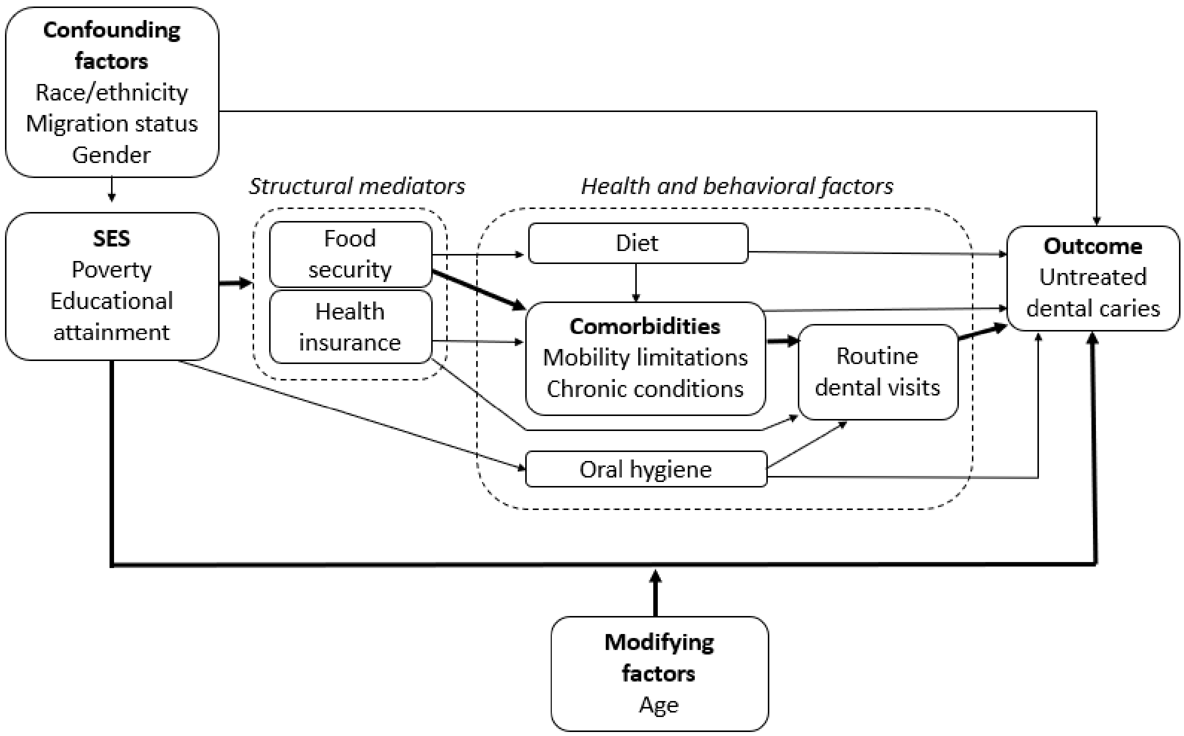
The health outcome of interest for this study centers on untreated dental caries, which are defined as teeth that have received no dental treatment or intervention for existing dental cavities. The definition and underlying mechanism of this measure differs in several ways from the separate outcome of general experiences of dental caries. First, general caries experiences present themselves across the lifespan and can encompass either currently or formerly carious teeth, including teeth that have been treated with fillings or other types of oral health intervention. In contrast, the term, *untreated* dental caries implies that teeth are currently in a carious state. The existence of untreated dental caries places emphasis on an immediate requirement for oral health intervention that, despite the need, has not been met. Second, unlike filled cavities, the untreated nature of this disease is likely to escalate into other dental health outcomes, including gum disease, tooth loss, and a decline in oral function. These differences highlight the significance of examining this outcome separately from the broader context of general dental caries experiences.

Effective public health surveillance of oral diseases also relies on the distinction between general caries experiences and untreated dental caries. The distributions and trajectories of these oral health outcomes each represent a unique population health need. For example, the rates of overall caries experiences have remained relatively static over the past two decades, since most older U.S. adults during that period (around 96%) developed at least one dental cavity in their lifetimes (NIH, 2021). In contrast, the prevalence of untreated dental caries within that same period decreased, lowering from 28% to 22%. This downward trend may suggest that certain factors like improved access to dental care potentially contributed to this change; alternatively, persistent SES disparities in dental care access may also reveal similar gaps across outcomes for untreated dental caries. Thus, SES disparities might appear differently for outcomes of untreated dental caries when compared to general experiences of dental caries. Overall, untreated dental caries is a time-sensitive oral health issue that is prevalent in older adult populations. This underscores the need to explore the influence of aging on this dental condition, along with the socially patterned effects of dental caries across various subgroups of older adults.

Conceptual Model

Figure 2.1 illustrates a conceptual model that aligns with the research aim for Study 2. The boldened arrow shows a direct link between SES variables (educational attainment and poverty status) and the dependent variable, untreated dental caries. This association is modified by age. Arrows also show possible confounding by race/ethnicity, migration status, and gender on the key relationship. The mediating variables at the center of Figure 2.1 are divided into (1) structural mediators and (2) health and behavioral factors. The structural mediators directly stem from the SES domain. These variables include food security and health insurance. Food security is boldened as the primary mediating variable in Study 2. The structural mediators directly influence the next set of mediators, which include health and behavioral factors (diet, mobility limitations, chronic conditions, and oral hygiene). The arrow between food security and comorbidities is boldened to highlight a main pathway of interest. All health and behavioral mediators have a direct influence on untreated dental caries. Last, the most distal mediating variable is routine dental visits, which stems from comorbidities and has a direct effect on dental caries. This variable is also part of the main pathway of interest.

Figure 2.1. Conceptual model of Study 2: The association between SES and untreated dental caries among older U.S. adults with mediation by food security.



Research Questions:

2.1. Are the observed differences in untreated dental caries across the four age groups of adults (50-59 years, 60-69 years, 70-79 years, and 80+ years) explained by lower SES (poverty and education)?

2.2. If there is an association between SES and dental caries, to what extent does food insecurity explain disadvantages in dental caries among older adults after accounting for SES?

2.3. To what degree do routine dental visits attenuate the impact that low-SES has on the prevalence of untreated dental caries across different age groups of older adults?

Hypotheses:

2.1. Low SES is associated with untreated dental caries, such that the magnitude of this association will increase in older age groups.

2.2. Food insecurity is associated with untreated dental caries. Food insecurity partially mediates the primary association between SES and untreated dental caries.

2.3. Having a routine dental visit is inversely associated with untreated dental caries. Dental visits are expected to partially mediate the relationship between SES and untreated dental caries.

Methods

Data collection and key variables

Data from this analysis were derived from the 2015-16 and 2017-2018 National Health and Nutrition Examination Survey (NHANES) questionnaire and mobile examination center (MEC). Additional details on the NHANES study design were described in the methods section of Study 1. The sample from NHANES 2013-14 was not included in this analysis because its measure for dental caries differed from more recent NHANES waves starting in 2015. For example, the questionnaire from 2013-14 did not include root caries as part of the count of dental caries (only surface caries) and it did not differentiate between teeth with untreated dental caries and teeth that were formerly carious but later filled. The two waves from the 2015-16 and 2017-18 cycles were pooled because they included the most complete and recent NHANES data with consistent definitions of this measure. In total, 5,361 participants above 50 years of age were seen by a MEC clinician between 2015 and 2018. Of those respondents, about 87%, or 4,639 respondents were dentate. As a result, the sample size of dentate adults over age 50 years was 4,639. This dissertation study was approved by the UCLA Institutional Review Boards (IRBs).

The dependent variable for Study 2 was the presence of untreated surface caries or root caries. This variable was collected during the MEC oral health examination, which also collected information on tooth counts, coronal caries, root caries, dental sealants, and dental care recommendations; exams were conducted by dentists licensed to practice in at least one U.S. state (CDC & NCHS, 2021). Permanent teeth that had an untreated carious surface condition or root caries were individually flagged. All teeth except wisdom teeth (teeth numbered 01, 16, 17, and 32) were part of this count (CDC & NCHS, 2018). Information was also available on teeth that were both carious and treated with fillings. Those data were not part of this measure since the study outcome focused on existing root or surface caries that were untreated. The total possible sum of untreated dental caries ranged from 0 to 28 teeth for each participant. Each sum was converted to a binary variable that categorized participants as having either zero teeth with untreated dental caries or at least one tooth with untreated dental caries. The binary operationalization of this variable was used in previous studies on oral disease in older U.S. adults (Bidinotto et al., 2021). Additionally, the counts data for untreated dental caries were collapsed into a binary variable because participant counts after one or more carious teeth mostly had empty cells (more details provided in Figure 2.2 results). All participants who went to the MEC clinics had no missing information for the dependent variable.

Income and educational attainment were key predictors of untreated dental caries in this analysis. The collection and operationalization of income, education, and other covariates (age, gender, race/ethnicity, nativity, health insurance, occupation status, diabetes, smoking, and flossing) were described in the methods section of Study 1. Of these variables, income yielded the largest number of missing responses from the sample population (dentate adults aged 50 years and older). This variable had the highest proportion of missing respondents in the sample population. The number of respondents in Study 2 with missing information for income was 528, which constituted 11% of dentate respondents aged 50 years and older. Age and gender, and race/ethnicity had zero missing responses. Diabetes had 186 (4%) missing responses, whereas the other covariates (education level, migration status, insurance type, flossing, and smoking) each had fewer than 1.1% of respondents missing from the sample population.

Food security was the key mediating variable in the Study 2 analysis. NHANES questionnaire items that were related to food security were adapted from the U.S. Food Security Survey Module (CDC & NCHS, 2022; USDA, 2022a). This instrument was originally published by the U.S. Department of Agriculture (USDA) in 1997 and has been validated by the Committee on National Statistics to monitor and evaluate food security in adults and children (USDA, 2022a). Food security was a household-level variable that was derived from 10 questionnaire items for participants who resided in households without children and 18 items for households with at least one child under 18 years of age (CDC & NCHS, 2022). Questions were asked about difficulties in food availability, access, and quality. The responses to these questions were scored and summed (see Appendix 2.1 for specific details on the food security questionnaire items).

Cutoff scores determined four categories of food security: (1) full food security, (2) marginal food security, (3) low food security, and (4) very low food security. Households that reported no affirmative responses were labeled as having full food security, while those that indicated one to two positive responses were defined as having marginal food security. Households with children under 18 years of age that had from three to seven affirmative responses were defined as having low food security, and scores from eight to 18 indicated very low food security. In households without children, scores from three to five were defined as having low food security, and scores from six to 10 were categorized as having very low food security. The final operationalization of food security was an ordinal variable that assigned respondents to one of the following four groups: full food security, marginal food security, low food security, or very low food security. A similar approach was conducted in previous studies that examined food security and dental outcomes in U.S. adults (Wiener et al., 2018). The total number of missing respondents for this variable was 182, or 4% of the original sample population.

Last, the variable, most recent dental visit, was included as a covariate in this model. The collection and original operationalization of this variable were described in further detail in the Study 1 methods section. In summary, this variable determined the timeframe of the most recent dental visit by the participant. For Study 2, responses for this variable were collapsed into three categories for analysis: (1) Within the past 12 months, (2) between one to five years, and (3) more than five years or have never visited a dentist. The third category collapsed responses for "more than five years" and "never visited a dentist" due to the small sample size of participants who had never visited a dentist (n= 54, or 1.4% of the total sample).

A binary version of this variable was originally considered, which separated individuals by having a dental visit in the past 12 months (yes or no). However, sensitivity analyses showed that the 3-category version of recent dental visits improved model fit compared to the binary version, while also exhibiting statistically significant associations with the dependent variable in all three categories. Overall, this variable had 12 respondents (0.3% of the sample population) with missing information.

Statistical Analyses

The sample population consisted of MEC participants from NHANES 2015-16 and 2017-18 who were dentate and ages 50 years and older (n=4,639). About 748 participants (or 16% of the sample population) had missing information for at least one variable of interest. Appendix 2.2 shows patterns of missing variables. Income had the highest proportion of missing observations (7% of the total sample) followed by observations that had data missing for both income and food insecurity (4%) and diabetes (3%). Patterns of missingness across the other variables did not show any outstanding evidence of bias. From these results, a possible correlation was suspected between food insecurity and income.

Before imputing the missing data, all variables were assessed for collinearity and correlation. No collinearity was detected, as each covariate had a variance inflation factor score below the standard cutoff point of 2.5. Correlation between food insecurity and income was tested by checking whether the coefficients changed substantially in a full model relative to two other models: one that controlled only for food security and a second that controlled for income only, plus demographic variables (see Appendix 2.3). Overall, the coefficients for both income and food security remained similar (in terms of statistical significance and in magnitude) in the full and simple models, indicating that no signs of correlation were present between those variables.

Chi-square tests then determined whether the distribution of variables in the complete case sample was significantly different from that of the missing subsample (see Appendix 2.4). A higher proportion of foreign-born Hispanics and foreign-born participants with 15+ years of residence in the U.S. were represented in the excluded sample (10.8% and 21.1%, respectively) compared to the complete case sample (6.4% and 13.0%, respectively). Because of those differences between the subsamples and the high number of missing responses for income (11%), a complete-case analytical approach was not used. Thus, all observations with one or more missing values (n=748, or 16% of the total sample) used multiple imputation to estimate each missing data point (Rubin, 1996). NHANES survey weights were also applied to account for the NHANES sampling design and adjust for nonresponse bias (CDC & NCHS, n.d.a).

The next set of sensitivity analyses investigated age as a potential moderator in the association between SES (income and education) and untreated dental caries (see Appendix 2.5). An interaction between gender and age was also included in case any age differences between male and female participants influenced the outcome variable. Model 1 was a simple model, which consisted of the following covariates: income, education, and gender. Models 2 through 5 included the variables from the simple model with the inclusion of one or more age interaction terms. Model 2 included an interaction term between age and education, Model 3 modeled an interaction between age and income, and Model 4 had an interaction term between age and gender. The results from Appendix 2.5 show that no age-SES interactions from any of the models were statistically significant. Similar results were found for the age-gender interaction. Furthermore, the addition of the interaction terms in Models 2 through 5 did not improve model fit relative to the simple model (Model 1). Thus, a more parsimonious model without interactions was chosen over a model that contained one or more interaction terms that included age.

Although no significant age-SES interactions were detected, the data were stratified by age to assess how other age-related characteristics, such as food insecurity or diabetes, could differentially influence untreated dental caries across specific age populations. The descriptive characteristics of the analytic sample (see Table 2.1) were then stratified by four 10-year age groups of adults: 50 to 59 years, 60 to 69 years, 70 to 79 years, and 80+ years. These groupings were used in all univariate and multivariate analyses to compare differences in untreated dental caries and key covariates across various stages of middle and older adulthood (Dye et al., 2018; Griffin et al., 2012). Bivariate associations (shown in Figure 2.3) were then examined between the dependent variable and four covariates (income, education, food security, and frequency of dental visits). These bivariate relationships corresponded with each hypothesis from Study 2.

Next, stepwise binary logistic regression was used to model all key predictors and the dependent variable, untreated dental caries. A negative binomial regression analysis was originally considered because dental caries was a count variable with a large distribution of zeroes (see Figure 2.2). However, the count version of this variable was not selected since having more untreated dental caries does not necessarily represent better or worse oral health conditions when comparing older adults with varying counts of missing teeth. For instance, individuals with many missing teeth might have fewer dental caries (but worse oral health) than fully dentate individuals with a greater number of dental caries. Thus, quantifying dental caries as a continuous measure might misrepresent the severity of oral health problems, as the number of missing teeth varied across this population (the issue of permanent tooth loss will be explored in depth in Study 3). The binary version of untreated dental caries (yes or no) was ultimately selected to perform binary logistic regressions for the final analytic models.

Covariates were added sequentially across five models in the total population and within each age subgroup (see Appendices 2.6-2.11). This ordering was selected according to the conceptual model in Study 2. The first and simplest model examined the key relationship between untreated dental caries, income, and educational attainment. Model 2 included the SES variables from Model 1 and the main mediating variable, food security. Confounding variables, which were gender, race/ethnicity, and nativity of Hispanic older adults, were added in Model 3. Model 4 incorporated the health insurance and occupation status variables with variables from the previous models. Last, Model 5 added variables from the health and behavioral domain (diabetes, flossing, smoking status, and frequency of dental services).

Reference groups were selected based on large cell counts and advantageous socioeconomic positions. They also represented the highest level within ordinal variables to capture gradients in the odds for untreated dental caries. Goodness-of-fit tests (Akaike information criterion [AIC], Bayesian information criterion [BIC], log-likelihood ratio) compared logistic regression results across each model in the total population (Appendix 2.6). In the revised set of models, sampling weights and imputed data were applied to the entire sample, followed by stratification by age (see Appendices 2.7-2.11). The estimates of the relevant covariates associated with each hypothesis (income, education, food security, and frequency of dental visits) were collected from these sequential models and presented as the primary outcomes in Tables 2.2-2.5. All analyses were performed using STATA version SE/15.1 statistical software.

Results

Descriptive results

Descriptive characteristics for key variables are found in Table 2.1. In the total analytic sample of dentate participants ages 50 years and older, around one-quarter of adults had one or more teeth with untreated dental caries. These proportions were similar by age group, though adults above 80 years of age had the highest proportion of untreated dental caries (26.8%). In the total sample, the largest proportions of adults ages 50 years and older had a high school education or less (35.5%), an income level between $20,000 and $74,999 (44.6%), and full food security (78.2%). Most of the sample also identified as female (53.1%), non-Hispanic White (71.3%), were born in the U.S. (84.1%), had private insurance (71.9%), had no self-reported diagnosis of diabetes (81.0%), never smoked (54.8%), and had a dental visit in the past 12 months (68.1%).

Certain characteristics varied across age groups. For example, differences were found in the representation of individuals with a low socioeconomic status (defined as having less than a high school education and an income less than $20,000). Specifically, the highest percentages of such individuals were present among adults ages 70 to 80 years, and even higher among those ages 80 years and above. In contrast, the proportions of adults with a college degree and who had incomes greater than $100,000 were incrementally larger in the younger age groups. Overall, compared to younger participants, older age groups had progressively higher rates of full food security, higher rates of diabetes, fewer Hispanic and foreign-born participants, more female participants, and fewer people who currently smoked. The prevalence of annual dental visits was higher among adults aged 60 to 80 years compared to participants in the 50 to 60-year age range and those above 80 years of age. Additionally, the age groups with the lowest percentage of annual dental visits also exhibited the highest proportions of adults who had never been to a dentist or had delayed a dental visit for more than 5 years.

Table 2.1. Baseline characteristics from 2015-2018 NHANES dentate participants stratified by age*

	Total		Age 50-59		Age 60-69		Age 70-79		Age 80+	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*
Presence of untreated dental caries (Dependent variable)	24.5	*1.5*	24.7	*2.1*	24.9	*1.9*	22.3	*2.1*	26.8	*3.0*
Most recent dental visit										
Within the past 12 months	68.1	*1.8*	61.1	*2.5*	73.5	*2.7*	74.0	*2.0*	69.8	*2.4*
Between 1-5 years	21.5	*1.4*	26.8	*1.9*	17.8	*2.1*	17.2	*1.5*	19.3	*1.6*
More than 5 years, or never	10.3	*0.8*	12.1	*1.2*	8.7	*1.1*	8.8	*1.1*	10.9	*1.9*
Had an unmet dental care need in past year	16.1	*1.2*	20.3	*1.9*	14.8	*1.6*	12.5	*1.2*	8.9	*1.1*
Level of education										
High school or less	35.5	*1.5*	34.8	*2.5*	33.6	*2.2*	36.4	*2.3*	44.4	*2.8*
Some college	31.2	*1.3*	33.2	*1.7*	30.6	*2.4*	29.0	*2.3*	28.5	*2.2*
College graduate	33.3	*2.0*	32.0	*2.7*	35.8	*2.9*	34.6	*3.1*	27.1	*2.4*
Income level										
<$20,000	14.7	*0.9*	14.1	*1.2*	14.6	*1.5*	13.6	*1.9*	20.0	*2.1*
$20,000-$74,999	44.6	*1.5*	38.8	*2.0*	45.1	*2.3*	50.8	*2.8*	57.8	*3.1*
$75,000-99,999	12.6	*1.1*	14.0	*1.6*	12.3	*2.4*	12.9	*2.6*	6.5	*1.7*
$100,000+	28.1	*2.1*	33.1	*2.7*	27.9	*2.7*	22.7	*2.8*	15.7	*3.0*
Food security										
Full food security	78.2	*1.4*	71.8	*2.1*	81.0	*2.0*	84.1	*1.9*	87.1	*1.6*
Marginal food security	8.7	*0.9*	11.0	*1.3*	7.3	*1.1*	7.0	*1.3*	6.6	*1.5*
Low food security	7.4	*0.6*	9.7	*1.1*	6.1	*0.7*	5.9	*1.0*	5.0	*1.7*
Very low food security	5.6	*0.5*	7.6	*0.9*	5.6	*1.3*	3.0	*0.7*	1.3	*0.5*
Gender										
Female	53.1	*0.7*	51.3	*1.5*	52.6	*1.4*	54.6	*2.1*	60.4	*1.7*
Male	46.9	*0.7*	48.7	*1.5*	47.4	*1.4*	45.4	*2.1*	39.6	*1.7*
Race/ethnicity & nativity										
U.S.-born Hispanic	3.9	*0.5*	5.0	*0.6*	3.3	*0.7*	3.5	*0.7*	2.1	*0.5*
Foreign-born Hispanic	7.0	*0.9*	9.4	*1.2*	5.9	*0.8*	5.2	*1.0*	2.7	*0.7*
Non-Hispanic White	71.3	*2.3*	64.9	*2.6*	73.1	*2.4*	76.8	*2.6*	84.1	*1.9*
Non-Hispanic Black	9.3	*1.1*	11.1	*1.3*	9.3	*1.3*	7.1	*1.0*	5.7	*1.2*
Non-Hispanic Asian	4.8	*0.7*	5.2	*0.9*	4.7	*0.7*	4.5	*1.0*	3.7	*1.1*
Other race or multiracial	3.6	*0.6*	4.4	*0.8*	3.6	*0.9*	2.8	*0.8*	1.7	*0.6*
Length of stay in the U.S.										
U.S.-born	84.1	*1.4*	81.0	*1.7*	86.1	*1.5*	85.1	*1.8*	90.0	*1.9*
non-U.S. born, <15 yrs	1.8	*0.3*	2.5	*0.7*	1.2	*0.2*	1.7	*0.6*	0.7	*0.3*
non-U.S. born, 15+ yrs	14.1	*1.3*	16.5	*1.6*	12.7	*1.4*	13.2	*1.5*	9.3	*2.0*

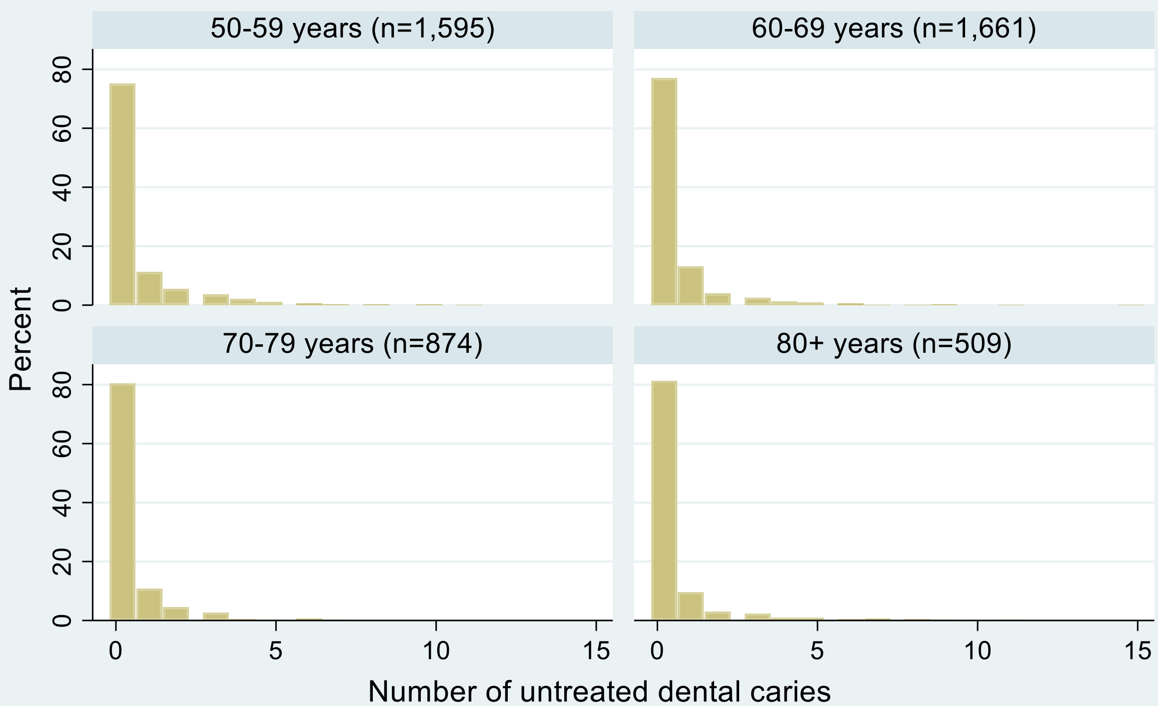
Table 2.1 continued

Occupation status										
Employed	48.3	*1.1*	74.5	*1.7*	43.9	*1.7*	14.8	*1.3*	8.5	*1.4*
Not employed	16.7	*1.0*	21.5	*1.7*	16.9	*2.0*	9.1	*1.5*	8.3	*1.5*
Retired	35.0	*1.3*	4.0	*0.8*	39.3	*2.3*	76.2	*2.0*	83.2	*2.0*
Health insurance status										
Private	71.9	*1.5*	70.7	*1.8*	71.3	*2.6*	74.3	*2.3*	75.4	*2.1*
Public	21.0	*1.1*	17.9	*1.3*	22.7	*2.1*	24.1	*2.3*	23.3	*2.1*
No insurance	7.1	*0.9*	11.4	*1.4*	6.0	*1.2*	1.5	*0.5*	1.3	*0.7*
Has diabetes	19.0	*0.9*	14.2	*1.6*	20.7	*1.9*	26.0	*1.6*	21.7	*2.1*
Daily flossing										
0 days	22.3	*1.0*	20.1	*1.2*	23.2	*1.9*	22.0	*1.7*	30.7	*2.2*
1 to 6 days	36.1	*1.1*	40.3	*1.6*	35.0	*1.9*	32.6	*2.5*	26.5	*2.6*
7 days	41.6	*1.3*	39.6	*1.6*	41.7	*2.5*	45.3	*2.6*	42.8	*2.5*
Smoking status										
Never smoked	54.8	*1.3*	57.3	*2.2*	50.9	*2.3*	54.4	*2.1*	58.8	*2.5*
Former smoker	32.1	*1.0*	24.6	*1.5*	36.4	*2.2*	38.8	*2.1*	38.0	*2.4*
Current smoker	13.1	*0.7*	18.1	*1.4*	12.8	*1.2*	6.8	*0.9*	3.3	*0.8*
N	4,639		1,595		1,661		874		509	

*Percentages for analytic sample were imputed and calculated with NHANES sampling weights to reflect the national U.S. adult population.

Figure 2.2 illustrates the distribution of untreated dental caries, presented through histograms, and organized by age groups. The values along the X-axis that represented untreated dental caries ranged from zero to 15 teeth. Across all age categories, most participants had zero untreated dental caries. Having one carious tooth was the next highest frequency in all age groups (approximately 10%), while the percentage of participants with two untreated dental caries ranged from three to four percent. Fewer than two percent of participants had more than six untreated dental caries across all age categories.

Figure 2.2. Histograms of counts of untreated dental caries by age group*



*Data come from the sample population of dentate adults ages 50 years+ from NHANES 2015-18 (n=4,639); no sampling weights applied.

Bivariate results

Figure 2.3 illustrates four different sets of bivariate results that are related to each hypothesis in Study 2. The first two panels depict the bivariate results of the SES variables (income and education, respectively). Both Panel 1 and Panel 2 show that participants with lower levels of income and education had the highest percentages of untreated dental caries. These differences in oral health outcomes by SES appear on a gradient. For example, only about 11% of participants in the highest income bracket had untreated dental caries, followed by 15% who earned between $75,000, to $99,999, then 29% with incomes between $20,000 to $74,999, and 44% who had incomes less than $20,000. A similar pattern was observed with education. Individuals with a high school diploma or less had the highest rate of untreated dental caries (34.6%), followed by participants with some college (24.9%), and then college graduates (11.7%).

In Panel 3, differences in untreated dental caries by food insecurity were explored. The data show that greater levels of food insecurity were associated with higher rates of untreated dental caries. This relationship was partially graded. For instance, individuals with full food security had the lowest rates of untreated dental caries (19.3%), while those in the "very low" food security category had the highest proportion of untreated dental caries (47.1%). Those in the "marginal" and "low" food security categories had similar rates of untreated dental caries (42.0% and 41.4% respectively) and were in between the rates of the other two categories.

Last, Panel 4 shows the bivariate association between untreated dental caries and frequency of dental visits. These variables had an inverse association, in which the proportion of adults with untreated dental caries increased as the frequency of dental visits decreased. Only 15.2% of adults who had visited the dentist in the last 12 months had untreated dental caries, in contrast to 38.0% of adults whose most recent dental visit was between one and five years ago, and 57.9% of adults who had never undergone a prior dental examination or whose most recent visit exceeded five years. The directions of all bivariate associations were consistent with their respective hypotheses. Therefore, these analyses were further advanced using multiple logistic regression.

Figure 2.3 Bivariate associations between untreated dental caries and 4 different covariates (income, education, food security, and dental visits) *

Panel 1: Participants with lower income have higher rates of untreated dental caries			
Income level	Has untreated dental caries		
	No	Yes	Total (%)
<$20,000	55.3	44.7	100
$20,000-$74,999	71.3	28.7	100
$75,000-99,999	83.9	16.1	100
$100,000+	89.0	11.0	100
Total (%)	**75.5**	**24.5**	**100**

Panel 2: Participants with lower educational attainment have higher rates of untreated dental caries			
Educational attainment	Has untreated dental caries		
	No	Yes	Total (%)
High school or less	64.9	35.1	100
Some college	75.1	24.9	100
College graduate	87.2	12.8	100
Total (%)	**75.5**	**24.5**	**100**

Panel 3: As food insecurity increases, the rate of untreated dental caries also increases			
Food security	Has untreated dental caries		
	No	Yes	Total (%)
Full food security	80.7	19.3	100
Marginal food security	58.0	42.0	100
Low food security	58.6	41.4	100
Very low food security	52.9	47.1	100
Total (%)	**75.5**	**24.5**	**100**

Panel 4: The rate of untreated dental caries increases as the frequency of dental visits decreases			
Frequency of dental visits	Has untreated dental caries		
	No	Yes	Total (%)
Within the past 12 months	84.8	15.2	100
Between 1 to 5 years	62.0	38.0	100
More than 5 years or never	42.1	57.9	100
Total (%)	**75.5**	**24.5**	**100**

Source: NHANES, 2015-2018

*n=4,639; Survey weights and imputed data used.

Multiple logistic regression results: SES and untreated dental caries

Tables 2.2 and 2.3 present odds ratios across five sequential models with respect to the outcome, the presence of untreated dental caries. These results focus on the estimates of the main SES predictors (income and education). The estimates depicted in Table 2.2 represented the total analytic sample, while those found in Table 2.3 were stratified by age category. These models illustrated how the relationship changed between SES variables and the outcome variable, untreated dental caries, upon the addition of the key mediating covariates (food insecurity and dental visits). The full logistic regression model (Model 5) encompassed all key predictors, including education, income, food insecurity, gender, race/ethnicity, nativity of Hispanic adults, occupation status, health insurance, frequency of dental visits, diabetes, flossing, and smoking.

Education

The first model (controlling for income and education) in Table 2.2 demonstrated that in the total sample, lower levels of education were associated with greater odds ratios (ORs) of having one or more untreated dental caries. Participants with some college had 1.7 times greater odds of having untreated dental caries than those with a college degree, while participants with a high school diploma or lower level of education had 2.4 greater odds of dental caries compared to the same reference group. These coefficients remained mostly the same after the successive inclusion of the mediating variable (food insecurity) in Model 2, the confounding variables in Model 3 (gender, race/ethnicity, and Hispanic nativity), and the socio-structural covariates in Model 4 (health insurance and occupation status). The SES estimates in Model 5 changed more notably after adding the health-related variables (dental visits, diabetes, flossing, and smoking). In this full model, the OR among participants with a high school diploma or less education decreased from 2.2 to 1.3, though it remained statistically significant. Among participants with some college education, the odds ratio for dental caries also declined but was no longer statistically significant in the full model. The reductions in these point estimates indicate that the health-related variables partially explained, or mediated, the observed disparities in untreated dental caries by educational attainment.

The age-stratified estimates for education (shown in Table 2.3) had the same direction of association as those found in the total sample (Table 2.2). However, across all age groups above 60 years, having “some college” was non-significant in Models 1 through 5. In addition, the odds ratios for the group with a “high school or less” level of education were similar in all sequential models until Model 5 variables were added. Those estimates reduced in magnitude and lost statistical significance across almost every age group, except for the 50- to 59-year category (OR: 1.8). Thus, within the full model, education exhibited no association with untreated dental caries among participants over 60 years of age.

Income

In the total population and within most age subgroups, lower income led to greater odds of untreated dental caries. The first model in Table 2.2 shows that participants with incomes less than $20,000 had nearly five times greater odds of having untreated dental caries compared to individuals in the highest income bracket ($100,000 or more). Those who earned between $20,000 to $74,999 had 2.6 greater odds of untreated dental caries compared to the same reference group. Participants in the next income level (between $75,000 to $99,999) showed no statistically significant association between income and untreated dental caries across all models and age categories. Estimates for income gradually decreased after the inclusion of the Model 2 mediating variable (food insecurity), followed by the Model 4 variables (occupation and health insurance) and the health-related variables from Model 5 (dental visits, diabetes, flossing, and smoking). For instance, participants in the total population with incomes less than $20,000 had an OR of 3.5 in Models 2 and 3. The OR for this group declined to 2.7 in Model 4, dropping further to 2.0 in the full model.

Table 2.3 shows the age-stratified estimates for income. In general, only the lowest income group ($20,000 or less) had a statistically significant association with dental caries in all age groups. In the simple model, participants with earnings under $20,000 displayed about three to six times greater odds of having untreated dental caries than participants with incomes above $100,000 (OR: 5.8 for adults between ages 50 to 59 years, OR: 4.6 for adults between ages 60 to 69 years, OR: 2.8 for adults between ages 70 to 79 years, and OR: 4.0 for adults above age 80 years). The variables added from each successive model led to lower values for those point estimates, though they all had the same directions of association. Furthermore, income was no longer statistically associated with untreated dental caries in the 70- to 79-year age group once the control variables from Model 3 were added. The same result occurred among adults between ages 60 to 69 years after the health-related variables in Model 5 were added. Overall, income was associated with untreated dental caries in the full model only among participants in the lowest income level who were in the youngest and oldest age groups (OR: 2.5 for ages 50 to 59 years and OR: 2.7 for adults above 80 years of age).

In summary, SES-driven disparities in untreated dental caries were primarily found among participants within the lowest income and education categories (less than $20,000 and high school or less). The sequential models further revealed that lower income was associated with higher odds of untreated dental caries across all age groups, whereas education exhibited no impact on dental caries within the oldest group of adults. After the integration of the health variables in Model 5, the link between income and dental caries remained statistically significant only within the oldest and youngest age brackets of the sample. The same mediators from Model 5 also eliminated the significant effect of education on untreated dental caries, except among adults between ages 50 and 59 years (OR: 1.8 for adults with a high school degree or less). Thus, the health-related variables introduced in Model 5, including dental visits, had partially mediating effects on the association between SES and untreated dental caries. Overall, the most substantial influence on untreated dental caries was linked to low income among adults over 80 years of age, mirroring comparable income disparities observed in adults between the ages of 50 to 59 years.

Table 2.2. Sequential logistic regression estimates for income and education: Odds ratios of untreated dental caries in the total sample population (n= 4,693)

Models	(1)	(2)	(3)	(4)	(5)
Variables					
Level of education					
High school or less	2.4**	2.2**	2.3**	2.2**	1.6*
Some college	1.7*	1.6*	1.7*	1.6*	1.3
College graduate (reference)					
Income level					
<$20,000	4.7**	3.5**	3.5**	2.7**	2.0*
$20,000-$74,999	2.6**	2.3**	2.3**	2.1*	1.7+
$75,000-99,999	1.4	1.4	1.4	1.3	1.3
$100,000+ (reference)					
Constant	0.1**	0.1**	0.1**	0.1**	0.1**

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; calculations used imputed data and sampling weights.

Table 2.3. Sequential logistic regression estimates for income and education: Odds ratios of untreated dental caries by age

	Age 50-59 years					Age 60-69 years					Age 70-79 years					Age 80+ years				
Models	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
<u>Variables</u>																				
Level of education																				
High school or less	2.9 **	2.7 *	2.7 *	2.6 *	1.8 +	2.6 *	2.3 *	2.4 *	2.3 +	1.8	2.6 *	2.5 *	2.4 *	2.3 *	1.5	1.0	0.9	0.9	0.9	0.7
Some college	2.2 +	2.1 +	2.0 +	2.0 +	1.5	1.5	1.5	1.6	1.5	1.3	1.9	1.8	1.9	1.8	1.3	0.9	0.8	0.8	0.8	0.8
College graduate (reference)																				
Income level																				
<$20,000	5.8 **	4.3 **	4.2 **	3.3 *	2.5 +	4.6 **	2.9 +	3.0 +	2.1	1.6	2.8 +	2.6 +	2.4	2.2	1.5	4.0 *	3.7 *	3.7 *	3.3 *	2.7 +
$20,000-$74,999	3.3 *	2.8 *	2.7 *	2.5 *	2.0	2.6 *	2.2 +	2.3 +	2.1 +	1.8	1.8	1.7	1.7	1.6	1.3	1.5	1.5	1.6	1.4	1.3
$75,000-99,999	1.6	1.5	1.5	1.4	1.5	1.6	1.5	1.6	1.7	1.6	0.8	0.8	0.8	0.7	0.5	1.6	1.6	1.7	1.2	1.1
$100,000+ (reference)																				
Constant	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.1 **	0.2 *	0.2 **	0.2 **	0.4	0.6
N	1,595					1,661					874					509				

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; calculations used imputed data and sampling weights.

Multiple logistic regression results: Food insecurity

Table 2.4 displays the odds ratios of untreated dental caries in the total sample. These results focused on the point estimates related to food insecurity and the frequency of dental visits and were calculated from the same five sequential models. Table 2.5 depicts the same information but stratifies the ORs by age category. In general, the findings from the total sample show that individuals with any level of food insecurity produced greater odds of having untreated dental caries, compared to adults with full food security. The coefficients remained the same in Model 2 and Model 3 but decreased slightly after the addition of the variables from Model 4 and Model 5. In Model 4, the coefficients for "low" and "very low" levels of food security became non-significant, but those representing "marginal" levels of food security remained statistically significant through all successive models, including the full logistic regression model (OR: 1.5).

The age-stratified results in Table 2.5 found that food insecurity did not play a role in predicting untreated dental caries in groups of adults older than 70 years. Within the two younger groups of adults between 50 and 69 years of age, food insecurity was associated with higher odds of untreated dental caries in Model 2. These point estimates decreased minimally in Models 3 and 4. In Model 5, the relationship between food insecurity and dental visits was no longer statistically significant in the 50- to 59-year age group. However, the comprehensive model indicated that adults between ages 60 to 69 years experiencing marginal (OR: 2.0) or very low (OR: 2.1) levels of food security displayed greater odds of untreated dental caries compared to adults of the same age range with secure food access.

Multiple logistic regression results: Frequency of dental visits

The variable pertaining to "most recent dental visit" was integrated into the full model (Model 5) along with the domain of health-related covariates, as illustrated in Table 2.4 and

Table 2.5. Within the total sample, individuals who visited the dentist less frequently exhibited higher odds of having untreated dental caries compared to adults who had undergone a dentist visit within the previous year. Participants who visited a dentist between the past one to five years showed 2.5 times greater odds of untreated dental caries than the reference group. These odds were even greater among adults who delayed a dental visit for more than five years or who had never visited a dentist (OR: 3.7). Similar trends were observed in the age-stratified sample. One exception was observed among the 80+ year age group, in which the least frequent category of dental visits showed a non-significant outcome. Nevertheless, adults within this age category who had not visited a dentist for a period of one to five years displayed about twice the odds of having untreated dental caries compared to those who had a dental visit in the past year. Overall, longer periods spent without visiting a dentist resulted in higher odds of exhibiting dental caries that required fillings.

Table 2.4. Sequential logistic regression estimates for food security and dental visits: Odds ratios of untreated dental caries in the total sample population (n= 4,693)

Models	(1)	(2)	(3)	(4)	(5)
Variables					
Food security	-				
Full food security (reference)					
Marginal food security		1.9**	1.9**	1.7*	1.5*
Low food security		1.7*	1.7*	1.5+	1.2
Very low food security		2.1**	2.1**	1.8*	1.3
Most recent dental visit	-				
Within the past 12 months (reference)					
Between 1-5 years					2.5**
More than 5 years, or never					3.7**
Constant		0.1**	0.1**	0.1**	0.1**

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; calculations used imputed data and sampling weights.

Table 2.5. Sequential logistic regression estimates for food security and dental visits: Odds ratios of untreated dental caries by age

	Age 50-59 years					Age 60-69 years					Age 70-79 years					Age 80+ years				
Models	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Variables																				
Food security	-					-					-					-				
Full food security (reference)																				
Marginal food security		1.8 +	1.8 +	1.7 +	1.6		2.1 *	2.3 *	2.2 *	2.0 *		1.6	1.5	1.4	1.2		1.6	1.5	1.5	1.2
Low food security		1.6	1.8 +	1.6	1.4		1.9 +	2.1 *	1.9 +	1.7		1.0	1.0	0.9	0.6		2.5	2.4	2.7	1.8
Very low food security		1.7	1.7	1.6	1.1		3.1 *	3.3 **	2.8 **	2.1 *		1.2	1.2	1.0	0.8		2.3	2.3	2.3	1.9
Most recent dental visit	-					-					-					-				
Within the past 12 months (reference)																				
Between 1-5 years					2.9 **					2.1 *					4.0 **					1.9 +
More than 5 years, or never					3.5 **					3.9 **					9.1 **					1.7
Constant		0.1 **	0.1 **	0.1 **	0.1 **		0.1 **	0.1 **	0.1 **	0.1 **		0.1 **	0.1 **	0.1 **	0.1 **		0.2 **	0.2 **	0.4	0.6
N	1,595					1,661					874					509				

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; calculations used imputed data and sampling weights.

Discussion

The purpose of Study 2 was to understand the extent to which food security influenced the association between SES and untreated dental caries in dentate older adults. Three hypotheses were tested that were in line with the aims of Study 2. Hypothesis 2.1 posited that lower levels of SES (income and education) were associated with the presence of untreated dental caries, particularly across older subgroups of adults. In Hypothesis 2.2, food insecurity was predicted to increase the likelihood of untreated dental caries, such that higher levels of food insecurity would mediate the relationship between SES and dental caries. Last, Hypothesis 2.3 predicted that routine dental visits were inversely related to the appearance of untreated dental caries and would produce a mediating effect within the SES-dental caries association.

In summary, lower SES increased the odds of untreated dental caries within certain subgroups of older adults. SES disparities in untreated dental caries were primarily found among participants with the lowest income and educational attainment (less than $20,000 and high school or less). After the integration of the health variables in the final sequential model, which included dental visits, the effect sizes for both income and education declined significantly. Consequently, the link between income and dental caries in the full model remained intact only within the oldest and youngest age groups in the sample, whereas education had no statistically significant association with untreated dental caries among adults older than age 60 years. Overall, the results from the full model found that the adults over 80 years of age with incomes below $20,000 had 2.7 times greater odds of having untreated dental caries compared to adults of the same age category who were in the highest income bracket ($100,000+).

In line with past oral health literature, our results found that lower levels of income were associated with an increased probability of untreated dental caries (CDC, 2019a). Unexpectedly, SES disparities for this outcome were not observed among groups of adults between 60 and 79 years of age. Instead, the youngest subgroup of adults from the sample (50 to 59 years) exhibited income-based disparities in dental caries, which were comparable to income disparities observed among adults over 80 years old. These generational variations are important to note. First, the oldest and most impoverished subset of U.S. adults demonstrated the greatest disparity and need for immediate dental treatment on carious teeth. Furthermore, the SES disadvantages in dental caries that were found among middle-aged adults may persist into their later years, potentially escalating into a more urgent public health concern as time progresses. In summary, our findings were partially aligned with this hypothesis, since not all older adults faced disadvantages in dental caries by SES. Nonetheless, income was a significant indicator of concurrent oral diseases, like untreated dental caries, that were prevalent across the oldest and most financially vulnerable segments of the U.S. population.

The findings related to Hypothesis 2.2 confirmed that food insecurity was linked to a greater likelihood of untreated dental caries but exclusively among dentate adults between ages 60 to 69 years. The initial models showed that food insecurity increased the odds of untreated dental caries within the subset of adults between ages 50 to 69 years but not for adults older than 70 years. However, after controlling for health-related variables in the comprehensive model, the effect sizes diminished, and the relationship was no longer statistically significant among adults in the 50- to 59-year age category. The final set of results revealed that dentate adults between 60- to 69-years of age who experienced marginal (OR: 2.0) or very low (OR: 2.1) levels of food security had greater odds of untreated dental caries compared to adults of the same age range with secure food access.

Relatively few studies have explored the subject of food insecurity as a social determinant of untreated dental caries in the older U.S. adult population. Recent investigations across some U.S. and Korean older adult populations have suggested that individuals with food insecurity were twice as likely to exhibit dental caries during dental examinations compared to adults without food insecurity, a pattern that was consistent with the outcomes of this study (Chi et al., 2020). Understanding the influence of food insecurity on oral diseases is of utmost significance in older adulthood. Susceptibility to tooth decay evolves across various life stages and may manifest uniquely among different cohorts of older individuals. In the case of the 60-69-year subgroup, disparities in dental caries due to food insecurity persisted even after accounting for SES. This same age group constitutes a subset of older adults that is most likely to experience food insecurity (Ziliak & Gunderson, 2020). Even though this pattern did not hold true for subsets of adults aged over 70 years, food insecurity still contributes to oral health issues across a large segment of an aging population.

Last, the relationship between frequency of dental visits and untreated dental caries was examined in Hypothesis 2.3. In summary, these findings showed that longer delays in dental check-ups increased the odds of having carious teeth. These patterns were observed across all age groups. Participants whose most recent dental visit occurred between the last one to five years had about double the odds of untreated dental caries compared to adults who visited a dentist in the previous 12 months; these odds were observed in adults between ages 60 to 69 years (OR: 2.1) and adults above 80 years (OR: 1.9). In the 50- to 59-year age group who had the same time gap in dental visits, the odds of having untreated dental caries were about three times as large as the reference group (OR: 2.9), and those odds were four times as large in the 70- to 79-year age category (OR: 4.0). Adults who had never visited a dentist or had postponed a dental appointment for five years or more exhibited even greater odds (ranging from 4 to 9 times the odds) of untreated dental caries compared to the same reference group, except for adults aged above 80 years, where the coefficient for this outcome was not statistically significant. Furthermore, the addition of health-related variables in the full model (Model 5), which included the dental visits variable, led to a reduction in the coefficients of income and education, or in some cases, eliminated their statistical significance. These changes across our sequential models suggest a possible mediating effect by dental visits on the main relationship between SES and untreated dental caries.

Other noteworthy findings emerged after controlling for the nativity of Hispanic adults (see Appendices 2.8 through 2.11). Separating Hispanic groups by nativity status explored whether a Hispanic Health Paradox existed for oral health outcomes, such as untreated dental caries. This subject was investigated in Study 1 with respect to dental care access. Results were inconclusive in the previous study, but findings from Study 2 illustrated significant differences in untreated dental caries by race/ethnicity and nativity among foreign-born Hispanic adults in the 60- to 69-year age group (OR: 0.56) and non-Hispanic Black adults in the 50- to 59-year age group (OR: 2.05). In congruence with one other study on oral health quality of life, Study 2 found that foreign-born Hispanic adults between ages 60 to 69 years had about 44% lower odds of having untreated dental caries compared to non-Hispanic White adults within the same age range (Sanders, 2010). However, it was anticipated that foreign-born Hispanic older adults would encounter worse outcomes for untreated dental caries than their U.S.-born counterparts due to the former group facing elevated social, economic, and language barriers, which hinder access to dental treatment and resources promoting good oral health (Andrade et al., 2020; Wehby et al., 2022). Some scholars argue that the paradox might appear differently in newer birth cohorts if exposures in the host environment, such as diet quality, undergo changes that favor the oral health of people who immigrated more recently (Sanders, 2010). Thus, future research should explore whether nativity status impacts oral health differences across different generations of older adults beyond the present timeframe.

This study had several limitations. First, these data were cross-sectional, limiting the ability to establish causal inference. However, the analytic validity was strengthened by the theoretical foundation that was used to inform the variable selections and justify the conceptual pathways that were modeled in this study. Using a theory-based approach was an important starting point for expanding this topic to populations who are typically overlooked in oral health literature.

A second limitation pertained to the smaller sample sizes for specific subpopulations of dentate older adults, including adults in the oldest age categories, foreign-born adults, and Hispanic adults. Samples sizes of dentate individuals were especially small within the oldest age groups, which may have reduced the ability to detect statistically meaningful associations between food insecurity and untreated dental caries. This was in part due to a higher prevalence of missing teeth within this demographic. Thus, a separate investigation was conducted to obtain an in-depth exploration into the connection between food insecurity and complete tooth loss (refer to Study 3). To account for low response rates in certain demographic groups, NHANES oversampled for racial/ethnic minorities, low-income, and older adults aged 80+ years beginning in the 2011 NHANES cycle (Johnson et al., 2014). This study also addressed the concern of limited sample sizes by pooling across four NHANES waves spanning from 2015 to 2018. Furthermore, survey weights and imputation techniques were also used to alleviate bias and improve model estimates (CDC & NCHS, n.d.a; Rubin, 1996).

A final constraint of this study was the lack of available data on dental insurance. Instead, medical insurance was adopted as a proxy variable to gauge financial access to dental care. Having access to private medical insurance might indicate that participants were also likely to possess dental coverage. In addition, private medical insurance could improve affordability of dental care by offsetting health-related expenses linked to other concurrent health conditions. For future iterations of survey instruments, national surveillance studies could potentially include indicators for dental insurance. This modification would offer a more comprehensive understanding of the role of dental insurance in oral health outcomes.

The goal of this study was to offer a clearer perspective of how specific aspects of SES, such as food insecurity, drive inequitable outcomes for untreated dental caries. The importance of oral health and its structural determinants receives little attention in older adulthood, a stage at which oral health outcomes are most likely to interfere with quality of life and when dental treatment becomes most essential. Although behaviors such as flossing and nutritious diets are linked to better oral health outcomes in older adults, identifying social determinants of oral health is important to mitigate the overwhelming prevalence of untreated dental caries in this population (Marchesan et al., 2020). Unfortunately, the pernicious impact of untreated dental caries combined with the lack of affordability of dental services, including limited benefits offered within public dental insurance programs, keeps older adults at heightened risk for emergency dental treatment, oral pain and discomfort, and elevated dental care costs (Bhoopathi et al., 2021; Kramarow, 2019; Vujicic et al., 2016). Untreated dental caries are devastating health conditions in themselves, but they can evolve into even worse problems that lead to permanent loss of teeth and functional limitations. Thus, prioritizing early treatment and structural-level interventions is important for protecting the oral health of current and future generations.

Study 3: The social and clinical determinants of permanent tooth loss

Abstract

Edentulism (complete tooth loss) is an irreversible condition that impairs oral function and diminishes quality of life. Having a low socioeconomic status (SES) can lead to disproportionate outcomes for major oral diseases in younger adult populations, but little is known about its effects on edentulism in older adulthood. The objective of Study 3 was to assess how social determinants of health such as income, food security, and regular access to dental care differentially impact outcomes for tooth loss among older U.S. adults. The dependent variable was permanent tooth loss, and the primary independent variables were education and income. Data came from the 2013-14, 2015-16, and 2017-2018 National Health and Nutrition Examination Survey (NHANES), a cross-sectional study administered by the National Center of Health Statistics. NHANES collects demographic, health, and nutritional information from a representative sample of 5,000 people in the U.S. every two years. Analyses were restricted to respondents ages 50 years and older at the time of data collection (n=7,861).

Zero-inflated negative binomial regression and logistic regression (represented in a hurdle model) were conducted in the final multivariate analyses. Data were stratified by age category (50-59 years, 60-69 years, 70-79 years, and 80+ years), because the magnitude of association between SES and permanent tooth loss varied across some age groups. Multiple imputation of missing variables and sampling weights were also applied in the final set of results. Key findings showed that lower levels of SES increased the probability of permanent tooth loss, particularly in the oldest age groups with the lowest educational attainment. In addition, participants between ages 60 to 69 years with “low” levels of food security had lower counts of permanent teeth compared to those with full food security, while all adults with “very low” food

security were most likely to experience complete tooth loss. Longer delays in dental visits were also associated with increased probabilities of permanent tooth loss; these outcomes were most salient in participants above 70 years of age for tooth counts, and in adults ages 60 years and older for edentulism outcomes. Permanent tooth loss is a ubiquitous but overlooked public health. Addressing social and modifiable risk factors is important for oral disease prevention, especially among low-resourced older adults.

Introduction

Edentulism (complete loss of permanent teeth) is an irreversible health condition that impairs oral function, causes pain, and reduces quality of life (Emami et al., 2013). Between 2011 and 2016, approximately 17% of adults aged 65 and older experienced complete tooth loss (CDC, 2019b). During this same period, the average number of natural teeth remaining among dentate older adults was 21 out of 28 teeth, assuming no wisdom teeth were still present (CDC, 2019b). Having lower socioeconomic status (SES) is a key fundamental cause of disease (Phelan, Link, and Tehranifar, 2010). Low SES is hypothesized to also be associated with disproportionately worse oral health outcomes within the older U.S. adult population. Previous findings suggest that older adults with lower income have an increased risk of edentulism compared to those with higher income (Seerig et al., 2015; Huang and Park, 2015). Having less income and education restricts access to flexible resources such as health insurance, healthy food sources, oral health education, and annual dental visits (Tiwari et al., 2016; CDC, 2019b). Even though an increased access to those resources likely produces a protective effect against permanent tooth loss in older adults, no current studies have proposed specific mechanisms through which those factors mitigate the effect of SES on tooth loss in older adult populations.

Structural factors such as food security might explain the association between SES and permanent tooth loss in older adulthood. Chronic deprivation of nutritious food sources combined with a high consumption of processed and sugary (and often inexpensive) meals are risk factors for oral infections, which can ultimately lead to complete tooth loss (Bidinotto et al., 2021). A review of the literature shows that only one study has investigated the effect of food security on the oral health needs of U.S. older adults; those findings suggested that older adults with food insecurity were more likely to have an unmet dental care need than those with full food security (Wiener et al., 2018). So far, no current studies have examined the role of food security in permanent tooth loss. Similarly, little is known about how access to oral health care might attenuate the relationship between SES and tooth loss in older adults. Having an annual preventive dental visit can target and treat relatively minor dental problems before they develop into permanent tooth loss. Thus, the frequency of dental care visits may play a salient role in preventing edentulism in older adults.

The purpose of Study 3 aims to better understand structural and clinical pathways that are potentially linked to tooth loss in four age groups of adults (50 to 59 years, 60 to 69 years, 70 to 79 years, and 80+ years). The first aim of this study examined the extent to which low SES increased the risk of permanent tooth loss with older age. The second aim explored whether food insecurity influenced greater risk of tooth loss in older adults, potentially having mediating effect within the main relationship (SES and permanent tooth loss). Lastly, the third aim of this study investigated whether regular access to dental care had a protective effect against permanent tooth loss. The next section provides a literature review on permanent tooth loss in the U.S. and its impact on the general health of older adults. A conceptual model will then outline several key mechanisms that correspond with the study's main research questions and hypotheses. Next, the methods section will define key variables and outline the analytic plan for the study. In the results section, key findings will be highlighted. Last, the discussion at the end of this chapter will present and interpret the main results from the study, summarize the methodological limitations and strengths, and describe the overall contributions of this work to the broader oral health literature.

Literature Review

Trends in permanent tooth loss among older U.S. adults

Edentulism, or the complete loss of permanent teeth, is a serious oral condition that is pervasive in older adulthood. About one in six of adults over 65 years of age have zero permanent teeth (NIH, 2021). This risk rapidly increases with older age, as edentulism is twice as prevalent among adults ages 75 years and older (26%) than adults between 65 to 74 years of age (13%) (Dye et al., 2015). Over the past several decades, rates of edentulism have steadily decreased. Between 2000 and 2016, prevalence of edentulism among older U.S. adults declined from 32% to 17% (NIH, 2021). The rate of edentulism among adults aged 64 to 74 years changed even more dramatically since the 1960's, with a drop in prevalence from 50% to 13% in 2016 (NIH, 2021). Functional dentition, which is defined as having more than 20 teeth, has also improved in the past 20 years (from 31% to 51%). On average, the number of natural teeth among non-edentulous older adults increased from 19 teeth in 1999 to 21 teeth in 2016 (CDC, 2019b). Despite notable strides in oral health over the past fifty years, the average number of missing teeth stands at approximately seven, excluding wisdom teeth (CDC, 2019b). This figure hovers just above the threshold of functional dentition, continuing to have a detrimental effect on daily oral functioning and quality of life. In addition to these prevalence rates, the persistent social and economic disparities in tooth loss also contribute to concerning oral health burdens among older adults in the U.S.

SES disparities in permanent tooth loss

Economic hardship limits access to oral health-related resources, which could increase risks for tooth loss. National surveillance studies have found that U.S. older adults who live in poverty are three times more likely to lose all their permanent teeth compared to those who reside above the poverty threshold (NIH, 2021). Stratification by SES also shows disproportionately worse outcomes in functional dentition among older adults with lower income than those with higher income levels. Over the past 20 years, the prevalence of having a functional dentition increased from 42% to 62% among older U.S. adults living above the poverty line, while older adults residing in poverty only had functional dentition rates improve from 15% to 25% during that same period (NIH, 2021). Furthermore, older adults residing in rural areas with less oral health care infrastructure were more likely to experience higher rates of tooth loss compared to older adults living in urban areas with better access to dental resources (Caldwell et al., 2017). The overall reduction of permanent tooth loss over the past sixty years shows improved prospects for oral health outcomes in older adulthood. Nonetheless, SES gradients are rampant, such that older adults who live in poverty remain at highest risk of edentulism and the health risks associated with this disease.

Health consequences related to tooth loss

Tooth loss is a significant health issue, but it can also be detrimental to other aspects of physical health and well-being. Extensive tooth loss interferes with physical functioning, self-reported general health, communication, and eating (Parker et al., 2020; Zhu & Hollis, 2014). Removable dentures can support some oral functions. However, chewing food with dentures has been found to be less efficient than chewing with natural teeth (Bessadet et al., 2013). Eventually, tooth loss can lead to poorer diet quality and lower nutritional intake among older adults (Zhu & Hollis, 2014). Because tooth loss may restrict healthy dietary patterns, older adults with severe tooth loss or edentulism were found to have elevated risks of obesity and involuntary weight loss (do Nascimento Tôrres, 2013; Kusama et al., 2021; Sheiham et al., 2002). Furthermore, edentulism and tooth loss have been linked with all-cause mortality among older adults with chronic conditions, such as cardiovascular disease and respiratory illnesses (Kotronia et al., 2021). Not only is tooth retention important for cosmetic and functional purposes, but it also impacts risks for other health issues, including premature mortality.

Permanent tooth loss: A culmination of unaddressed oral health issues

One major cause of tooth loss is the progression of untreated oral diseases. Mild signs of tooth decay, for instance, can eventually lead to severe infection, enamel degradation, and complete tooth loss if initial symptoms are not properly recognized and treated (Mayo Clinic, 2022). As a final consequence of oral disease, tooth loss appears more conspicuously in later life stages, since it takes longer than other oral diseases to develop (Dye et al., 2015). Preliminary oral conditions such as untreated dental caries and periodontal diseases are more common than permanent tooth loss, even within older adult populations (Dye et al., 2015; Eke et al., 2018). In addition, older adults with chronic conditions, such as diabetes, asthma, emphysema, heart disease, rheumatoid arthritis, and history of stroke, are the population at highest risk for developing severe tooth loss (defined as having eight or fewer teeth) (Parker et al., 2020). Although intermediate dental problems and chronic diseases increase susceptibility to edentulism, permanent tooth loss is not a fixed outcome in older adulthood. Permanent teeth may be preserved with appropriate clinical interventions and regular access to oral health resources. Yet, the distribution and availability of such resources are not always equitable.

Oral conditions are socially patterned, such that many of the same social factors that shape oral diseases like dental caries also influence permanent tooth loss. For instance, longitudinal findings from Swedish populations have found that SES disadvantages across the life course increased the likelihood of tooth loss with older age; these results resembled the associations between low childhood SES and increased risk of dental caries among middle-aged adults from New Zealand (Ramsay et al., 2018; Thomson et al., 2004). Within a sample of older adults from a community in rural Colorado, tooth loss was associated with older age, lower SES, having no dental insurance, and infrequent preventive dental visits (Tiwari et al., 2016). National trends for dental caries among older U.S. adults also followed similar patterns (CDC, 2019a; Dye et al., 2015). Underlying social drivers of oral health, such as SES, likely shape both tooth loss and clinical precursors to tooth loss.

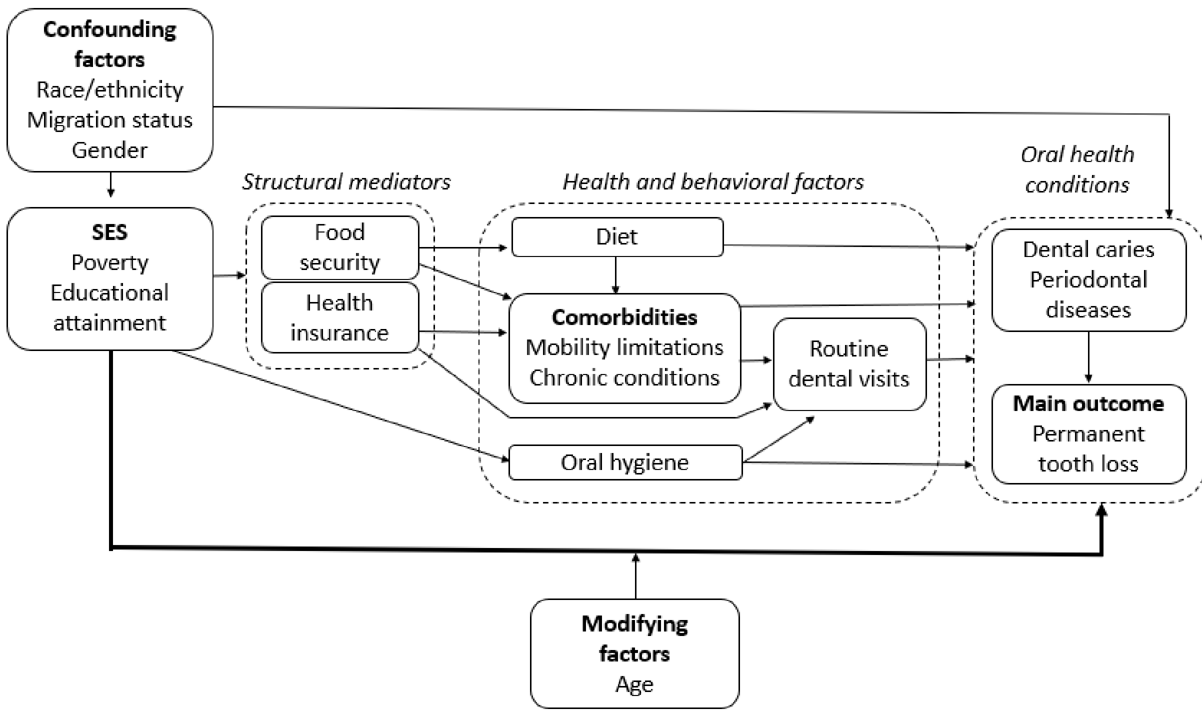
The racial/ethnic differences in tooth loss are not consistent with the disparities observed in outcomes for dental caries. For instance, non-Hispanic Black older adults were twice as likely to have complete loss of permanent teeth compared to non-Hispanic White or Mexican American older adults (Dye et al., 2015). Outcomes for dental caries, on the other hand, show that both Hispanic and non-Hispanic Black older adults had disproportionately higher rates of untreated dental caries compared to other racial/ethnic groups (NIH, 2021). Based on these data, we might expect poorer outcomes for tooth loss among Black older adults compared to other racial/ethnic groups, whereas Hispanic older adults might have relatively better outcomes for tooth loss, despite having higher rates of dental caries. So far, the literature for tooth loss among U.S. older adults is scarce and has produced mixed results on the association of race/ethnicity on tooth retention, even after controlling for SES (Caldwell, 2017; Lee et al., 2022a). Ultimately, racial/ethnic inequities are not the same across all types of oral conditions. These discrepancies warrant further investigation by examining how other salient factors, such as nativity of Hispanic groups, food insecurity, chronic conditions, and use of dental services, shape outcomes related to tooth loss in older adulthood.

In summary, the social consequences of different oral diseases are not homogenous. That is, each oral health outcome produces different health burdens across different subpopulations of older adults. Even though dental caries and tooth loss largely share the same etiology and are detrimental to oral health and overall physical health, tooth loss has a more prolonged onset. It may also be a result of more advanced forms of oral diseases, which are more expensive to treat than fillings for smaller dental cavities. Thus, the degree to which SES impacts dental caries or gum disease may not be identical to its effect on tooth loss after considering how other factors change the severity and progression of oral diseases over time. The role of various social, health, and age-specific factors on outcomes for tooth loss is largely unknown but will be explored further in this present study.

Conceptual Model

Figure 3.1 shows a conceptual model that represents the mechanisms and corresponding research questions for Study 3. A boldened arrow highlights the main relationship between SES variables (educational attainment and poverty status) and the dependent variable, permanent tooth loss. The figure shows that age modifies the main relationship, and that possible confounding occurs by race/ethnicity, migration status, and gender. Two sets of mediating variables are located between the main variables. These mediating variables are categorized as either (1) structural mediators (food security and health insurance) and (2) health and behavioral mediators (diet, mobility limitations, chronic conditions, oral hygiene, and routine dental visits). Overall, SES influences the structural mediators, and the structural mediators influence the health and behavioral mediators. All health and behavioral mediators have a direct effect on the domain labeled "oral health conditions," which consist of dental caries, periodontal diseases, and permanent tooth loss. The last arrow in the model shows that within the oral health conditions domain, preliminary oral conditions (periodontal diseases and dental caries) influence outcomes for permanent tooth loss, which is labeled as the main outcome variable in Study 3.

Figure 3.1. Conceptual model of Study 3: The association between SES and permanent tooth loss among older U.S. adults with mediation by key structural and clinical factors.



Research Questions:

3.1. Are the observed differences in permanent tooth loss across four age groups of adults (50-59 years, 60-69 years, 70-79 years, and 80+ years) explained by lower SES (poverty and education)?

3.2. To what extent does food insecurity explain disadvantages in permanent tooth loss among older adults, after accounting for SES?

3.3. To what degree do routine dental visits mitigate the impact that low-SES has on permanent tooth loss across different age groups of older adults?

Hypotheses:

3.1. Lower SES is associated with a higher risk of permanent tooth loss. This association is moderated by age, such that the magnitude of this association increases across older age groups.

3.2. Food insecurity is associated with permanent tooth loss and partially mediates the primary association between SES and permanent tooth loss.

3.3. Having a regular dental visit is inversely associated with permanent tooth loss, partially mediating the primary association between SES and permanent tooth loss.

Methods

Data collection and key variables

The data used for this study came from the 2013-14, 2015-16, and 2017-18 National Health and Nutrition Examination Survey (NHANES), a cross-sectional study administered by the National Center of Health Statistics. NHANES collects demographic, health, and nutritional data from a nationally representative sample of approximately 5,000 people in the United States every two years. Self-reported data and physical examination results were collected by trained interviewers and licensed medical personnel. Oral health data for untreated dental caries and missing teeth were collected from the NHANES mobile examination centers (MEC). The resulting sample size of adults over age 50 years across the three NHANES cycles was 7,861 participants. This dissertation study was approved by the UCLA Institutional Review Boards (IRBs).

Permanent tooth loss was the dependent variable for this analysis. Individual tooth counts were collected during the MEC oral health examinations (see Study 2 methods for more information on the MEC variables). Permanent teeth were numbered one through 32 and were individually classified as being either present, lost, partially lost, or with dental implants (CDC & NCHS, 2018). Teeth marked as "present" were summed to calculate the total number of teeth present per individual. Thus, the total possible sum of teeth present ranged from 0 to 32 teeth for each participant. The counts data were also collapsed into a dichotomous variable (complete tooth loss vs. no complete tooth loss) because of inflated responses for "0 teeth present" in older age groups (more details on the distribution of tooth counts are provided in the Figure 3.2-3.3 results). Overall, no respondents who participated in the MEC dental examination had missing information for the dependent variable, counts of permanent teeth.

Income and educational attainment were the main independent variables for Study 3. The collection and operationalization of income, education, and other covariates (age, gender, race/ethnicity, nativity, health insurance, occupation status, diabetes, smoking, and flossing) were described in the methods section of Study 1. Details on food insecurity and frequency of dental visits were described in Study 2. In Study 3, the income variable had the highest proportion of missing respondents from the sample population of adults ages 50 years and older (9.8%, or n=767). Diabetes had 331 (4.2%) missing responses and food insecurity had 227 (2.9%) missing responses. All other covariates (education level, dental visits, race/ethnicity, insurance type, occupation status, flossing, and smoking) each had fewer than 0.3% of observations missing from the sample population. Age and gender had no missing responses.

Statistical Analyses

The sample population consisted of MEC participants ages 50 years and older from the 2013-14, 2015-16, and 2017-18 NHANES cycles (n=7,861). About 1,164 participants (or 14% of the sample population) had missing information for at least one variable of interest. Patterns of missing variables are explored in Appendix 3.1. From these trends, we found that income had the highest proportion of missing observations (6% of the total sample), followed by diabetes (4%). About 3% of observations had missing information for both income and food insecurity. Patterns of missingness across the other variables did not show any outstanding evidence of bias. A possible correlation was suspected between food insecurity and income, given that food insecurity is contingent on income, as observed by the co-occurring missing data for both income and food insecurity.

Before checking for correlation patterns, the baseline characteristics of missing observations in the sample were examined. The distribution of variables in a complete case sample was compared with the variable distribution of participants with one or more missing responses (see Appendix 3.2). Chi-squared tests were used to detect statistically significant differences between the two subsamples. Results showed that a higher proportion of foreign-born Hispanic adults were represented in the excluded sample (10.8%) than in the complete case sample (5.7%). A similar discrepancy was found among foreign-born participants with 15+ years of residence in the U.S., as 19.3% of this subgroup were represented in the missing subsample while 12.3% were in the complete case subsample. Due to the significant differences between the complete case sample and the missing subsample, coupled with a high proportion of missing responses for income (10%), a complete-case analytical approach was not selected for this study. About 14% of the total sample (n=1,164) had one or more missing data points, which were estimated using multiple imputation (Rubin, 1996). NHANES survey weights were also applied to the final sets of results to account for the NHANES sampling design and to adjust for nonresponse bias (CDC & NCHS, n.d.a).

The next set of sensitivity analyses explored the potential correlation between food insecurity and income (see Appendices 3.3-3.4). In Appendix 3.3, three logistic regression models for the outcome of complete tooth loss compared changes in the odds ratios upon the inclusion of either (1) food insecurity, (2) income, or (3) both food insecurity and income to a model with demographic variables only (education, sex, race/ethnicity, Hispanic nativity). Appendix 3.4 conducted the same model tests but compared outcomes for tooth counts using zero-inflated negative binomial (ZINB) regression. A decrease in magnitude or loss in statistical significance for food insecurity in the full model would suggest that the effects observed by food insecurity in the simple model were explained by the association between income and the dependent variable.

The results for income were similar in both the logistic and the ZINB regression models. The income coefficients declined slightly but had similar magnitudes in the full and simplified models; the coefficients also remained statistically significant across all models. In the logistic regression model in Appendix 3.3, food insecurity was statistically significant in the simple model but not in the full model with income. The ZINB regression models in Appendix 3.4 produced similar non-significant results for food insecurity in the full model, except among those within the category of “low food security.” The coefficient for “low” food security decreased (from -0.10 to -0.05) but maintained statistical significance in the full ZINB regression model with income. While food insecurity exhibited correlation effects in the logistic regression model, the ZINB regression model revealed that some levels of food insecurity may have an association with tooth loss, independent of income. Thus, both income and food insecurity were kept in the final set of ZINB regression results. Collinearity was also tested. Each covariate had a variance inflation factor score below the standard cutoff point of 2.5, confirming that the variables in the full model were not collinear.

Additional sensitivity analyses tested the possible interaction between age and SES variables in a binary logistic regression model for complete tooth loss (see Appendix 3.5). The potential interaction by gender and SES was also tested. Model 1 controlled for income, education, and gender. Models 2 through 5 included the variables from the simple model with the inclusion of an age-related interaction term. Model 2 included an interaction term between age and education, Model 3 modeled an interaction between age and income, and Model 4 had an interaction term between age and gender. The results from Appendix 3.5 showed that no age-education interactions were statistically significant in Model 2, but individuals with lower levels of income exhibited a significant interaction with age in Model 3. In Model 4, no significant interaction effects on tooth loss were found between age and gender. Furthermore, the addition of the age-education interaction term in Models 2 did not improve model fit relative to the simple model (Model 1), while Models 3 and 4 did show an improvement in model fit with the inclusion of their respective interaction terms. Although a few significant age-SES interactions were detected, a more parsimonious model without interactions was chosen over a model that contained one or more interaction terms that included age. Therefore, the data were stratified by age in the final multivariate models. This approach also provided information on age-related differences across other characteristics, such as food insecurity or diabetes, and their distinct influences on tooth loss within specific age groups.

Baseline characteristics of the total sample were analyzed using weighted and imputed data. Results were stratified by age using the following categories: 50 to 59 years, 60 to 69 years, 70 to 79 years, and 80 years or older (see Table 3.1). Histograms were then used to explore the distributions of the tooth counts within the total population (including edentulous participants) and within the dentate population only (see Figures 3.2 -3.3). Next, bivariate relationships (shown in Figure 3.4) were explored between the binary outcome for complete tooth loss, and each of the four covariates related to the Study 3 hypotheses: education, income, food insecurity, and frequency of dental visits.

In the final multivariate analysis, both a binary outcome (complete tooth loss: yes or no) and a counts outcome for the number of teeth present were investigated within a hurdle model. First, a sensitivity analysis examined the binary outcome only (complete tooth loss) using stepwise binary logistic regression in the total population (see Appendix 3.6). From these results, we observed that having a low educational attainment and less frequent dental visits were associated with complete tooth loss and that the full model had the best goodness-of-fit. Next, a full model with the counts data was tested for overdispersion; this test determined whether a zero-inflated Poisson (ZIP) regression or a zero-inflated negative binomial (ZINB) regression was most appropriate for modeling the dependent variable (see Appendix 3.7). A significant p-value was found across all age groups for the dispersion parameter, alpha, indicating that a ZINB regression provided a better model fit than a ZIP regression.

Variables were added incrementally across five ZINB regression models, based on their arrangement in the conceptual model depicted in Figure 3.1. Model 1 controlled for income and educational attainment, which were the main SES variables. Model 2 incorporated the SES variables from the previous model plus the main mediating variable, food security. Model 3 included the variables in the previous models and the confounding variables, which were gender, race/ethnicity, and nativity of Hispanic older adults. Health insurance and occupation status were added to Model 4. Last, Model 5 was the full model that incorporated all variables from the previous models and added the health-related variables (diabetes, flossing, smoking status, and frequency of dental services). Reference groups were chosen for their large sample sizes or advantageous socioeconomic standings. Additionally, they represented the highest tier within ordinal variables to display gradients in their changing coefficients for tooth loss. Log-likelihood, Akaike's Information Criterion (AIC), and Bayesian Information Criterion (BIC) tests informed goodness-of-fit of the final model.

Last, the sequential models were fit into a ZINB regression for the total sample and separately by age group. Each set of results was then organized into hurdle models, which classified the coefficients into a binary component (complete tooth loss vs. no complete tooth loss) and a counts component that predicted the average number of present teeth (see Appendices 3.8-3.12). The hurdle model results for the SES variables (income and education) were grouped into separate tables for the total population (Table 3.2) and by each stratified age group (Table 3.3). The coefficients for food insecurity and dental visits were also imported into their own tables for the total population (Table 3.4) and by age category (Table 3.5). These results were isolated from the general set of results because of their relevance to the hypotheses for Study 3. Sampling weights and multiple imputation data were applied in the final analyses per NHANES analytic guidelines (CDC & NCHS, n.d.a; Rubin, 1996). All analyses were conducted using STATA version SE/15.1 statistical software.

Results

Univariate results

Table 3.1 shows the weighted and imputed baseline characteristics of the analytic sample, consisting of U.S. adults ages 50 years and older (n=7,861). Results were stratified by age group (50 to 59 years, 60 to 69 years, 70 to 79 years, and 80+ years). In the total sample, about 10% of participants had complete tooth loss, while the average number of permanent teeth recorded for each participant was 20.6 teeth out of 32 teeth (or out of 28 teeth, excluding wisdom teeth). Other dental-related characteristics showed that only 65% of the total sample had a dental visit in the past 12 months, 37% flossed daily, and 30% did not floss at all in the past week. Regarding SES factors, about 38% of participants had a high school education or less, 46% had an income between $20,000 and $74,999, approximately 46% were employed, and 79% had full food security. In terms of other demographic and health characteristics, a majority of the sample identified as female (52.9%), non-Hispanic White (72.5%), U.S.-born (85.3%), and had access to private insurance (69.7%). Furthermore, 80.5% of participants had no diagnosis of diabetes, and 52.1% reported no history of smoking.

Comparing these characteristics by age group, we found that the average number of permanent teeth incrementally decreased by age group, from 23.2 teeth among 50- to 59-year-olds, to 20.5 teeth among 60- to 69-year-olds, 18.1 teeth among 70- to 79-year-olds, and 15.1 teeth among adults ages 80 years and older. Similarly, the rates of edentulism increased across older age groups. The rate of complete tooth loss nearly doubled in adults between ages 50 to 59 years (4.9%) and 60 to 69 years (9.8%). Approximately 16% of adults ages 70 to 79 years were edentulous, while adults above 80 years of age had the highest rate of complete tooth loss (21.0%). Other notable differences by age group indicated that the proportions of non-Hispanic

White adults, female participants, rates full food security, those with a high school diploma as their highest education level, and those earning less than $20,000 per year, increased progressively in older age brackets. Furthermore, in comparison to younger participants, older participants exhibited higher rates of diabetes, were less likely to be current smokers, and were more prone to delaying a dental visit for five years or longer, including those who had never visited a dentist.

Table 3.1. Baseline characteristics from 2013-2018 NHANES participants stratified by age group*

	Total		Age 50-59		Age 60-69		Age 70-79		Age 80+	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*
Has complete tooth loss (Dependent variable)	10.0	*0.8*	4.9	*0.7*	9.8	*1.0*	15.8	*1.4*	21.0	*1.8*
Mean number of teeth present	*20.6*	*0.3*	*23.2*	*0.3*	*20.5*	*0.3*	*18.1*	*0.4*	*15.1*	*0.5*
Number of teeth present (quartiles)										
0 to 10 teeth	19.2	*1.0*	10.6	*1.1*	19.2	*1.3*	27.8	*1.9*	38.6	*2.0*
11 to 22 teeth	23.6	*0.8*	20.2	*1.3*	24.2	*1.6*	27.3	*1.5*	28.8	*1.7*
23 to 27 teeth	32.0	*0.9*	34.8	*1.5*	32.8	*1.5*	29.1	*1.5*	23.3	*1.7*
28 to 32 teeth	25.2	*0.9*	34.4	*1.4*	23.8	*1.5*	15.8	*1.3*	9.3	*1.2*
Most recent dental visit										
Within the past 12 months	64.8	*1.4*	61.9	*1.8*	68.2	*1.9*	66.8	*1.9*	61.4	*2.0*
Between 1-5 years	21.2	*0.9*	24.9	*1.4*	18.9	*1.3*	18.5	*1.2*	19.3	*1.4*
More than 5 years, or never	14.0	*0.9*	13.2	*1.1*	12.9	*1.2*	14.8	*1.2*	19.3	*1.6*
Had an unmet dental care need in past year	15.0	*0.9*	19.2	*1.3*	14.4	*1.3*	10.9	*0.8*	7.6	*0.9*
Level of education										
High school or less	38.1	*1.3*	35.7	*2.1*	36.8	*1.8*	40.3	*1.6*	48.2	*2.2*
Some college	30.8	*1.0*	32.1	*1.5*	30.8	*1.8*	30.0	*1.6*	26.7	*1.5*
College graduate	31.1	*1.5*	32.2	*2.2*	32.4	*2.1*	29.7	*2.1*	25.1	*2.0*
Income level										
<$20,000	17.4	*1.1*	15.9	*1.4*	16.1	*1.2*	19.0	*1.8*	24.9	*1.9*
$20,000-$74,999	45.7	*1.1*	39.2	*15.5*	47.3	*1.9*	51.1	*2.2*	57.1	*2.3*
$75,000-99,999	11.3	*0.8*	12.9	*1.2*	11.2	*1.7*	11.0	*1.7*	5.8	*1.0*
$100,000+	25.6	*1.6*	32.1	*2.2*	25.5	*2.0*	18.9	*2.0*	12.3	*2.0*
Food security										
Full food security	78.6	*1.0*	73.3	*1.6*	80.4	*1.4*	82.4	*1.4*	87.0	*1.1*
Marginal food security	8.4	*0.6*	10.0	*0.9*	7.5	*0.8*	7.2	*1.1*	6.6	*1.0*
Low food security	7.4	*0.5*	9.5	*0.9*	6.2	*0.6*	6.4	*0.8*	4.5	*1.1*
Very low food security	5.7	*0.4*	7.3	*0.7*	5.9	*0.9*	3.9	*0.5*	1.9	*0.6*
Gender										
Female	52.9	*0.6*	51.0	*1.1*	52.1	*1.1*	54.8	*1.5*	59.6	*1.4*
Male	47.1	*0.6*	49.0	*1.1*	47.9	*1.1*	45.2	*1.5*	40.4	*1.4*
Race/ethnicity & nativity										
U.S.-born Hispanic	3.6	*0.5*	4.6	*0.6*	3.3	*0.5*	3.1	*0.5*	1.9	*0.5*
Foreign-born Hispanic	6.3	*0.7*	8.0	*0.9*	6.0	*0.7*	5.1	*0.8*	2.9	*0.6*
Non-Hispanic White	72.5	*1.8*	67.6	*2.0*	73.4	*2.0*	75.6	*2.0*	83.5	*1.7*
Non-Hispanic Black	9.9	*1.0*	11.3	*1.1*	10.0	*1.1*	8.5	*1.0*	7.0	*1.1*
Non-Hispanic Asian	4.4	*0.5*	4.7	*0.7*	4.4	*0.5*	4.5	*0.7*	3.1	*0.7*
Other race or multiracial	3.2	*0.4*	3.8	*0.6*	2.9	*0.6*	3.3	*0.6*	1.6	*0.4*
Length of stay in the U.S.										
U.S.-born	85.3	*1.0*	82.9	*1.3*	86.6	*1.1*	85.8	*1.4*	90.1	*1.2*
non-U.S. born, <15 yrs	1.5	*0.2*	2.0	*0.4*	1.1	*0.2*	1.5	*0.4*	0.8	*0.2*
non-U.S. born, 15+ yrs	13.2	*0.9*	15.1	*1.2*	12.3	*1.0*	12.6	*1.2*	9.2	*1.2*

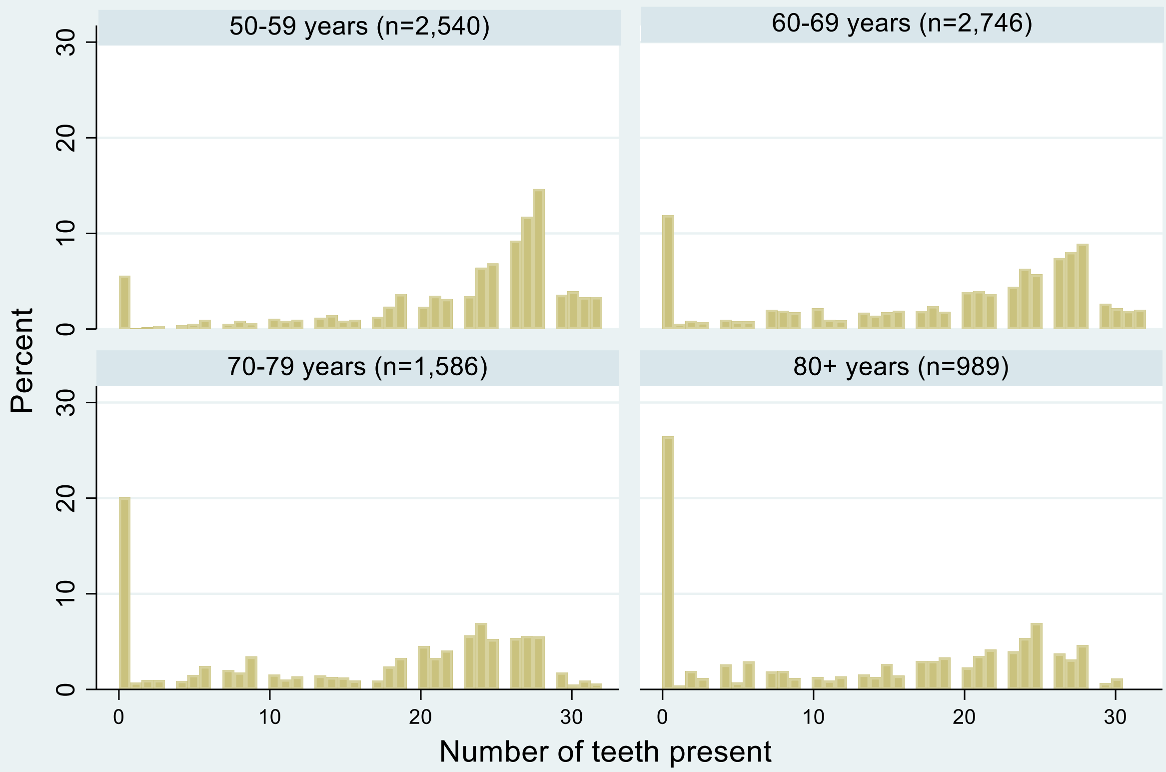
Table 3.1 continued

Occupation status										
Employed	45.8	*1.0*	72.0	*1.7*	43.1	*1.4*	14.3	*1.0*	6.3	*0.8*
Not employed	18.2	*0.9*	24.5	*1.7*	18.4	*1.4*	9.5	*1.1*	7.6	*0.9*
Retired	36.1	*0.9*	3.5	*0.6*	38.4	*1.6*	76.2	*1.4*	86.1	*1.2*
Health insurance status										
Private	69.7	*1.2*	69.9	*1.6*	69.6	*1.8*	69.3	*2.0*	70.0	*2.0*
Public	22.6	*0.9*	17.5	*1.0*	23.5	*1.6*	28.8	*1.9*	28.5	*1.9*
No insurance	7.8	*0.6*	12.6	*1.2*	6.9	*0.9*	2.0	*0.5*	1.5	*0.5*
Has diabetes	19.5	*0.7*	14.2	*1.2*	21.9	*1.3*	25.7	*1.2*	21.5	*1.3*
Daily flossing										
0 days	29.9	*1.0*	24.9	*1.1*	29.4	*1.5*	34.6	*1.3*	44.0	*2.1*
1 to 6 days	32.7	*0.8*	38.6	*1.3*	32.8	*1.5*	26.6	*1.8*	20.3	*1.5*
7 days	37.3	*1.1*	36.6	*1.3*	37.8	*2.0*	38.8	*1.9*	35.7	*2.4*
Smoking status										
Never smoked	52.1	*1.0*	54.6	*1.7*	47.6	*1.7*	51.8	*1.6*	57.0	*2.3*
Former smoker	33.0	*0.8*	24.9	*1.1*	37.4	*1.7*	39.1	*1.6*	40.0	*2.1*
Current smoker	14.9	*0.8*	20.5	*1.4*	14.9	*0.9*	9.1	*0.9*	3.0	*0.6*
N	7,861		2,540		2,746		1,586		989	

*Percentages for analytic sample were imputed and calculated with NHANES sampling weights to reflect the national U.S. adult population.

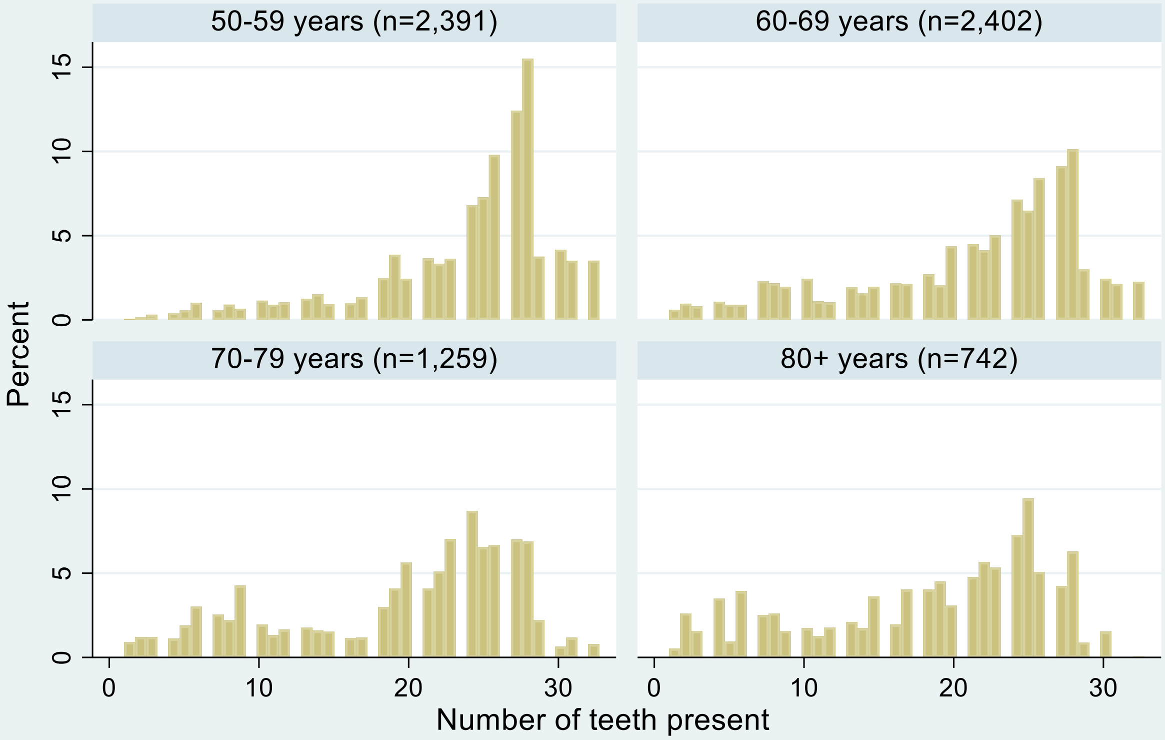
Figure 3.2 and Figure 3.3 depict the histogram distributions of the number of permanent teeth categorized by age group. Figure 3.2 represents the percentages of teeth in the entire sample population, encompassing both edentulous and dentate individuals. Meanwhile, Figure 3.3 displays the distribution exclusively for participants with one or more permanent teeth. In Figure 3.2, the distributions ranged from zero to 32 teeth. Notably, zero permanent teeth had the highest proportion among adults over 60 years, with an increasing gradient across older age groups. The range of values in Figure 3.3 was one to 32 teeth. Both sets of histograms indicated that most dentate adults had between 23 to 27 teeth. The quartiles of teeth distributions within the weighted sample (see Table 3.1) presented comparable outcomes.

Figure 3.2. Histograms of teeth present in total sample, stratified by age group*



Data come from the sample population of adults ages 50+ years from NHANES 2013-2018 (n=7,861); no sampling weights applied.

Figure 3.3. Histograms of teeth present within dentate population, stratified by age*



Data come from the sample of dentate adults ages 50+ years from NHANES 2013-2018 (n=6,794); no sampling weights applied.

Bivariate results

Figure 3.4 presents four sets of bivariate associations, each corresponding to the hypotheses in Study 3. The first two panels show the percentages of complete tooth loss according to SES categories (income and education, respectively). These panels demonstrate that groups with higher levels of income and education had lower proportions of complete tooth loss. Additionally, a gradient pattern was observed in these trends. For instance, fewer than 3% of participants in the highest income bracket had complete tooth loss, followed by 4% for those earning between $75,000 to $99,999, then 11% of respondents with incomes between $20,000 to $74,999, and 23% for those earning less than $20,000. In terms of educational attainment, individuals with a high school diploma or less showed the highest rate of complete tooth loss (18.0%), followed by participants with some college education (8.1%), and then college graduates (2.2%).

The next panel (Panel 3) illustrates the bivariate association between food insecurity and complete tooth loss. In general, individuals experiencing higher levels of food insecurity demonstrated higher rates of complete tooth loss. Specifically, individuals with full food security exhibited the lowest rates of complete tooth loss at 8.2%, in contrast to those classified under 'very low' food security, who had the highest proportion of tooth loss at 20.0%. Those falling into the “marginal” and “low” food security categories experienced rates of tooth loss at 14.5% and 16.9% respectively, placing them between the rates observed in the other two categories.

Lastly, Panel 4 depicts the bivariate association between the frequency of dental visits and complete tooth loss. These variables showed an inverse association, with the proportion of adults experiencing complete tooth loss increasing as the frequency of dental visits decreased. Only 3.2% of adults who had visited the dentist in the last 12 months experienced complete tooth loss, compared to 12.8% of adults whose most recent dental visit was between one and five years ago, and 37.5% of adults who had either never undergone a prior dental examination or whose most recent visit exceeded five years. Overall, noteworthy differences in tooth loss by SES were evident, indicating widening disparities between the highest and lowest SES categories. All observed associations aligned with their respective hypotheses, supporting the decision to extend the analyses using multiple logistic regression.

Figure 3.4 Bivariate associations between complete tooth loss and 4 different covariates (income, education, food security, and dental visits)*

Panel 1: Participants with lower income have higher rates of complete tooth loss

Income level	Has complete tooth loss No	Yes	Total (%)
<$20,000	77.4	22.6	100
$20,000-$74,999	89.2	10.8	100
$75,000-99,999	95.6	4.4	100
$100,000+	97.4	2.6	100
Total (%)	**90.0**	**10.0**	**100**

Panel 2: Participants with lower educational attainment have higher rates of complete tooth loss

Educational attainment	Has complete tooth loss No	Yes	Total (%)
High school or less	82.0	18.0	100
Some college	91.9	8.1	100
College graduate	97.8	2.2	100
Total (%)	**90.0**	**10.0**	**100**

Panel 3: As food insecurity increases, the rate of complete tooth loss also increases

Food security	Has complete tooth loss No	Yes	Total (%)
Full food security	91.8	8.2	100
Marginal food security	85.5	14.5	100
Low food security	83.1	16.9	100
Very low food security	80.0	20.0	100
Total (%)	**90.0**	**10.0**	**100**

Panel 4: The rate of complete tooth loss increases as the frequency of dental visits decreases

Frequency of dental visits	Has complete tooth loss No	Yes	Total (%)
Within the past 12 months	96.8	3.2	100
Between 1 to 5 years	87.2	12.8	100
More than 5 years or never	62.5	37.5	100
Total (%)	**90.0**	**10.0**	**100**

Source: NHANES, 2013-2018

*n=7,861; Survey weights and imputed data used.

ZINB regression results: SES and tooth loss

Tables 3.2 and 3.3 display ZINB coefficients from five sequential models, focusing on the main SES predictors (income and education) for tooth loss. That is, both tables include fully adjusted models (model 5) but only coefficients for income and education are shown. The coefficients in Table 3.2 apply to the entire analytical sample, while those in Table 3.3 were stratified by age category. Both tables represent hurdle models, which model their coefficients using two parts: the first as a ZINB component that estimates the number of teeth present in the sample, and a separate logistic regression component that estimates outcomes for zero teeth (complete tooth loss). The progressive addition of key variables to the simple model (Model 1) determined whether potential mediators (such as food insecurity and dental visits) altered the association between SES and permanent tooth loss. The comprehensive model in Model 5 encompassed all predictors, including education, income, food insecurity, gender, race/ethnicity, nativity of Hispanic adults, occupation status, health insurance, frequency of dental visits, diabetes, flossing, and smoking.

Education

Results from the total sample in Table 3.2 found that higher educational attainment was associated with more counts of permanent teeth. These associations were statistically significant in all sequential models. In the simple model, having some college was associated with a 0.1 increase in permanent teeth compared to individuals with a high school degree or less. Among those with a college degree or higher, individuals had 0.2 more permanent teeth compared to the same reference group. These estimates were the same across all models, except for Model 5, in which the coefficient for “college degree or more” decreased from 0.2 to 0.1 but remained statistically significant. This reduction suggests that possible mediation occurred after the inclusion of the health-related variables in Model 5. Next, the binary component for education illustrated a similar trend in the full model, showing that the likelihood of complete tooth loss was lower mainly among participants with higher levels of education. Specifically, the probability of having zero permanent teeth was lowest among college graduates (β= -1.2), followed by those with some college (β= -0.5) compared to the reference group (high school degree or less).

Table 3.3 shows the age-stratified results for the effect of educational attainment on tooth loss. In general, the counts estimates for all age groups were similar in magnitude as the total population in Table 3.2. Most coefficients did not change upon the inclusion of mediating variables, apart from adults between 60 to 69 years of age, in which “some college” became non-significant after the addition of the Model 5 predictors. In Model 5, adults between ages 70 and 79 years with a college degree also showed a slightly lower estimate compared to the previous models (from 0.2 to 0.1), though it remained statistically significant. Interestingly, among adults aged 80 years or older, the estimates for "some college" were not statistically significant in any of the sequential models. However, adults over 80 years with a college degree had, on average, 0.2 more teeth than their counterparts with a high school diploma in the same age group. All other age groups within that education level had a coefficient of 0.1 in the comprehensive model. Furthermore, the binary components across all age groups mirrored those in the total population, demonstrating reductions in the probability of complete tooth loss among participants with a college degree.

Income

In summary, lower income was associated with fewer permanent teeth and with a greater likelihood of complete tooth loss. These results were found in the full models within the total population and among adults between the ages of 60 and 80 years. In Table 3.3, participants who earned between \$20,000 to \$74,999 had 0.1 more teeth than individuals who made less than \$20,000 across all models. In the simple model, participants in the next income levels (between \$75,000 to \$99,999 and \$100,000+) had 0.2 more teeth than those from the previous reference group. Estimates for those two income groups decreased to 0.1 after the inclusion of the Model 4 predictors (health insurance and occupation) but still held statistical significance across all models. The results for the binary outcome confirmed these trends until the addition of health-related variables in Model 5. The inclusion of those variables reduced or eliminated statistically significant effects of income on complete tooth loss in the total sample.

The age-stratified results in Table 3.3 showed similar trends for the association between income and tooth loss. Most income coefficients decreased or lost statistical significance upon the inclusion of the predictors from Models 4 and 5. In the full counts model, only adults within the 60- to 69-year and 70- to 79-year age categories demonstrated a significant association between income and tooth loss. Among 60- to 69-year-olds, individuals with an income above \$100,000 had 0.1 more teeth than those with an income below \$20,000. Adults between 70 to 79 years of age had the same outcome for those who earned above \$100,000 ($\beta = 0.1$) and those with earnings between \$20,000 to \$74,999 ($\beta = 0.1$), while those with earnings between \$75,000 to \$99,000 had a coefficient of 0.2. Furthermore, the binary results in each age group matched those in the total sample; income lost statistical significance upon inclusion of the predictors in the full model, except among adults between 50 to 59 years with an income above \$100,000 ($\beta = -2.1$). This effect suggests strong mediation by Model 5 variables in the link between income and complete tooth loss.

Table 3.2. SES estimates for tooth counts among adults ages 50+ years (n=7,861): Zero-inflated negative binomial (ZINB) regression results across five sequential hurdle models

	Models				
Counts outcome: Teeth present	(1)	(2)	(3)	(4)	(5)
Level of education					
High school or less (reference)					
Some college	0.1**	0.1**	0.1**	0.1**	0.1**
College graduate	0.2**	0.2**	0.2**	0.2**	0.1**
Income level					
<$20,000 (reference)					
$20,000-$74,999	0.1**	0.1**	0.1**	0.1*	0.1*
$75,000-99,999	0.2**	0.2**	0.2**	0.1**	0.1**
$100,000+	0.2**	0.2**	0.2**	0.1**	0.1**
Constant	2.9**	2.9**	3.0**	3.0**	3.0**
Binary logistic regression component: Complete tooth loss estimated by SES variables					
Level of education					
High school or less (reference)					
Some college	-0.8**	-0.8**	-0.8**	-0.8**	-0.5**
College graduate	-1.8**	-1.8**	-1.8**	-1.8**	-1.2**
Income level					
<$20,000 (reference)					
$20,000-$74,999	-0.7**	-0.7**	-0.7**	-0.5**	-0.3+
$75,000-99,999	-1.4**	-1.4**	-1.4**	-1.2**	-0.4
$100,000+	-1.8**	-1.7**	-1.8**	-1.4**	-0.4
Constant	-0.9**	-1.0**	-0.9**	-1.6**	-1.6**
lnalpha	-2.9**	-2.9**	-3.0**	-3.0**	-3.2**

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

Table 3.3. SES estimates for tooth counts (by age group): Zero-inflated negative binomial (ZINB) regression results across five sequential hurdle models

	Age 50-59 years					Age 60-69 years					Age 70-79 years					Age 80+ years				
Models	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Counts outcome: # teeth present																				
Level of education																				
High school or less (reference)																				
Some college	0.1**	0.1*	0.1**	0.1**	0.1*	0.1*	0.1*	0.1*	0.1*	0.0	0.1*	0.1*	0.1*	0.1*	0.1+	0.1	0.1	0.1	0.1	0.0
College graduate	0.1**	0.1**	0.1**	0.1**	0.1**	0.2**	0.1**	0.2**	0.1**	0.1**	0.2**	0.2**	0.2**	0.2**	0.1**	0.2**	0.2**	0.2**	0.2**	0.2*
Income level																				
<$20,000 (reference)																				
$20,000-$74,999	0.1+	0.0	0.0	0.0	0.0	0.1**	0.1*	0.1*	0.1+	0.0	0.2**	0.1*	0.1*	0.1*	0.1+	0.2*	0.1+	0.1+	0.1	0.1
$75,000-99,999	0.1*	0.1+	0.1+	0.0	0.0	0.2**	0.2**	0.2**	0.1*	0.1	0.3**	0.2**	0.2**	0.2**	0.2*	0.1	0.1	0.1	0.1	0.0
$100,000+	0.1**	0.1**	0.1**	0.1	0.0	0.2**	0.2**	0.2**	0.2*	0.1+	0.2**	0.2**	0.2**	0.2**	0.1*	0.2*	0.2*	0.2*	0.2*	0.1
Constant	3.0**	3.1**	3.1**	3.1**	3.1**	2.9**	3.0**	3.0**	3.0**	3.0**	2.8**	2.8**	2.9**	2.9**	2.8**	2.7**	2.8**	2.8**	2.8**	2.7**
Binary logistic regression component: Complete tooth loss estimated by SES variables																				
Level of education																				
High school or less (reference)																				
Some college	-0.5+	-0.5+	-0.7*	-0.7*	-0.5+	-0.8**	-0.8**	-0.9**	-0.8**	-0.4	-0.8**	-0.8**	-0.8**	-0.8**	-0.4	-0.8**	-0.8**	-0.8**	-0.8**	-0.5
College graduate	-1.6+	-1.6+	-1.7*	-1.8*	-1.0	-2.5**	-2.5**	-2.6**	-2.6**	-1.7**	-1.5**	-1.5**	-1.5**	-1.5**	-0.5	-1.5**	-1.5**	-1.5**	-1.5**	-1.2*
Income level																				
<$20,000 (reference)																				
$20,000-$74,999	-0.9**	-0.9*	-1.0*	-0.6	-0.5	-0.4+	-0.2	-0.3	0.0	0.2	-1.1**	-1.0**	-1.0**	-1.0**	-0.6	-0.5+	-0.4	-0.4	-0.4	-0.1

Table 3.3 continued

$75,000-99,999	-2.0 *	-2.0 *	-2.1 *	-1.7 +	-1.0	-0.5	-0.3	-0.4	-0.1	0.8	-1.7 *	-1.5 *	-1.6 *	-1.6 *	-0.9	-1.1	-1.1	-1.1	-1.0	-0.4
$100,000+	-3.3 **	-3.3 **	-3.4 **	-2.9 *	-2.1 +	-1.0 *	-0.8 +	-0.8 +	-0.6	0.7	-1.6 *	-1.4 *	-1.4 *	-1.4 *	-0.3	-1.2 +	-1.1 +	-1.1 +	-1.0 +	0.0
Constant	-1.5 **	-1.5 *	-1.1 +	-1.8 *	-1.5 +	-1.2 **	-1.4 **	-1.4 **	-1.7 **	-2.3 **	-0.3	-0.5 *	-0.6 +	-0.4	-0.4	-0.5 *	-0.6 *	-0.8 *	-1.6 *	-2.0 *
lnalpha	-4.4 **	-4.5 **	-4.6 **	-4.7 **	-6.0 *	-2.9 **	-3.0 **	-3.0 **	-3.0 **	-3.3 **	-2.4 **	-2.4 **	-2.5 **	-2.5 **	-2.7 **	-1.8 **	-1.9 **	-1.9 **	-1.9 **	-2.1 **
N	2,540					2,746					1,586					989				

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

ZINB regression results: Food insecurity

Table 3.4 focuses on the point estimates related to food insecurity (hypothesis 3.2) and the frequency of dental visits (hypothesis 3.3) and their effects on tooth loss in the total analytic sample. With respect to food insecurity, the findings from the total sample revealed that only participants with "low" levels of food security had lower tooth counts compared to individuals with full food security (β= -0.03). Results were non-significant among adults with "marginal" or "very low" levels of food security. The coefficients remained mostly the same across all sequential models. However, the point estimate for "low" food security slightly declined in magnitude (by 0.03 units) upon the inclusion of the health-related variables in Model 5. Furthermore, the binary outcomes from the same table revealed no significant associations between complete tooth loss and food insecurity in the total sample population.

The age-stratified results in Table 3.5 found that only 60- to 69-year-olds with "low" food security had fewer teeth than their counterparts in the same age group with full food security (β= -0.1). No other age groups showed a significant relationship between food security and tooth counts in the full model. From the simple model to the comprehensive model, most coefficients maintained the same magnitude and level of statistical significance. The outcome for "low" food security within the 80+ year age group was one exception, as this coefficient lost statistical significance between Model 4 and Model 5. In the binary portion of the age-stratified model, a clear link was observed between complete tooth loss and higher levels of food insecurity among adults between ages 60 to 69 years and 70 to 79 years. However, those results were no longer statistically significant upon the inclusion of predictors from Model 5.

ZINB regression results: Frequency of dental visits

The association between tooth counts and dental visit frequency was explored only within the comprehensive model (Model 5), given the integration of health-related variables, including dental visits. As shown in Table 3.4, participants from the total sample who visited the dentist less frequently had fewer permanent teeth compared to those who had a dental visit within the past 12 months. Longer durations between visits were associated with an increased number of missing teeth. For instance, participants who visited a dentist within the previous one to five years had 0.3 fewer teeth than adults who had visited a dentist in the past 12 months. In contrast, those who delayed a dental visit for more than five years or who had never visited a dentist had 0.7 fewer teeth than the reference group. The binary results reflected similar oral health disparities observed in the counts data. Specifically, adults with a past-year dental visit had the lowest probability of experiencing complete tooth loss (reference group) followed by those who received an oral health examination within the previous one to five years (β= 0.84). Participants who had never visited a dentist or prolonged a dental examination for five years or longer showed the highest probability of complete tooth loss (β= 1.71).

The age-stratified analysis in Table 3.5 revealed mostly similar patterns as those found in the total analytic sample. Participants aged 60 or older who delayed a dental visit for five or more years, or who had never visited a dentist, tended to have fewer permanent teeth compared to those who had a dental visit in the past year. There were no significant differences in tooth counts among participants who delayed a dental visit for one to five years. Additionally, the risk of tooth loss increased with older age. In the 60-69 age group, adults who visited the dentist less frequently (5+ years or never) had 0.1 fewer teeth than those with a dental visit in the past year, while adults above 70 years within the same category of dental visits had 0.2 fewer permanent teeth compared to their counterparts from the reference group. Moreover, the probability of complete tooth loss exhibited a stepwise increase with less frequent dental visits. This binary outcome was statistically significant across all age groups, except among those between 50 to 59 years of age. More pronounced disparities in edentulism by dental visits were observed among adults above 80 years of age. In summary, prolonged intervals without a dental examination were associated with a lower count of permanent teeth and an elevated likelihood of complete tooth loss. This impact was particularly notable in older age groups.

Table 3.4. Food security and dental visits coefficients for tooth counts in adults ages 50+ years (n=7,861): Zero-inflated negative binomial (ZINB) regression results across five sequential hurdle models

	Models				
Counts outcome: Teeth present	(1)	(2)	(3)	(4)	(5)
Food security	-				
Full food security (reference)					
Marginal food security		-0.03	-0.03	-0.04	-0.02
Low food security		-0.04+	-0.05*	-0.06*	-0.03+
Very low food security		-0.03	-0.03	-0.04	-0.01
Most recent dental visit	-	-	-	-	
Within the past 12 months (reference)					
Between 1-5 years					-0.03+
More than 5 years, or never					-0.07*
Constant		2.94**	2.95**	3.03**	2.99**
Binary logistic regression component: Complete tooth loss estimated by food security or dental visits					
Food security	-				
Full food security (reference)					
Marginal food security		-0.03	0.03	0.08	-0.15
Low food security		0.03	0.15	0.21	-0.25
Very low food security		0.17	0.20	0.24	-0.12
Constant		-0.96**	-0.88**	-1.58**	-1.57**
Most recent dental visit	-	-	-	-	
Within the past 12 months (reference)					
Between 1-5 years					0.84**
More than 5 years, or never					1.71**
Constant					-1.57**
lnalpha	-2.94**	-2.94**	-2.97**	-3.01**	-3.22**

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

Table 3.5. Food security and dental visits coefficients for tooth counts (by age group): Zero-inflated negative binomial (ZINB) regression results across five sequential hurdle models

	Age 50-59 years					Age 60-69 years					Age 70-79 years					Age 80+ years				
Models	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Counts outcome: # teeth present																				
Food security	-					-					-					-				
Full food security (reference)																				
Marginal food security		0.0	-0.1 +	0.0	0.0		0.0	0.0	0.0	0.0		-0.1 *	-0.1 +	-0.1 +	-0.1		-0.2	-0.2	-0.2	-0.1
Low food security		-0.1	-0.1 +	-0.1	0.0		-0.1 *	-0.1 **	-0.1 *	-0.1 *		-0.1	0.0	0.0	0.0		-0.3 +	-0.3 +	-0.3 +	-0.2
Very low food security		-0.1 +	-0.1 +	-0.1	0.0		-0.1	-0.1	-0.1	0.0		-0.1	-0.1	-0.1	0.0		-0.3	-0.2	-0.2	-0.2
Most recent dental visit	-	-	-	-		-	-	-	-		-	-	-	-		-		-	-	
Within the past 12 months (reference)																				
Between 1-5 years					0.0					-0.1					-0.1					-0.1
More than 5 years, or never					0.0					-0.1 +					-0.2 *					-0.2 *
Constant		3.1 **	3.1 **	3.1 **	3.1 **		3.0 **	3.0 **	3.0 **	3.0 **		2.8 **	2.9 **	2.9 **	2.8 **		2.8 **	2.8 **	2.8 **	2.7 **
Binary logistic regression component: Complete tooth loss estimated by food security or dental visits																				
Food security	-					-					-					-				
Full food security (reference)																				
Marginal food security		-0.2	-0.1	-0.3	-0.5		0.2	0.3	0.2	0.2		0.5 +	0.5 +	0.5 +	-0.1		0.3	0.2	0.1	-0.2
Low food security		0.2	0.3	0.1	-0.1		0.2	0.3	0.2	0.0		0.4	0.5 +	0.5 +	0.1		0.5	0.4	0.4	-0.4
Very low food security		0.0	0.4	-0.2	-0.2		0.7 +	0.7 *	0.7 +	0.1		0.7 +	0.8 +	0.7 +	0.3		1.2	1.0	1.0	0.4
Constant		-1.5 *	-1.1 +	-1.8 *	-1.5 +		-1.4 **	-1.4 **	-1.7 **	-2.3 **		-0.5 *	-0.6 +	-0.4	-0.4		-0.6 *	-0.8 *	-1.6 *	-2.0 *
Most recent dental visit	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-	

Table 3.5 continued

Within the past 12 months (reference)				
Between 1-5 years	0.0	1.1**	1.2**	0.8**
More than 5 years, or never	0.6	2.1**	2.0**	2.4**
Constant	-1.5+	-2.3**	-0.4	-2.0*
lnalpha	-4.5** -4.6** -4.7** -6.0*	-3.0** -3.0** -3.0** -3.3**	-2.4** -2.5** -2.5** -2.7**	-1.9** -1.9** -1.9** -2.1**
N	2,540	2,746	1,586	989

** p<0.001, * p<0.01, + p<0.05

Model (1): education, income

Model (2): education, income, food security

Model (3): education, income, food security, gender, race/ethnicity, Hispanic nativity

Model (4): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status

Model (5): education, income, food security, gender, race/ethnicity, Hispanic nativity, health insurance, occupation status, dental visits, diabetes, flossing, smoking

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; calculations used imputed data and sampling weights.

Discussion

The purpose of Study 3 was to examine the degree to which SES-related factors impacted permanent tooth loss in older U.S. adults. To accomplish this aim, three hypotheses were investigated with respect to the social determinants of oral health outlined in the conceptual model for Study 3. The first hypothesis examined whether lower SES was associated with a greater risk of permanent tooth loss across older subgroups of U.S. adults. In Hypothesis 3.2, we explored whether important structural factors, such as food insecurity, mediated the main association by increasing the likelihood of permanent tooth loss in older adults. Furthermore, Hypothesis 3.3 investigated a possible mediating role by routine dental care, examining it as a protective factor. It was anticipated that less frequent dental visits, indicative of limited access to timely treatment and prevention of oral diseases, would be associated with higher probabilities of complete tooth loss and a reduced count of permanent teeth.

In general, our data showed that lower levels of education and income were linked to fewer permanent teeth and a higher prevalence of edentulism (complete tooth loss). The estimates for the SES variables were compared across five sequential models to test for mediating effects by other variables. The predictors introduced in Model 4 (occupation and insurance) and Model 5 (dental visits, diabetes, flossing, and smoking) either diminished the effect sizes for SES or eliminated their statistical significance within some age categories. This decrease suggests partial mediation of the main association following the incorporation of health-related variables in Model 5 or insurance-related variables in Model 4.

Overall, the results from the full counts models showed a significant association between lower income and higher risk of tooth loss among adults between 60 to 79 years of age. In the full counts model for educational attainment, higher education had a significant protective effect against tooth loss in nearly all age groups, except among adults with "some college" in the 60- to 69-year age category and those with "some college" who were 80 years and older. Although tooth loss in oldest age category was not significantly impacted by income, adults above 80 years of age with a college degree had 0.2 more permanent teeth than adults in the same age group with a high school diploma. Similarly, the outcomes for the binary component, complete tooth loss, revealed that adults above 80 years of age with a college degree had a 120% lower probability of showing complete tooth loss compared to the same reference group. Furthermore, higher income had a protective effect against edentulism only among adults in their 50's with incomes above $100,000.

These findings were mostly consistent with prior research on the relationship between SES and permanent tooth loss. Recent cross-sectional data from the past decade have shown higher rates of tooth loss among older U.S. adults, particularly those with lower SES (Dye et al., 2019). Additionally, some studies have identified disparities in tooth loss primarily related to poverty status (NIH, 2021). In contrast, our findings revealed that education had a more robust effect on tooth loss than income level within the oldest age groups, while income had a stronger protective effect against tooth loss among adults between 50 to 59 years of age. Moreover, the effect of SES on tooth loss was expected to have a stronger magnitude within older subgroups of adults, as tooth loss results from cumulative harmful exposures to the oral cavity. As previously noted, SES model estimates were only statistically significant for education but not for income within the older age categories. Nonetheless, the most pronounced disparity in the number of missing teeth was observed among adults aged 80 years and above when comparing adults within the highest and lowest levels of educational attainment. In summary, most adults above age 50 years with a college degree or more had a greater number of permanent teeth present in the oral cavity and had the lowest risks of edentulism.

With respect to the second set of findings, the association between food insecurity and tooth loss was evident only in certain age groups. Adults between ages 60 to 69 years with “low” levels of food security had, on average, fewer permanent teeth than individuals with “full” food security (β= -0.1). Participants with "very low" and "marginal" levels of food security did not yield statistically significant estimates in the full counts model, regardless of age. In the binary component of the full ZINB models, food insecurity was not associated with complete tooth loss. Most observed associations between food insecurity and tooth loss in simpler models were no longer statistically significant after the addition of the “dental visits” predictor in the full model.

The impact of food insecurity on permanent tooth loss has been a relatively understudied area in the broader oral health literature. So far, no current research has explored any causal links between food insecurity and tooth loss. Some studies from older adult populations have shown a correlation between low SES and a higher prevalence of food insecurity (National Council on Aging, 2021). It is well established that food insecurity regulates access to healthy diets, which plays a significant role in preventing oral diseases (Lee et al., 2022b). Based on these trends, we hypothesized that food insecurity increased the risk of permanent tooth loss with older age, potentially mediating the primary relationship between SES and tooth loss. Our findings were partially aligned with those predictions. Mixed outcomes were observed by age group and after examining separate outcomes for tooth counts and edentulism (complete tooth loss). For example, only adults between 60 to 69 years of age with “low” levels of food security had diminished tooth counts, while the binary models showed no significant associations between food insecurity and edentulism across all age categories.

Furthermore, separating the food insecurity categories into “low” and “very low” contributed to some valuable insights. The “low” food security group implies not having enough resources to purchase healthy foods, while “very low” food security is more about struggling with having enough food to begin with. This distinction was important when comparing results between the counts data and binary components of the ZINB regression models. In the counts data, only individuals between ages 60 to 69 years categorized with “low” levels of food insecurity had significantly fewer teeth than adults with “full” food security. This result signifies that while facing financial strain, the ability to still afford healthy food led to fewer permanent teeth compared to individuals with “marginal” or “very low” food security. This outcome could be attributed to potentially different dietary patterns among individuals with varying levels of food insecurity. Another factor to consider is that a substantial proportion of adults above 70 years of age had zero permanent teeth and were consequently eliminated from the counts model, resulting in smaller sample sizes and non-significant estimates for this portion of the analysis. In general, these findings suggest that severe challenges in affording meals had a particularly strong impact on edentulism, especially among adults in their 60’s. These disparities justify the need to further investigate and address experiences of food insecurity in older adulthood, their impact on dietary patterns, and their connection to preventing oral diseases.

Finally, the effect of routine dental care on tooth loss was the third aim of this study. Our findings revealed that longer delays between dental visits were associated with a greater number of missing teeth and an elevated risk of complete tooth loss. These associations were most evident within older age groups, with the most substantial effects observed in adults over age 70 for tooth counts and in adults ages 80 years and older for complete tooth loss. Furthermore, the addition of health-related variables in the full model (Model 5), which included the dental visits variable, resulted in smaller or non-significant coefficients for income and education. These shifts suggest that dental visits could have partially mediated the primary association between SES and tooth loss.

While limited research has explored the role of dental care access in preventing tooth loss among U.S. older adults, our results resembled patterns observed in other populations. In a longitudinal study involving older Swedish adults, long-term dental visits were linked to an improvement in oral health-related quality of life (Åstrøm et al., 2018). Additionally, preventive dental visits have been associated with a lower likelihood of tooth loss among dental patients in Japan compared to patients who solely received specialized treatment for dental problems (Saito et al., 2019). Given that an annual dental examination can address minor oral health issues before they progress to complete tooth loss, the protective effect that annual dental visits had on tooth loss within our sample was unsurprising. Overall, these findings validate the importance of ensuring universal access to preventive dental care and highlight the need to address oral health disparities in both SES and dental care access within older populations.

This study had several limitations. First, the data came from a cross-sectional study and did not allow for assumptions of causality. However, the validity of this study was supported by the incorporation of a robust theoretical framework, which guided the selection of variables and provided a solid rationale for the conceptual pathways modeled in this study. Second, about 10% of participants in the analytic sample had missing information for income, while samples sizes were relatively small among Hispanic participants, adults born outside the U.S., and older subsets of adults. However, starting in 2011, NHANES oversampled for various groups including Hispanic adults, non-Hispanic Black adults, adults with lower income, and adults above 80 years of age to account for nonresponse bias (Johnson et al., 2014). Using multiple imputation and pooling participants from at least two NHANES survey waves also increased sample sizes and improved estimate precision (CDC & NCHS, n.d.a; Rubin, 1996). To better understand the long-term effects of SES on oral health outcomes, future studies are encouraged to prioritize longitudinal research focused on oral health within the U.S.

Third, certain associations may have not been evident through the tooth counts data alone. To improve detection of statistically significant results, this study might also explore tooth loss as an ordinal variable based on the following categories: edentulism (zero teeth), severe tooth loss (having fewer than eight teeth), and low functional dentition (having fewer than 20 teeth) (Parker et al., 2020). Collapsing the continuous data into these meaningful categories could potentially unveil specific patterns with important implications for oral health policy. Nonetheless, the application of hurdle models with ZINB regression allowed us to distinguish between outcomes for complete tooth loss and those corresponding to the average counts of missing teeth. Furthermore, no measures for dental insurance were available in the NHANES dataset at this time. Medical insurance was used to approximate the resources available for dental care. Future iterations of NHANES and other national surveys may consider including response options for dental coverage, in addition to those for medical insurance. This information would provide a more comprehensive understanding of the accessibility of oral health services, particularly among Medicare recipients and uninsured populations.

The findings presented in Study 3 address a significant gap in the oral health literature. Few existing studies in this field are grounded in theory or consider age-related factors influencing edentulism, despite older adults and individuals with low SES experiencing the highest burden of irreversible oral diseases (Seerig et al., 2015; Huang and Park, 2015). This issue tends to be overlooked in both research and by broader segments of society due to the common perception that tooth loss is an inevitable part of aging. Although tooth loss is pervasive in older adult populations, it is preventable. Thus, addressing modifiable factors, such as better access to dental care and nutritious food sources, is an important step to changing our expectations of oral wellness through the life course. With appropriate interventions, policy shifts, and universal access to oral health-related resources, maintaining permanent teeth can be achievable at every stage of life.

Conclusion

The objective of this dissertation was to investigate the relationship between SES factors and oral health-related outcomes among U.S. adults ages 50 years and older. The first aim of this dissertation focused on dental care access and whether there were differences in receiving routine dental care by SES, diabetes diagnosis, or nativity status among U.S. Latinos. The second study examined outcomes for untreated dental caries and investigated whether associations with SES were mediated by food insecurity or frequency of dental visits. Next, the third study mirrored similar aims as study 2 but emphasized outcomes for permanent tooth loss and edentulism. These aims were explored within three studies to inform our understanding of key mechanisms that drive oral health outcomes among older U.S. adults.

Collectively, each study found that SES disparities persisted across all three oral health outcomes, such that participants with lower levels of education and income were less likely to have regular dental check-ups, had a higher likelihood of untreated dental caries, and faced an elevated risk of permanent tooth loss compared to those with higher SES. These disparities were most evident in adults over 80 years of age with low educational attainment. Although food insecurity was not associated with tooth loss, it had a detrimental effect on untreated dental caries among adults between 60 to 69 years of age. Specifically, individuals with “marginal” or “very low” levels of food security had double the odds of showing untreated dental caries compared to adults with “full” food security. As untreated dental caries can manifest into permanent tooth loss, further study is warranted on this subject. Namely, the use of a longitudinal study design for this area of research would provide better understanding of the progression of oral diseases from a life course perspective. Thirdly, receiving less frequent dental care was strongly associated with fewer permanent teeth, higher likelihood of untreated dental caries, and a greater probability of complete tooth loss, or edentulism.

The key takeaways from these studies underscore the adverse impact of socially patterned diseases. First, they illustrate that adults with low SES were most susceptible to developing oral diseases while simultaneously lacking the necessary oral health care to address them, showing increasing gaps among older age groups. Second, they reveal that limited access to oral health-related resources such as nutritious food and regular dental care contributed to worse oral health outcomes, independent of SES. Although food insecurity did not play a significant role in predicting oral diseases for all age groups, having routine dental care was a robust protective factor across all age groups and oral health outcomes, including dental caries, permanent tooth loss, and edentulism. This evidence is instrumental for instituting policy changes with respect to offering universal oral health care and improving the accessibility and quality of nutritional and dental health services for older adults.

This dissertation had several limitations. First, all three studies utilized cross-sectional data from NHANES, limiting generalizability of our target population. Second, the indicators collected outside of the MEC exam were self-reported. This could lead to some concerns of bias and patterns of missingness, particularly for income, which had almost a 10% missing response rate in the analytic sample. These issues were addressed with multiple imputation in the final analyses and with NHANES sampling strategies, which oversamples for adults above age 80+ years, racial/ethnic minorities, and participants with low income (Johnson et al., 2014).

Third, an indicator for dental insurance was not available in the NHANES dataset, which is useful for understanding affordability of oral health services. Lastly, limited information was available during the start of the COVID-19 pandemic, beginning with the 2019-20 survey wave.

Because the pandemic interrupted the collection of NHANES data between 2020 and 2021, the 2017-18 NHANES wave was used as the most recent and reliable data source for our measures. Future iterations of NHANES and other national health surveys may include validated measures for dental insurance, as well as indicators for oral health experiences and behaviors with respect to the COVID-19 pandemic. This information could enhance understanding of oral health access and utilization. Furthermore, future studies could strengthen the current oral health literature by implementing longitudinal cohort studies that are based in the U.S. That is, following oral health outcomes over participants' life spans would help track time-based patterns in oral health and find causal relationships.

In summary, older adults in the U.S. are vulnerable to poor oral health outcomes that are largely shaped by a combination of social, behavioral, and clinical factors across the life course. Even though oral diseases disproportionately burden older adult populations, poor oral health is not an inevitable part of aging. The assumption that tooth loss is a normal experience of older adulthood is both dangerous and untrue. Many social factors that contribute to poor oral health, including low SES, food insecurity, and lacking access to dental care, are modifiable.

Unfortunately, current policies sparingly address social determinants of oral health. Public safety nets such as Medicare do not even offer basic oral health services for older adults (U.S. Centers for Medicare & Medicaid Service, n.d.). Rather than providing universal access to preventive oral health care, Medicare only offers dental coverage for emergency dental services, which may be more invasive and costly than routine exams and cleanings (U.S. Centers for Medicare & Medicaid Service, n.d.). Isolating and disregarding dental care from basic health coverage sends a harmful message to the public about the importance of oral health. It appears trivial and non-essential, and therefore, signals that people should treat their own oral health needs as such. Reversing this perspective requires, at a minimum, establishing that universal dental coverage in the U.S. is an essential health care need. This is a first step to changing the paradigm of oral health prevention in the U.S.

In addition to problems related to dental care access, the consequences of oral diseases are themselves life-altering. Untreated dental problems lead to irreversible outcomes including permanent tooth loss, oral pain, limited ability to eat or speak, and a diminished quality of life. Furthermore, oral diseases have an adverse effect on general health. Poor oral health has been linked to a greater risk of cardiovascular and respiratory illness as well as all-cause mortality in older adults (Kotronia et al., 2021). The progression of oral diseases is usually inconspicuous. Without early detection and intervention, these issues can grow in severity and in financial cost. While addressing clinical and behavioral factors is important for preventing oral disease and related health consequences, more sustainable approaches to oral health prevention must place emphasis on social drivers of oral health. Improving social conditions can promote better oral health outcomes for current and future generations.

APPENDICES

Appendix 1.1. Ordered logistic regression results for 3-category specification of past-year dental visits with Brant test*

Variables	Coefficient	95% CI	p-value
Level of education			
High school or less (reference)			
Some college	-0.46	(-0.56, -0.36)	<0.001
College graduate	-0.99	(-1.12, -0.85)	<0.001
Income level			
<$20,000 (reference)			
$20,000-$74,999	-0.49	(-0.59, -0.39)	<0.001
$75,000-99,999	-1.20	(-1.39, -1.00)	<0.001
$100,000+	-1.42	(-1.58, -1.25)	<0.001
/cut1	-0.68	(-0.77, -0.59)	
/cut2	0.64	(0.55, 0.73)	
Brant test of parallel regression assumption			
	chi2	p>chi2	df
All SES variables**	17.75	0.003	5
Some college	0.40	0.528	1
College graduate**	5.48	0.019	1
$20,000-$74,999	3.74	0.053	1
$75,000-99,999	0.32	0.571	1
$100,000+**	7.02	0.008	1

*Non-weighted and non-imputed data were used from NHANES 2013-18 participants ages 50+ years (n= 7,734); Brant test cannot be used with survey weights.

**A significant test statistic (p<0.05) provides evidence that the parallel regression assumption has been violated.

Appendix 1.2: Odds ratios of dental visits and variation by SES specifications
(using non-imputed data from NHANES 2013-18 participants ages 50+ years)

	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)	Model 5 OR (SE)	Model 6 OR (SE)	Model 7 OR (SE)
Level of education							
High school or less (reference)							
Some college	1.597**	1.599**	1.519**	1.733**	1.570**	1.572**	1.505**
	(0.091)	(0.091)	(0.088)	(0.097)	(0.090)	(0.090)	(0.088)
College graduate	2.590**	2.617**	2.803**	3.652**	2.534**	2.561**	2.778**
	(0.183)	(0.184)	(0.196)	(0.244)	(0.180)	(0.181)	(0.195)
Income level (4-category)							
<$20,000 (reference)							
$20,000-$74,999	1.532**				1.475**		
	(0.089)				(0.088)		
$75,000-99,999	3.215**				3.138**		
	(0.337)				(0.334)		
$100,000+	3.986**				3.916**		
	(0.355)				(0.359)		
Income level (3-category)							
<$20,000 (reference)							
$20,000-$74,999		1.530**				1.473**	
		(0.089)				(0.088)	
$75,000+		3.675**				3.598**	
		(0.281)				(0.285)	
Poverty income ratio (PIR)							
PIR<1.3 (reference)							
1.3≤ PIR<1.85			1.199+				1.149
			(0.093)				(0.090)
PIR≥1.85			2.457**				2.349**
			(0.143)				(0.143)
Occupation status							
Employed (reference)							
Not employed				0.648**	0.839*	0.837*	0.853+
				(0.042)	(0.057)	(0.057)	(0.059)
Retired				1.024	1.221**	1.217**	1.144+
				(0.057)	(0.071)	(0.070)	(0.066)
Constant	0.532**	0.531**	0.523**	0.877*	0.531**	0.531**	0.535**
	(0.026)	(0.026)	(0.025)	(0.042)	(0.035)	(0.035)	(0.034)
Observations	7,386	7,386	7,264	7,386	7,386	7,386	7,264

Appendix 1.2 continued

AIC	9375.5	9376.8	9252.8	9627.9	9344.9	9346.4	9237.1
BIC	9417.0	9411.4	9287.2	9662.4	9400.2	9394.8	9285.3
-2 Log Likelihood	-4682	-4683	-4621	-4809	-4664	-4666	-4612
df	5	4	4	4	7	6	6
Pseudo R2	0.079	0.078	0.075	0.054	0.082	0.082	0.077

** p<0.001, * p<0.01, + p<0.05

Appendix 1.3 Patterns of missing data in the main sample of adults ages 50+ years (n=8,674)*

Missing-value patterns
(1 means complete)

	Pattern								
Percent	1	2	3	4	5	6	7	8	9
85%	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	0
4	1	1	1	1	1	1	1	0	1
<1	1	1	1	1	1	1	1	0	0
<1	1	1	1	1	1	1	0	1	1
<1	1	1	1	1	1	0	1	1	1
<1	1	1	1	0	1	1	1	1	1
<1	1	1	1	1	0	1	1	1	1
<1	1	1	1	1	1	0	1	1	0
<1	1	0	1	1	1	1	1	1	1
<1	1	1	1	1	1	1	0	1	0
<1	1	1	0	1	1	1	1	1	1
<1	1	1	1	1	0	1	1	1	0
<1	0	1	1	1	1	1	1	1	1
<1	1	1	1	0	1	1	1	1	0
<1	1	1	1	1	1	0	1	0	0
<1	1	0	1	1	1	1	0	1	1
<1	1	1	0	0	0	1	0	1	0
<1	1	1	0	0	1	1	1	1	0
<1	1	1	0	1	0	1	1	0	1
<1	1	1	0	1	0	1	1	1	0
<1	1	1	0	1	1	1	1	0	0
<1	1	1	0	1	1	1	1	1	0
<1	1	1	1	1	0	0	1	1	0
<1	1	1	1	1	0	1	0	0	0
<1	1	1	1	1	0	1	0	1	0
<1	1	1	1	1	1	1	0	0	0
<1	1	1	1	1	1	1	0	0	1
100%									

*Where variables are: (1) race/ethnicity and nativity (2) occupation (3) smoking (4) flossing (5) education (6) health insurance (7) dental visits (8) diabetes, and (9) income

Appendix 1.4. Differences in the baseline characteristics between the missing and complete case samples from 2013-2018 NHANES participants age 50+ years

%	Total		
	Missing obs.	Complete case sample	p-value
One or more dental visits in the past year (Dependent variable)	64.0	64.5	0.845
Level of education			0.655
High school or less	38.3	38.9	
Some college	29.3	30.6	
College graduate	32.4	30.6	
Income level			0.546
<$20,000	19.6	17.0	
$20,000-$74,999	47.1	45.5	
$75,000-99,999	12.0	11.2	
$100,000+	21.3	26.3	
Gender			0.920
Female	53.5	53.3	
Male	46.5	46.7	
Race/ethnicity & nativity			<0.001
U.S.-born Hispanic	4.5	3.6	
Foreign-born Hispanic	9.2	6.1	
Non-Hispanic White	64.1	73.2	
Non-Hispanic Black	12.8	9.6	
Non-Hispanic Asian	6.4	4.4	
Other race or multiracial	3.2	3.2	
Length of stay in the U.S.			<0.001
U.S.-born	79.5	85.6	
non-U.S. born, <15 yrs	1.5	1.5	
non-U.S. born, 15+ yrs	19.0	12.9	
Occupation status			0.593
Employed	43.7	45.8	
Not employed	19.9	18.4	
Retired	36.4	35.7	
Health insurance status			0.427
Private	66.8	69.5	
Public	24.9	22.6	
No insurance	8.3	7.9	
Has diabetes	21.5	19.1	0.163
Daily flossing			0.974
0 days	30.5	30.5	
1 to 6 days	32.4	32.1	

Appendix 1.4 continued

7 days	37.6	37.4	
Smoking status			0.100
Never smoked	56.1	51.2	
Former smoker	29.5	33.1	
Current smoker	14.4	15.6	
N	1,288	7,386	

*Percentages used sampling weights to reflect the national U.S. older adult population; above data are not imputed.

**p-values indicate significant differences in the characteristics between missing and analytic samples; calculated by weighted F-tests.

Appendix 1.5: Odds ratios of dental visits and variation by SES x age and gender x age interactions

	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)
Level of education				
High school or less (reference)				
Some college	1.6** (0.9)	1.3* (0.1)	1.6** (0.1)	1.6** (0.1)
College graduate	2.6** (0.2)	2.1** (0.2)	2.6** (0.2)	2.6** (0.2)
Income level				
<$20,000 (reference)				
$20,000-$74,999	1.6** (0.9)	1.6** (0.1)	1.3+ (0.1)	1.6** (0.1)
$75,000-99,999	3.3** (0.3)	3.4** (0.4)	2.8** (0.5)	3.4** (0.3)
$100,000+	4.1** (0.4)	4.3** (0.4)	4.1** (0.6)	4.2** (0.4)
Gender				
Female (reference)				
Male	0.7** (0.1)	0.7** (0.1)	0.7** (0.1)	0.7** (0.1)
Age category				
50-59 years (reference)				
60-69 years		1.0 (0.1)	1.0 (0.1)	1.2 (0.1)
70-79 years		1.0 (0.1)	1.0 (0.1)	1.3* (0.1)
80+ years		1.0 (0.1)	0.9 (0.1)	1.1 (0.1)
Education*Age				
Some college*60-69 years		1.2 (0.2)		
Some college*70-79 years		1.3 (0.2)		
Some college*80+ years		1.3 (0.2)		
College grad*60-69 years		1.2 (0.2)		
College grad*70-79 years		1.8* (0.3)		
College grad*80+ years		1.6+ (0.4)		
Income*Age				
$20,000-$74,999*60-69 years			1.1 (0.2)	
$20,000-$74,999*70-79 years			1.3 (0.2)	
$20,000-$74,999*80+ years			1.7* (0.3)	
$75,000-$99,999*60-69 years			1.4 (0.3)	
$75,000-$99,999*70-79 years			1.0 (0.3)	
$75,000-$99,999*80+ years			2.3 (1.0)	
$100,000+*60-69 years			1.0 (0.2)	
$100,000+*70-79 years			1.0 (0.3)	
$100,000+*80+ years			0.9 (0.3)	
Gender*Age				
Male*60-69 years				1.0 (0.1)
Male*70-79 years				0.8 (0.1)
Male*80+ years				1.2 (0.2)
Constant	0.6** (0.0)	0.6** (0.0)	0.7** (0.1)	0.6** (0.0)
Observations	7,386	7,386	7,386	7,386

Appendix 1.5 continued

AIC	9318.4	9313.3	9316.5	9313.8
BIC	9366.7	9423.8	9447.7	9403.6
-2 Log Likelihood	-4652.2	-4640.6	-4639.2	-4643.9
df	7	16	19	13
Pseudo R2	0.085	0.087	0.087	0.086

Likelihood Ratio Test: Model 1 is the reduced model

	Mod1 vs Mod2	Mod1 vs Mod3	Mod1 vs Mod4
LR chi2	23.2	25.9	16.6
Prob > chi2	0.006	0.011	0.011

** p<0.001, * p<0.01, + p<0.05

Model 1: Control for education + income + gender

Model 2: Control for education + income + gender + age*education

Model 3: Control for education + income + gender + age*income

Model 4: Control for education + income + gender + age*gender

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; Above data are not imputed.

Appendix 1.6. Logistic regressions of adults age 50+ years (n= 7,386): Odds ratios for past-year dental visits by 4 models of predictors (using non-imputed data)

	Model 0		Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less (reference)										
Some college	1.81**	(1.62, 2.01)	1.60**	(1.43, 1.79)	1.60**	(1.43, 1.80)	1.51**	(1.34, 1.69)	1.31**	(1.16, 1.48)
College graduate	3.90**	(3.43, 4.44)	2.59**	(2.25, 2.97)	2.65**	(2.30, 3.05)	2.45**	(2.12, 2.83)	1.99**	(1.71, 2.31)
Income level										
<$20,000 (reference)										
$20,000-$74,999			1.53**	(1.37, 1.72)	1.55**	(1.38, 1.74)	1.35**	(1.20, 1.53)	1.26**	(1.11, 1.43)
$75,000-99,999			3.22**	(2.62, 3.95)	3.35**	(2.73, 4.13)	2.76**	(2.22, 3.42)	2.37**	(1.89, 2.96)
$100,000+			3.99**	(3.35, 4.75)	4.09**	(3.43, 4.89)	3.29**	(2.72, 3.97)	2.74**	(2.25, 3.34)
Gender										
Female (reference)										
Male					0.68**	(0.62, 0.76)	0.68**	(0.61, 0.75)	0.82**	(0.74, 0.91)
Race/ethnicity & nativity status										
U.S.-born Hispanic					0.96	(0.79, 1.16)	1.02	(0.85, 1.24)	0.88	(0.72, 1.08)
Foreign-born Hispanic					1.09	(0.94, 1.27)	1.39**	(1.19, 1.62)	1.19+	(1.01, 1.41)
Non-Hispanic White (reference)										
Non-Hispanic Black					0.66**	(0.58, 0.76)	0.71**	(0.62, 0.81)	0.73**	(0.64, 0.84)
Non-Hispanic Asian					0.85	(0.72, 1.02)	0.96	(0.80, 1.15)	0.87	(0.72, 1.05
Other race or multiracial					0.69+	(0.52, 0.92)	0.74	(0.55, 1.00)	0.76	(0.55, 1.03)
Health insurance status										
Private (reference)										
Public							0.72**	(0.64, 0.81)	0.78**	(0.69, 0.88)
No insurance							0.35**	(0.29, 0.42)	0.36**	(0.30, 0.44)

Appendix 1.6 continued

Occupation status										
Employed (reference)										
Not employed							0.85+	(0.74, 0.98)	1.01	(0.87, 1.17)
Retired							1.14+	(1.01, 1.29)	1.23*	(1.09, 1.40)
Has diabetes										
No (reference)										
Yes									0.89	(0.79, 1.00)
Daily flossing										
0 days (reference)										
1 to 6 days									2.47**	(2.17, 2.81)
7 days									3.70**	(3.27, 4.20)
Smoking status										
Never smoked (reference)										
Former smoker									0.92	(0.81, 1.03)
Current smoker									0.64**	(0.55, 0.75)
Constant	0.78**	(0.73, 0.83)	0.53**	(0.48, 0.59)	0.70**	(0.61, 0.79)	0.93	(0.78, 1.11)	0.53**	(0.44, 0.65)
AIC	9684.35		9375.52		9274.86		9098.11		8594.76	
BIC	9705.07		9416.96		9357.74		9208.61		8739.81	
-2 Log Likelihood	-4839.18		-4681.76		-4625.43		-4533.05		-4276.38	
df	3		6		12		16		21	
Pseudo R2	0.0477		0.0787		0.0897		0.1074		0.1579	

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; Above data are not imputed.

Appendix 1.7. Logistic regressions of total sample of adults age 50+ years (n= 7,386): Odds ratios for past-year dental visits by 4 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education								
High school or less (reference)								
Some college	1.58**	(1.37, 1.83)	1.52**	(1.32, 1.77)	1.47**	(1.27, 1.71)	1.27*	(1.07, 1.51)
College graduate	3.13**	(2.62, 3.74)	3.08**	(2.56, 3.70)	2.92**	(2.42, 3.52)	2.32**	(1.89, 2.84)
Income level								
<$20,000 (reference)								
$20,000-$74,999	1.83**	(1.56, 2.15)	1.81**	(1.54, 2.13)	1.61**	(1.36, 1.91)	1.48**	(1.25, 1.75)
$75,000-99,999	3.76**	(2.68, 5.26)	3.76**	(2.68, 5.29)	3.29**	(2.36, 4.58)	2.76**	(2.00, 3.81)
$100,000+	4.52**	(3.57, 5.69)	4.42**	(3.49, 5.60)	3.75**	(2.91, 4.82)	2.93**	(2.28, 3.77)
Gender								
Female (reference)								
Male			0.70**	(0.61, 0.80)	0.71**	(0.62, 0.82)	0.88	(0.75, 1.02)
Race/ethnicity & nativity status								
U.S.-born Hispanic			0.83	(0.64, 1.08)	0.89	(0.69, 1.16)	0.76	(0.57, 1.02)
Foreign-born Hispanic			0.86	(0.70, 1.06)	1.13	(0.90, 1.42)	0.95	(0.73, 1.23)
Non-Hispanic White (reference)								
Non-Hispanic Black			0.59**	(0.51, 0.68)	0.63**	(0.54, 0.74)	0.65**	(0.56, 0.76)
Non-Hispanic Asian			0.76+	(0.62, 0.93)	0.85	(0.68, 1.05)	0.78+	(0.62, 0.98)
Other race or multiracial			0.70	(0.45, 1.10)	0.72	(0.45, 1.14)	0.75	(0.47, 1.21)
Health insurance status								
Private (reference)								
Public					0.71**	(0.60, 0.84)	0.77*	(0.66, 0.89)
No insurance					0.36**	(0.27, 0.48)	0.36**	(0.27, 0.48)
Occupation status								
Employed (reference)								
Not employed					1.01	(0.82, 1.25)	1.16	(0.93, 1.44)
Retired					1.34*	(1.13, 1.61)	1.40*	(1.16, 1.69)
Has diabetes								
No (reference)								
Yes							0.82+	(0.69, 0.98)
Daily flossing								
0 days (reference)								
1 to 6 days							2.49**	(2.02, 3.07)
7 days							4.08**	(3.25, 5.11)

Appendix 1.7 continued

Smoking status								
Never smoked (reference)								
Former smoker							0.84	(0.69, 1.01)
Current smoker							0.62**	(0.50, 0.76)
Constant	0.55**	(0.47, 0.63)	0.74*	(0.62, 0.88)	0.85	(0.68, 1.08)	0.51**	(0.39, 0.66)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Appendix 1.8. Odds ratios for past-year dental visits by 4 models of predictors using an imputed and weighted sample of 50 to 59 year-old adults (n= 2,782)

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education								
High school or less (reference)								
Some college	1.29	(0.98, 1.70)	1.25	(0.94, 1.67)	1.18	(0.88, 1.57)	1.07	(0.77, 1.48)
College graduate	2.25**	(1.63, 3.10)	2.21**	(1.59, 3.08)	2.07**	(1.47, 2.91)	1.71*	(1.17, 2.48)
Income level								
<$20,000 (reference)								
$20,000-$74,999	1.42+	(1.06, 1.90)	1.44+	(1.07, 1.95)	1.17	(0.84, 1.62)	1.10	(0.79, 1.53)
$75,000-99,999	3.70**	(2.21, 6.18)	3.84**	(2.26, 6.54)	2.83**	(1.63, 4.93)	2.42*	(1.44, 4.07)
$100,000+	4.68**	(3.20, 6.86)	4.82**	(3.26, 7.12)	3.21**	(2.00, 5.14)	2.69**	(1.68, 4.30)
Gender								
Female (reference)								
Male			0.72+	(0.55, 0.93)	0.73+	(0.56, 0.96)	0.84	(0.63, 1.12)
Race/ethnicity & nativity status								
U.S.-born Hispanic			1.05	(0.66, 1.67)	1.08	(0.68, 1.71)	0.91	(0.56, 1.48)
Foreign-born Hispanic			1.03	(0.70, 1.51)	1.29	(0.86, 1.95)	1.04	(0.67, 1.64)
Non-Hispanic White (reference)								
Non-Hispanic Black			0.97	(0.73, 1.29)	0.97	(0.86, 1.95)	0.93	(0.70, 1.24)
Non-Hispanic Asian			1.13	(0.83, 1.54)	1.18	(0.85, 1.63)	1.04	(0.74, 1.45)
Other race or multiracial			0.97	(0.50, 1.87)	0.91	(0.47, 1.74)	0.95	(0.53, 1.70)
Health insurance status								
Private (reference)								
Public					0.76	(0.54, 1.07)	0.78	(0.55, 1.12)
No insurance					0.29**	(0.20, 0.41)	0.30**	(0.20, 0.43)
Occupation status								
Employed (reference)								
Not employed					0.93	(0.69, 1.27)	1.02	(0.75, 1.40)
Retired					2.08	(0.72, 6.01)	1.90	(0.64, 5.68)
Has diabetes								
No (reference)								
Yes							0.84	(0.62, 1.14)
Daily flossing								
0 days (reference)								
1 to 6 days							1.64*	(1.14, 2.34)
7 days							2.82**	(1.90, 4.19)

Appendix 1.8 continued

Smoking status								
Never smoked (reference)								
Former smoker							0.87	(0.58, 1.32)
Current smoker							0.67+	(0.48, 0.93)
Constant	0.57**	(0.44, 0.74)	0.67+	(0.48, 0.94)	1.06	(0.70, 1.61)	0.80	(0.51, 1.26)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Appendix 1.9. Odds ratios for past-year dental visits by 4 models of predictors using an imputed and weighted sample of 60 to 69 year-old adults (n= 2,993)

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education								
High school or less (reference)								
Some college	1.86**	(1.41, 2.47)	1.79**	(1.35, 2.38)	1.72*	(1.28, 2.32)	1.41+	(1.03, 1.92)
College graduate	3.97**	(2.78, 5.67)	3.93**	(2.73, 5.67)	3.73**	(2.54, 5.48)	2.89**	(1.94, 4.30)
Income level								
<$20,000 (reference)								
$20,000-$74,999	1.94**	(1.41, 2.68)	1.88**	(1.38, 2.55)	1.66*	(1.21, 2.27)	1.53+	(1.08, 2.17)
$75,000-99,999	4.13**	(2.45, 6.94)	3.91**	(2.31, 6.61)	3.32**	(2.05, 5.36)	2.98**	(1.82, 4.87)
$100,000+	4.77**	(2.96, 7.70)	4.56**	(2.84, 7.31)	3.94**	(2.43, 6.39)	2.90**	(1.69, 4.99)
Gender								
Female (reference)								
Male			0.68*	(0.53, 0.88)	0.68*	(0.52, 0.87)	0.91	(0.71, 1.17)
Race/ethnicity & nativity status								
U.S.-born Hispanic			1.05	(0.73, 1.52)	1.10	(0.77, 1.57)	0.93	(0.63, 1.37)
Foreign-born Hispanic			0.91	(0.65, 1.28)	1.09	(0.75, 1.58)	0.88	(0.60, 1.31)
Non-Hispanic White (reference)								
Non-Hispanic Black			0.47**	(0.35, 0.61)	0.49**	(0.37, 0.64)	0.50**	(0.37, 0.69)
Non-Hispanic Asian			0.66+	(0.46, 0.95)	0.74	(0.51, 1.08)	0.65	(0.42, 1.00)
Other race or multiracial			0.55	(0.24, 1.27)	0.57	(0.23, 1.41)	0.61	(0.21, 1.73)
Health insurance status								
Private (reference)								
Public					0.71+	(0.53, 0.96)	0.82	(0.60, 1.11)
No insurance					0.51+	(0.28, 0.94)	0.55	(0.29, 1.04)
Occupation status								
Employed (reference)								
Not employed					0.97	(0.67, 1.39)	1.15	(0.78, 1.71)
Retired					1.38+	(1.03, 1.86)	1.34	(0.98, 1.84)
Has diabetes								
No (reference)								
Yes							0.74	(0.52, 1.05)
Daily flossing								
0 days (reference)								
1 to 6 days							3.55**	(2.53, 4.97)
7 days							4.33**	(3.16, 5.94)

Appendix 1.9 continued

Smoking status								
Never smoked (reference)								
Former smoker							0.74+	(0.57, 0.96)
Current smoker							0.60+	(0.41, 0.88)
Constant	0.54**	(0.43, 0.67)	0.77	(0.57, 1.04)	0.88	(0.55, 1.42)	0.50+	(0.26, 0.95)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Appendix 1.10. Odds ratios for past-year dental visits by 4 models of predictors using an imputed and weighted sample of 70 to 79 year-old adults (n= 1,744)

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education								
High school or less (reference)								
Some college	1.80**	(1.32, 2.44)	1.70*	(1.24, 2.31)	1.62*	(1.18, 2.21)	1.37	(0.94, 1.99)
College graduate	4.73**	(3.07, 7.27)	4.80**	(3.12, 7.37)	4.52**	(2.92, 7.00)	3.36**	(2.17, 5.21)
Income level								
<$20,000 (reference)								
$20,000-$74,999	2.32**	(1.63, 3.29)	2.25**	(1.56, 3.23)	2.10**	(1.42, 3.09)	1.72+	(1.11, 2.65)
$75,000-99,999	3.02*	(1.55, 5.90)	2.99*	(1.49, 5.99)	2.81*	(1.43, 5.52)	1.93	(0.96, 3.88)
$100,000+	4.61**	(2.66, 7.98)	4.39**	(2.46, 7.83)	3.95**	(2.12, 7.33)	2.72*	(1.38, 5.34)
Gender								
Female (reference)								
Male			0.65*	(0.48, 0.88)	0.65*	(0.47, 0.88)	0.79	(0.55, 1.13)
Race/ethnicity & nativity status								
U.S.-born Hispanic			0.42*	(0.26, 0.68)	0.43*	(0.27, 0.69)	0.36**	(0.22, 0.59)
Foreign-born Hispanic			0.81	(0.56, 1.17)	1.03	(0.69, 1.54)	1.01	(0.63, 1.61)
Non-Hispanic White (reference)								
Non-Hispanic Black			0.42**	(0.30, 0.59)	0.45**	(0.32, 0.64)	0.50*	(0.34, 0.76)
Non-Hispanic Asian			0.70	(0.43, 1.12)	0.82	(0.52, 1.31)	0.84	(0.51, 1.38)
Other race or multiracial			0.65	(0.30, 1.40)	0.66	(0.31, 1.43)	0.76	(0.34, 1.70)
Health insurance status								
Private (reference)								
Public					0.61*	(0.46, 0.81)	0.61*	(0.45, 0.81)
No insurance					0.37	(0.11, 1.20)	0.34+	(0.12, 0.98)
Occupation status								
Employed (reference)								
Not employed					1.19	(0.69, 2.07)	1.40	(0.78, 2.50)
Retired					1.22	(0.84, 1.77)	1.19	(0.80, 1.76)
Has diabetes								
No (reference)								
Yes							0.97	(0.72, 1.31)
Daily flossing								
0 days (reference)								
1 to 6 days							3.07**	(2.02, 4.67)
7 days							5.99**	(4.15, 8.65)

Appendix 1.10 continued

Smoking status								
Never smoked (reference)								
Former smoker							0.91	(0.65, 1.28)
Current smoker							0.45*	(0.25, 0.81)
Constant	0.52**	(0.37, 0.71)	0.76	(0.52, 1.10)	0.82	(0.46, 1.46)	0.48+	(0.26, 0.89)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Appendix 1.11. Odds ratios for past-year dental visits by 4 models of predictors using an imputed and weighted sample of adults ages 80+ years (n= 1,155)

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education								
High school or less (reference)								
Some college	1.75*	(1.19, 2.57)	1.76*	(1.17, 2.65)	1.72+	(1.15, 2.58)	1.49	(0.99, 2.23)
College graduate	2.94**	(1.95, 4.43)	2.98**	(1.92, 4.63)	2.89**	(1.84, 4.55)	2.50**	(1.56, 4.03)
Income level								
<$20,000 (reference)								
$20,000-$74,999	2.29**	(1.67, 3.16)	2.11**	(1.51, 2.95)	2.04**	(1.46, 2.84)	2.14*	(1.44, 3.20)
$75,000-99,999	6.50*	(2.53, 16.72)	6.75*	(2.58, 17.70)	6.46*	(2.46, 16.95)	7.21*	(2.40, 21.63)
$100,000+	3.89**	(1.94, 7.78)	4.04**	(1.99, 8.17)	3.81**	(1.88, 7.73)	3.60*	(1.54, 8.44)
Gender								
Female (reference)								
Male			0.71+	(0.54, 0.94)	0.70+	(0.53, 0.93)	1.01	(0.73, 1.40)
Race/ethnicity & nativity status								
U.S.-born Hispanic			0.65	(0.30, 1.39)	0.68	(0.32, 1.48)	0.73	(0.36, 1.51)
Foreign-born Hispanic			0.68	(0.28, 1.63)	0.80	(0.33, 1.94)	0.82	(0.27, 2.47)
Non-Hispanic White (reference)								
Non-Hispanic Black			0.30**	(0.20, 0.44)	0.31**	(0.21, 0.48)	0.41**	(0.26, 0.65)
Non-Hispanic Asian			0.27**	(0.15, 0.51)	0.30**	(0.16, 0.56)	0.29*	(0.15, 0.57)
Other race or multiracial			0.64	(0.22, 1.87)	0.66	(0.23, 1.90)	0.64	(0.17, 2.47)
Health insurance status								
Private (reference)								
Public					0.83	(0.58, 1.19)	0.99	(0.68, 1.43)
No insurance					0.41	(0.08, 2.05)	0.50	(0.10, 2.49)
Occupation status								
Employed (reference)								
Not employed					0.72	(0.32, 1.62)	0.76	(0.31, 1.85)
Retired					0.92	(0.49, 1.75)	0.95	(0.48, 1.91)
Has diabetes								
No (reference)								
Yes							0.65+	(0.44, 0.95)
Daily flossing								
0 days (reference)								
1 to 6 days							3.09**	(2.06, 4.64)
7 days							5.63**	(3.97, 7.99)

Appendix 1.11 continued

Smoking status								
Never smoked (reference)								
Former smoker							0.65+	(0.43, 0.97)
Current smoker							0.69	(0.32, 1.49)
Constant	0.52**	(0.40, 0.66)	0.72+	(0.54, 0.96)	0.88	(0.47, 1.65)	0.45	(0.20, 1.01)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Appendix 2.1 Household food security questionnaire

The household interview for food security is based on the U.S. Food Security Survey Module (U.S. FSSM) questionnaire (CDC & NCHS, 2022; USDA, 2022a). There are 18 items for households with children under the age of 18 years and 10 items for households without children. Questions refer to all household members, not just NHANES participants.

<u>Food security categories</u>

1 = Household full food security: no affirmative response in any of these items.
2 = Household marginal food security: 1-2 affirmative responses.
3 = Household low food security: 3-5 affirmative responses for household without children under the age of 18; 3-7 affirmative responses for household with children.
4 = Household very low food security: 6-10 affirmative responses for household without children under the age of 18; 8-18 affirmative responses for household with children.

Affirmative responses for FSSM questions are defined as:

- Answered "often true" or "sometimes true" (i.e., codes 1 or 2) for items FSD032a, FSD032b, FSD032c, FSD032d, FSD032e, or FSD032f.
- Answered "yes" (i.e., code 1) for items FSD041, FSD061, FSD071, FSD081, FSD092, FSD111, FSD122, FSD141, or FSD146.
- Answered "almost every month", or "some months but not every month" (i.e., codes 1 or 2) for items FSD052, FSD102, or FSD132.

<u>Food security questionnaire (*Item No.*)</u>

1. *FSD032A* {I/we} worried whether {my/our} food would run out before {I/we} got money to buy more.

Response:

1	Often true
2	Sometimes true
3	Never true
7	Refused
9	Don't know

2. *FSD032B* The food that {I/we} bought just didn't last, and {I/we} didn't have enough money to get more food.

Response:

1	Often true

2 Sometimes true

3 Never true

7 Refused

9 Don't know

3. *FSD032C* {I/we} couldn't afford to eat balanced meals.

Response:

1 Often true

2 Sometimes true

3 Never true

7 Refused

9 Don't know

4. *FSD041* In the last 12 months, did {you/you or other adults in your household} ever cut the size of your meals or skip meals because there wasn't enough money for food?

Response:

No

Yes

5. *FSD052* How often did this happen?

Response:

1 Almost every month

2 Some months but not every month

3 Only 1 or 2 months

7 Refused

9 Don't know

6. *FSD061* In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?

Response:

No

Yes

7. *FSD071* [In the last 12 months], were you ever hungry but didn't eat because there wasn't enough money for food?

Response:

No

Yes

8. *FSD081* [In the last 12 months], did you lose weight because there wasn't enough money for food?

Response:

No

Yes

9. *FSD092* [In the last 12 months], did {you/you or other adults in your household} ever not eat for a whole day because there wasn't enough money for food?

Response:

No

Yes

10. *FSD102* How often did this happen?

Response:

1	Almost every month
2	Some months but not every month
3	Only 1 or 2 months
7	Refused
9	Don't know

<u>Questionnaire continues for households with at least one child under 18 years of age:</u>

11. *FSD032D* (I/we) relied on only a few kinds of low-cost foods to feed {CHILD'S NAME / THE CHILDREN} because there wasn't enough money for food.

Response:

1	Often true
2	Sometimes true
3	Never true
7	Refused

9 Don't know

12. *FSD032E* (I/we) couldn't feed {CHILD'S NAME / THE CHILDREN} a balanced meal because there wasn’t enough money for food.

Response:

1 Often true

2 Sometimes true

3 Never true

7 Refused

9 Don't know

13. *FSD032F* {CHILD'S NAME WAS /THE CHILDREN WERE} not eating enough because there wasn't enough money for food.

Response:

1 Often true

2 Sometimes true

3 Never true

7 Refused

9 Don't know

14. *FSD111* In the last 12 months, did you ever cut the size of {CHILD'S NAME's/any of the children's} meals because there wasn't enough money for food?

Response:

No

Yes

15. *FSD122* [In the last 12 months], did {CHILD'S NAME/any of the children} ever skip meals because there wasn't enough money for food?

Response:

No

Yes

16. *FSD132* How often did this happen?

Response:

1 Almost every month

2 Some months but not every month

3 Only 1 or 2 months

7 Refused

9 Don't know

17. *FSD141* In the last 12 months, {was CHILD'S NAME/were any of the children} ever hungry but there wasn't enough money for food?

Response:

No

Yes

18. *FSD146* [In the last 12 months], did {CHILD'S NAME/any of the children} ever not eat for a whole day because there wasn't enough money for food?

Response:

No

Yes

Appendix 2.2. Patterns of missing observations in the total sample of dentate adults ages 50+ years from NHANES 2015-2018 (n=4,639)*

Missing-value patterns
(1 means complete)

Percent	Pattern 1	2	3	4	5	6	7	8	9	10
84%	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	0
4	1	1	1	1	1	1	1	1	0	0
3	1	1	1	1	1	1	1	0	1	1
<1	1	1	1	1	1	1	1	0	1	0
<1	1	1	1	1	1	1	0	1	1	1
<1	1	1	1	1	1	1	1	0	0	0
<1	1	1	1	0	1	1	1	1	1	1
<1	1	1	1	1	0	1	1	1	1	1
<1	1	1	1	1	1	0	1	1	1	1
<1	1	0	1	1	1	1	1	1	1	1
<1	1	1	1	1	0	1	1	1	1	0
<1	1	1	1	1	1	0	1	1	0	0
<1	1	1	1	1	1	1	0	1	1	0
<1	1	1	0	1	1	1	1	1	1	1
<1	1	1	1	1	1	1	0	1	0	0
<1	0	1	1	1	1	1	1	1	1	1
<1	1	0	1	1	1	1	0	1	1	1
<1	1	1	0	0	1	0	0	1	1	0
<1	1	1	0	0	1	1	1	1	1	0
<1	1	1	0	1	1	0	1	0	1	1
<1	1	1	0	1	1	0	1	1	1	0
<1	1	1	0	1	1	1	1	0	1	0
<1	1	1	0	1	1	1	1	1	1	0
<1	1	1	1	0	1	1	1	1	0	0
<1	1	1	1	1	0	0	1	1	1	0
<1	1	1	1	1	0	1	1	0	0	0
<1	1	1	1	1	0	1	1	0	1	0
<1	1	1	1	1	0	1	1	1	0	0
<1	1	1	1	1	1	0	0	0	0	0
<1	1	1	1	1	1	0	0	1	0	0
<1	1	1	1	1	1	0	1	1	1	0
<1	1	1	1	1	1	1	0	0	1	0
<1	1	1	1	1	1	1	0	0	1	1
<1	1	1	1	1	1	1	1	1	0	1
100%										

*Where variables are: (1) race/ethnicity and nativity, (2) occupation, (3) smoking, (4) flossing, (5) health insurance, (6) education, (7) dental visits, (8) diabetes, (9) food security, and (10) income.

Appendix 2.3. Tests for correlation between food security and income: Odds ratios for presence of untreated dental caries (n= 4,639)

	Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI
Level of education						
High school or less	2.49**	(1.90, 3.15)	2.91**	(2.29, 3.69)	2.23**	(1.72, 2.88)
Some college	1.70*	(1.21, 2.39)	1.99**	(1.44, 2.74)	1.63*	(1.15, 2.29)
College graduate (reference)						
Income level						
<$20,000	4.68**	(3.07, 7.13)			3.48**	(2.21, 5.49)
$20,000-$74,999	2.61**	(1.74, 3.91)			2.31**	(1.54, 3.46)
$75,000-99,999	1.44	(0.75, 2.79)			1.37	(0.72, 2.61)
$100,000+ (reference)						
Food security						
Full food security (reference)						
Marginal food security			2.40**	(1.79, 3.21)	1.88**	(1.42, 2.48)
Low food security			2.27**	(1.66, 3.12)	1.67*	(1.19, 2.35)
Very low food security			2.97**	(2.13, 4.14)	2.06**	(1.44, 2.93)
Constant	0.09**	(0.06, 0.12)	0.13**	(0.10, 0.17)	0.09**	(0.06, 0.12)

** $p<0.001$, * $p<0.01$, + $p<0.05$

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; Above data are weighted and imputed.

Appendix 2.4. Differences in the baseline characteristics between the missing and complete case samples from 2015-2018 NHANES dentate participants age 50+ years

%	Total		
	Missing obs.	Complete case sample	p-value
Presence of untreated dental caries (Dependent variable)	27.4	24.1	0.2962
Most recent dental visit			0.9168
Within the past 12 months	67.7	68.3	
Between 1-5 years	22.3	21.4	
More than 5 years, or never	10.1	10.3	
Level of education			0.4563
High school or less	33.3	35.8	
Some college	30.3	31.4	
College graduate	36.4	32.8	
Income level			0.2358
<$20,000	21.0	13.9	
$20,000-$74,999	44.7	44.3	
$75,000-99,999	12.9	12.9	
$100,000+	21.5	29.0	
Food security			0.1858
Full food security	74.8	78.8	
Marginal food security	11.5	8.3	
Low food security	9.4	7.1	
Very low food security	4.3	5.8	
Gender			0.5206
Female	54.6	52.8	
Male	45.4	47.2	
Race/ethnicity & nativity			0.0001
U.S.-born Hispanic	4.1	3.9	
Foreign-born Hispanic	10.8	6.4	
Non-Hispanic White	62.5	72.7	
Non-Hispanic Black	12.9	8.8	
Non-Hispanic Asian	6.4	4.5	
Other race or multiracial	3.3	3.7	
Length of stay in the U.S.			0.0001
U.S.-born	77.4	85.2	
non-U.S. born, <15 yrs	1.5	1.8	
non-U.S. born, 15+ yrs	21.1	13.0	

Appendix 2.4 continued

Occupation status			0.9771
Employed	48.3	48.4	
Not employed	16.3	16.7	
Retired	35.4	34.9	
Health insurance status			0.2856
Private	67.9	72.6	
Public	24.0	20.5	
No insurance	8.0	6.9	
Has diabetes	20.2	19.0	0.4452
Daily flossing			0.6199
0 days	23.2	22.2	
1 to 6 days	33.8	36.5	
7 days	43.0	41.3	
Smoking status			0.1309
Never smoked	58.7	54.2	
Former smoker	27.0	32.9	
Current smoker	14.3	12.9	
N	748	3,891	

*Percentages used sampling weights to reflect the national U.S. older adult population; above data are not imputed.

**p-values indicate significant differences in the characteristics between missing and analytic samples; calculated by weighted F-tests.

Appendix 2.5: Odds ratios of untreated dental caries and variation by SES x age and gender x age interactions

	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)
Level of education				
High school or less	2.0** (0.2)	2.2** (0.4)	2.0** (0.2)	1.9** (0.2)
Some college	1.5* (0.2)	1.7* (0.3)	1.5* (0.2)	1.4* (0.2)
College graduate (reference)				
Income level				
<$20,000	3.8** (0.5)	3.9** (0.5)	4.2** (0.9)	3.9** (0.5)
$20,000-$74,999	2.5** (0.3)	2.5** (0.3)	2.6** (0.5)	2.5** (0.3)
$75,000-99,999	1.2 (0.2)	1.2 (0.2)	1.4 (0.3)	1.2 (0.2)
$100,000+ (reference)				
Gender				
Female (reference)				
Male	1.5** (0.1)	1.5** (0.1)	1.6** (0.1)	1.5* (0.2)
Age category				
50-59 years (reference)				
60-69 years		1.1 (0.2)	0.8 (0.2)	0.9 (0.1)
70-79 years		1.0 (0.3)	1.3 (0.4)	1.0 (0.1)
80+ years		1.3 (0.5)	1.4 (0.6)	0.9 (0.2)
Education*Age				
High school or less*60-69 years		0.9 (0.2)		
High school or less*70-79 years		0.9 (0.2)		
High school or less*80+ years		0.6 (0.2)		
Some college*60-69 years		0.8 (0.2)		
Some college*70-79 years		0.8 (0.3)		
Some college*80+ years		0.5 (0.2)		
Income*Age				
<$20,000*60-69 years			1.1 (0.3)	
<$20,000*70-79 years			0.7 (0.2)	
<$20,000*80+ years			0.7 (0.3)	
$20,000-$74,999*60-69 years			1.2 (0.4)	
$20,000-$74,999*70-79 years			0.7 (0.2)	
$20,000-$74,999*80+ years			0.5 (0.2)	
$75,000-$99,999*60-69 years			1.1 (0.4)	
$75,000-$99,999*70-79 years			0.6 (0.3)	
$75,000-$99,999*80+ years			0.8 (0.6)	

Appendix 2.5 continued

Gender*Age				
Male*60-69 years				1.1 (0.2)
Male*70-79 years				0.9 (0.2)
Male*80+ years				0.9 (0.2)
Constant	0.1** (0.0)	0.1** (0.0)	0.1** (0.0)	0.1** (0.0)
Observations	3,891	3,891	3,891	3,891
AIC	4491.7	4503.4	4503.8	4499.4
BIC	4535.6	4603.6	4622.9	4580.9
-2 Log Likelihood	-2238.9	-2235.7	-2232.9	-2236.7
df	7	16	19	13
Pseudo R2	0.063	0.064	0.065	0.064

Likelihood Ratio Test: Model 1 is the reduced model

	Mod1 vs Mod2	Mod1 vs Mod3	Mod1 vs Mod4
LR chi2	6.3	11.9	4.3
Prob > chi2	0.705	0.456	0.632

** p<0.001, * p<0.01, + p<0.05

Model 1: Control for education + income + gender

Model 2: Control for education + income + gender + age*education

Model 3: Control for education + income + gender + age*income

Model 4: Control for education + income + gender + age*gender

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; Above data are not imputed.

Appendix 2.6. Sequential logistic regression models of dentate adults ages 50+ years (n= 3,891): Odds ratios for untreated dental caries by 5 models of predictors (using non-imputed data)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	1.95**	(1.59, 2.39)	1.80**	(1.46, 2.21)	1.86**	(1.51, 2.30)	1.78**	(1.44, 2.20)	1.40*	(1.12, 1.75)
Some college	1.42*	(1.15, 1.77)	1.37*	(1.10, 1.70)	1.35*	(1.08, 1.68)	1.35*	(1.08, 1.69)	1.20	(0.96, 1.52)
College graduate (reference)										
Income level										
<$20,000	3.73**	(2.87, 4.84)	2.90**	(2.21, 3.82)	2.98**	(2.26, 3.93)	2.45**	(1.84, 3.27)	1.82**	(1.35, 2.46)
$20,000-$74,999	2.45**	(1.93, 3.11)	2.17**	(1.70, 2.77)	2.18**	(1.70, 2.79)	2.01**	(1.56, 2.58)	1.65**	(1.28, 2.13)
$75,000-99,999	1.22	(0.87, 1.72)	1.16	(0.82, 1.64)	1.15	(0.82, 1.63)	1.13	(0.79, 1.59)	1.10	(0.77, 1.58)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			1.69**	(1.37, 2.08)	1.72**	(1.39, 2.13)	1.63**	(1.32, 2.03)	1.48*	(1.18, 1.85)
Low food security			1.45*	(1.17, 1.80)	1.52**	(1.21, 1.90)	1.44*	(1.15, 1.81)	1.26	(1.00, 1.60)
Very low food security			1.99**	(1.55, 2.56)	1.96**	(1.52, 2.54)	1.80**	(1.39, 2.33)	1.44*	(1.09, 1.89)
Gender										
Female (reference)										
Male					1.54**	(1.33, 1.78)	1.56**	(1.35, 1.81)	1.21+	(1.03, 1.41)
Race/ethnicity & nativity										
U.S.-born Hispanic					1.13	(0.87, 1.47)	1.10	(0.84, 1.42)	1.08	(0.82, 1.43)
Foreign-born Hispanic					0.75+	(0.60, 0.93)	0.65**	(0.52, 0.82)	0.79	(0.62, 1.00)
Non-Hispanic White (reference)										
Non-Hispanic Black					1.65**	(1.36, 2.00)	1.57**	(1.30, 1.91)	1.39*	(1.13, 1.70)
Non-Hispanic Asian					0.92	(0.70, 1.20)	0.84	(0.64, 1.10)	0.85	(0.64, 1.12)
Other race or multiracial					1.72*	(1.16, 2.54)	1.63+	(1.10, 2.43)	1.49	(0.99, 2.26)

Appendix 2.6 continued

Health insurance status										
Private (reference)										
Public							1.51**	(1.27, 1.80)	1.39**	(1.16, 1.67)
No insurance							2.00**	(1.57, 2.55)	1.45*	(1.12, 1.87)
Has diabetes										
No (reference)										
Yes									1.36**	(1.15, 1.62)
Daily flossing										
0 days									1.76**	(1.45, 2.12)
1 to 6 days									1.02	(0.85, 1.23)
7 days (reference)										
Smoking status										
Never smoked (reference)										
Former smoker									1.04	(0.87, 1.24)
Current smoker									1.87**	(1.50, 2.34)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									1.99**	(1.67, 2.37)
More than 5 years, or never									3.09**	(2.49, 3.83)
Constant	0.12**	(0.10, 0.16)	0.12**	(0.10, 0.16)	0.09**	(0.07, 0.12)	0.09**	(0.07, 0.11)	0.07**	(0.05, 0.10)
AIC	4526.20		4486.66		4406.78		4370.42		4123.22	
BIC	4563.80		4543.06		4500.78		4476.94		4273.61	
-2 Log Likelihood	-2257.10		-2234.33		-2188.39		-2168.21		-2037.61	
df	6		9		15		17		24	
Pseudo R2	0.0553		0.0648		0.0840		0.0924		0.1470	

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018; above data are not imputed.

Appendix 2.7. Logistic regressions of total sample of dentate adults age 50+ years (n= 4,639): Odds ratios for untreated dental caries by 5 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	2.44**	(1.90, 3.15)	2.23**	(1.72, 2.88)	2.29**	(1.75, 3.00)	2.18**	(1.67, 2.84)	1.60*	(1.23, 2.08)
Some college	1.70*	(1.21, 2.39)	1.63*	(1.15, 2.29)	1.65*	(1.17, 2.33)	1.63*	(1.17, 2.27)	1.30	(0.94, 1.79)
College graduate (reference)										
Income level										
<$20,000	4.68**	(3.07, 7.13)	3.48**	(2.21, 5.49)	3.47**	(2.19, 5.52)	2.73**	(1.67, 4.47)	1.98*	(1.21, 3.24)
$20,000-$74,999	2.61**	(1.74, 3.91)	2.31**	(1.54, 3.46)	2.28**	(1.51, 3.45)	2.10*	(1.38, 3.19)	1.74+	(1.12, 2.72)
$75,000-99,999	1.44	(0.75, 2.79)	1.37	(0.72, 2.61)	1.35	(0.71, 2.56)	1.29	(0.69, 2.41)	1.27	(0.66, 2.43)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			1.88**	(1.42, 2.48)	1.87**	(1.39, 2.52)	1.73*	(1.30, 2.31)	1.54*	(1.18, 2.00)
Low food security			1.67*	(1.19, 2.35)	1.72*	(1.22, 2.41)	1.54+	(1.08, 2.20)	1.23	(0.88, 1.73)
Very low food security			2.06**	(1.44, 2.93)	2.05**	(1.48, 2.85)	1.80*	(1.24, 2.60)	1.32	(0.89, 1.97)
Gender										
Female (reference)										
Male					1.46**	(1.21, 1.77)	1.48**	(1.22, 1.80)	1.19	(0.97, 1.46)
Race/ethnicity & nativity status										
U.S.-born Hispanic					1.02	(0.66, 1.57)	0.97	(0.64, 1.49)	0.94	(0.60, 1.46)
Foreign-born Hispanic					0.75	(0.53, 1.07)	0.65+	(0.45, 0.94)	0.78	(0.54, 1.13)
Non-Hispanic White (reference)										
Non-Hispanic Black					1.81**	(1.39, 2.35)	1.72**	(1.32, 2.22)	1.47*	(1.12, 1.93)
Non-Hispanic Asian					0.97	(0.71, 1.32)	0.89	(0.66, 1.22)	0.89	(0.65, 1.24)
Other race or multiracial					1.96+	(1.08, 3.55)	1.87+	(1.03, 3.40)	1.64	(0.80, 3.36)

Appendix 2.7 continued

Health insurance status										
Private (reference)										
Public							1.42*	(1.12, 1.82)	1.36+	(1.08, 1.72)
No insurance							2.07*	(1.30, 3.28)	1.48	(0.92, 2.39)
Occupation status										
Employed (reference)										
Not employed							1.32	(0.95, 1.83)	1.25	(0.90, 1.74)
Retired							1.03	(0.78, 1.37)	1.13	(0.84, 1.53)
Has diabetes										
No (reference)										
Yes									1.41*	(1.12, 1.76)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									2.53**	(2.00, 3.19)
More than 5 years, or never									3.72**	(2.50, 5.54)
Daily flossing										
0 days (reference)										
1 to 6 days									0.67*	(0.51, 0.89)
7 days									0.78	(0.60, 1.00)
Smoking status										
Never smoked (reference)										
Former smoker									1.16	(0.91, 1.49)
Current smoker									2.41**	(1.71, 3.40)
Constant	0.09**	(0.06, 0.12)	0.09**	(0.06, 0.12)	0.07**	(0.05, 0.10)	0.06**	(0.04, 0.09)	0.07**	(0.04, 0.11)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018

Appendix 2.8. Logistic regressions of total sample of dentate adults ages 50-59 years (n= 1,595): Odds ratios for untreated dental caries by 5 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	2.92**	(1.79, 4.78)	2.67*	(1.59, 4.51)	2.71*	(1.59, 4.64)	2.61*	(1.53, 4.46)	1.78+	(1.02, 3.09)
Some college	2.15+	(1.21, 3.82)	2.05+	(1.12, 3.76)	2.01+	(1.09, 3.70)	1.97+	(1.07, 3.62)	1.49	(0.79, 2.80)
College graduate (reference)										
Income level										
<$20,000	5.79**	(2.98, 11.27)	4.30**	(2.12, 8.70)	4.24**	(2.04, 8.83)	3.34*	(1.56, 7.16)	2.48+	(1.15, 5.35)
$20,000-$74,999	3.31*	(1.76, 6.24)	2.82*	(1.47, 5.41)	2.74*	(1.41, 5.31)	2.51*	(1.30, 4.85)	1.97	(0.98, 3.95)
$75,000-99,999	1.62	(0.59, 4.45)	1.52	(0.57, 4.03)	1.49	(0.57, 3.90)	1.40	(0.55, 3.57)	1.47	(0.58, 3.71)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			1.79+	(1.10, 2.91)	1.80+	(1.10, 2.96)	1.69+	(1.04, 2.76)	1.62	(0.98, 2.61)
Low food security			1.64	(0.91, 2.93)	1.77+	(1.01, 3.10)	1.64	(0.91, 2.95)	1.38	(0.82, 2.33)
Very low food security			1.70	(0.92, 3.14)	1.68	(0.92, 3.07)	1.61	(0.86, 3.01)	1.09	(0.56, 2.12)
Gender										
Female (reference)										
Male					1.30	(0.92, 1.84)	1.31	(0.91, 1.87)	1.10	(0.79, 1.53)
Race/ethnicity & nativity status										
U.S.-born Hispanic					0.70	(0.35, 1.38)	0.69	(0.35, 1.36)	0.72	(0.33, 1.59)
Foreign-born Hispanic					0.69	(0.42, 1.12)	0.63	(0.37, 1.07)	0.91	(0.49, 1.68)
Non-Hispanic White (reference)										
Non-Hispanic Black					1.96*	(1.31, 2.93)	1.95*	(1.29, 2.93)	2.05*	(1.31, 3.22)
Non-Hispanic Asian					0.50*	(0.30, 0.83)	0.49*	(0.29, 0.81)	0.59	(0.33, 1.07)
Other race or multiracial					1.31	(0.64, 2.68)	1.36	(0.70, 2.63)	1.22	(0.50, 2.97)

Appendix 2.8 continued

Health insurance status										
Private (reference)										
Public							1.20	(0.80, 1.78)	1.10	(0.74, 1.64)
No insurance							1.69	(0.91, 3.11)	1.04	(0.56, 1.95)
Occupation status										
Employed (reference)										
Not employed							1.16	(0.74, 1.82)	1.09	(0.70, 1.69)
Retired							0.61	(0.21, 1.83)	0.78	(0.29, 2.11)
Has diabetes										
No (reference)										
Yes									1.20	(0.83, 1.73)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									2.89**	(1.82, 4.60)
More than 5 years, or never									3.48**	(1.91, 6.36)
Daily flossing										
0 days (reference)										
1 to 6 days									0.51*	(0.32, 0.83)
7 days									0.74	(0.46, 1.19)
Smoking status										
Never smoked (reference)										
Former smoker									1.41	(0.98, 2.05)
Current smoker									3.32**	(1.98, 5.56)
Constant	0.07**	(0.03, 0.13)	0.07**	(0.03, 0.13)	0.06**	(0.03, 0.12)	0.06**	(0.03, 0.12)	0.06**	(0.02, 0.15)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018

Appendix 2.9. Logistic regressions of total sample of dentate adults ages 60-69 years (n= 1,661): Odds ratios for untreated dental caries by 5 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	2.56*	(1.53, 4.26)	2.33*	(1.31, 4.13)	2.44*	(1.33, 4.49)	2.31+	(1.23, 4.35)	1.78	(0.98, 3.20)
Some college	1.52	(0.88, 2.61)	1.50	(0.86, 2.61)	1.57	(0.84, 2.92)	1.54	(0.81, 2.95)	1.31	(0.71, 2.42)
College graduate (reference)										
Income level										
<$20,000	4.61**	(2.23, 9.51)	2.85+	(1.28, 6.33)	2.99+	(1.33, 6.74)	2.14	(0.92, 5.00)	1.64	(0.68, 3.93)
$20,000-$74,999	2.62*	(1.36, 5.07)	2.21+	(1.10, 4.45)	2.33+	(1.14,4.76)	2.14+	(1.04, 4.40)	1.82	(0.88, 3.75)
$75,000-99,999	1.55	(0.52, 4.59)	1.49	(0.51, 4.41)	1.64	(0.56, 4.84)	1.65	(0.55, 4.91)	1.58	(0.49, 5.08)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			2.14*	(1.32, 3.46)	2.33*	(1.46, 3.73)	2.18*	(1.34, 3.55)	2.04*	(1.27, 3.29)
Low food security			1.89+	(1.13, 3.16)	2.09*	(1.24, 3.54)	1.85+	(1.13, 3.01)	1.66	(0.98, 2.81)
Very low food security			3.06*	(1.69, 5.53)	3.30**	(1.95, 5.61)	2.78**	(1.70, 4.52)	2.10*	(1.29, 3.43)
Gender										
Female (reference)										
Male					2.01**	(1.50, 2.69)	2.08**	(1.57, 2.76)	1.86*	(1.28, 2.70)
Race/ethnicity & nativity status										
U.S.-born Hispanic					1.06	(0.63, 1.78)	0.99	(0.60, 1.65)	0.98	(0.56, 1.73)
Foreign-born Hispanic					0.69	(0.41, 1.16)	0.57+	(0.34, 0.96)	0.56+	(0.32, 0.96)
Non-Hispanic White (reference)										
Non-Hispanic Black					1.37	(0.91, 2.04)	1.30	(0.87, 1.95)	0.96	(0.64, 1.43)
Non-Hispanic Asian					1.16	(0.68, 1.98)	0.99	(0.57, 1.70)	0.83	(0.45, 1.51)
Other race or multiracial					3.02	(0.94, 9.67)	3.01	(0.98, 9.20)	2.64	(0.71, 9.85)

Appendix 2.9 continued

Health insurance status										
Private (reference)										
Public							1.57	(0.97, 2.53)	1.63+	(1.03, 2.58)
No insurance							3.11*	(1.44, 6.72)	2.76+	(1.23, 6.21)
Occupation status										
Employed (reference)										
Not employed							1.56	(0.95, 2.55)	1.42	(0.82, 2.46)
Retired							1.19	(0.72, 1.98)	1.27	(0.77, 2.10)
Has diabetes										
No (reference)										
Yes									1.58+	(1.05, 2.37)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									2.13*	(1.38, 3.29)
More than 5 years, or never									3.92**	(2.19, 7.04)
Daily flossing										
0 days (reference)										
1 to 6 days									0.78	(0.44, 1.39)
7 days									0.89	(0.53, 1.48)
Smoking status										
Never smoked (reference)										
Former smoker									0.78	(0.50, 1.21)
Current smoker									1.67	(0.91, 3.08)
Constant	0.09**	(0.05, 0.17)	0.09**	(0.05, 0.17)	0.06**	(0.03, 0.10)	0.05**	(0.02, 0.09)	0.05**	(0.03, 0.11)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018

Appendix 2.10. Logistic regressions of total sample of dentate adults ages 70-79 years (n= 874): Odds ratios for untreated dental caries by 5 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	2.55*	(1.43, 4.55)	2.47*	(1.38, 4.41)	2.39*	(1.34, 4.25)	2.25*	(1.28, 3.98)	1.52	(0.94, 2.47)
Some college	1.88	(0.97, 3.63)	1.84	(0.95, 3.56)	1.86	(0.98, 3.55)	1.81	(0.95, 3.44)	1.32	(0.66, 2.63)
College graduate (reference)										
Income level										
<$20,000	2.82+	(1.25, 6.37)	2.58+	(1.10, 6.07)	2.43	(1.00, 5.91)	2.17	(0.87, 5.39)	1.47	(0.60, 3.57)
$20,000-$74,999	1.77	(0.89, 3.49)	1.70	(0.85, 3.37)	1.68	(0.82, 3.45)	1.62	(0.77, 3.37)	1.33	(0.59, 2.98)
$75,000-99,999	0.80	(0.25, 2.53)	0.79	(0.25, 2.50)	0.77	(0.23, 2.53)	0.69	(0.22, 2.13)	0.52	(0.16, 1.65)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			1.59	(0.84, 3.03)	1.53	(0.79, 2.96)	1.42	(0.70, 2.87)	1.24	(0.61, 2.50)
Low food security			1.03	(0.48, 2.21)	1.00	(0.47, 2.11)	0.90	(0.42, 1.93)	0.58	(0.25, 1.36)
Very low food security			1.23	(0.46, 3.34)	1.23	(0.45, 3.38)	0.98	(0.38, 2.56)	0.79	(0.27, 2.29)
Gender										
Female (reference)										
Male					1.10	(0.79, 1.51)	1.15	(0.83, 1.58)	0.74	(0.51, 1.09)
Race/ethnicity & nativity status										
U.S.-born Hispanic					1.99+	(1.03, 3.83)	1.95	(0.99, 3.83)	1.31	(0.59, 2.92)
Foreign-born Hispanic					1.09	(0.56, 2.14)	0.92	(0.48, 1.75)	1.02	(0.50, 2.10)
Non-Hispanic White (reference)										
Non-Hispanic Black					2.17*	(1.35, 3.49)	2.01*	(1.21, 3.34)	1.47	(0.76, 2.85)
Non-Hispanic Asian					1.34	(0.69, 2.60)	1.13	(0.57, 2.23)	1.42	(0.67, 3.02)
Other race or multiracial					2.04	(0.66, 6.29)	1.90	(0.59, 6.12)	1.79	(0.43, 7.52)

Appendix 2.10 continued

Health insurance status										
Private (reference)										
Public							1.51	(0.92, 2.48)	1.27	(0.73, 2.22)
No insurance							1.23	(0.41, 3.67)	0.89	(0.31, 2.56)
Occupation status										
Employed (reference)										
Not employed							2.07	(0.91, 4.74)	1.88	(0.81, 4.35)
Retired							1.43	(0.81, 2.53)	1.46	(0.81, 2.62)
Has diabetes										
No (reference)										
Yes									1.35	(0.95, 1.94)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									4.00**	(2.49, 6.40)
More than 5 years, or never									9.14**	(4.59, 18.21)
Daily flossing										
0 days (reference)										
1 to 6 days									1.10	(0.69, 1.75)
7 days									0.79	(0.52, 1.19)
Smoking status										
Never smoked (reference)										
Former smoker									1.54	(0.89, 2.67)
Current smoker									2.19	(0.88, 5.47)
Constant	0.10**	(0.05, 0.22)	0.10**	(0.05, 0.22)	0.09**	(0.04,0.19)	0.06**	(0.03, 0.12)	0.06**	(0.02, 0.14)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018

Appendix 2.11. Logistic regressions of total sample of dentate adults ages 80+ years (n= 509): Odds ratios for untreated dental caries by 5 models of predictors using imputed and weighted data

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	0.98	(0.51, 1.85)	0.94	(0.50, 1.77)	0.93	(0.48, 1.80)	0.85	(0.44, 1.64)	0.72	(0.35, 1.50)
Some college	0.85	(0.42, 1.73)	0.81	(0.41, 1.62)	0.78	(0.38, 1.63)	0.77	(0.39, 1.55)	0.76	(0.38, 1.50)
College graduate (reference)										
Income level										
<$20,000	4.01*	(1.63, 9.83)	3.73*	(1.56, 8.91)	3.66*	(1.52, 8.82)	3.28*	(1.38, 7.78)	2.70+	(1.05, 6.94)
$20,000-$74,999	1.49	(0.68, 3.24)	1.48	(0.69, 3.17)	1.58	(0.72, 3.48)	1.42	(0.68, 2.97)	1.29	(0.59, 2.84)
$75,000-99,999	1.58	(0.38, 6.57)	1.62	(0.38, 6.91)	1.65	(0.33, 8.16)	1.21	(0.25, 5.90)	1.14	(0.20, 6.34)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			1.55	(0.85, 2.84)	1.45	(0.75, 2.79)	1.48	(0.70, 3.11)	1.20	(0.51, 2.79)
Low food security			2.48	(0.99, 6.18)	2.44	(0.89, 6.70)	2.70	(0.91, 8.00)	1.84	(0.53, 6.41)
Very low food security			2.31	(0.58, 9.18)	2.29	(0.51, 10.31)	2.29	(0.42, 12.46)	1.89	(0.27, 13.06)
Gender										
Female (reference)										
Male					1.25	(0.75, 2.08)	1.16	(0.69, 1.97)	0.98	(0.55, 1.77)
Race/ethnicity & nativity status										
U.S.-born Hispanic					1.80	(0.67, 4.85)	1.61	(0.58, 4.52)	1.28	(0.40, 4.07)
Foreign-born Hispanic					0.59	(0.13, 2.59)	0.39	(0.07, 2.08)	0.38	(0.07, 2.09)
Non-Hispanic White (reference)										
Non-Hispanic Black					2.21+	(1.18, 4.13)	2.10+	(1.11, 3.98)	1.58	(0.79, 3.15)
Non-Hispanic Asian					3.01+	(1.28, 7.08)	2.46+	(1.03, 5.83)	1.89	(0.81, 4.38)
Other race or multiracial					4.54	(0.94, 21.96)	5.02	(0.94, 26.88)	5.67	(0.91, 35.21)

Appendix 2.11 continued

Health insurance status										
Private (reference)										
Public							1.59+	(1.04, 2.41)	1.55+	(1.06, 2.27)
No insurance							3.53	(0.20, 62.62)	3.11	(0.09, 111.97)
Occupation status										
Employed (reference)										
Not employed							0.71	(0.23, 2.17)	0.77	(0.25, 2.40)
Retired							0.35+	(0.13, 0.94)	0.37+	(0.14, 0.99)
Has diabetes										
No (reference)										
Yes									1.36	(0.68, 2.71)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									1.90+	(1.01, 3.60)
More than 5 years, or never									1.71	(0.80, 3.64)
Daily flossing										
0 days (reference)										
1 to 6 days									0.68	(0.35, 1.32)
7 days									0.56	(0.31, 1.00)
Smoking status										
Never smoked (reference)										
Former smoker									1.09	(0.60, 1.98)
Current smoker									1.61	(0.37, 7.03)
Constant	0.22*	(0.10, 0.48)	0.21**	(0.09, 0.46)	0.16**	(0.07, 0.39)	0.42	(0.11, 1.51)	0.55	(0.15, 2.05)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2015-2018

Appendix 3.1. Patterns of missing observations in the total sample of adults ages 50+ years from NHANES 2013-2018 (n=7,861)*

Missing-value patterns
(1 means complete)

Percent	Pattern 1	2	3	4	5	6	7	8	9	10
86%	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	0
4	1	1	1	1	1	1	1	1	0	1
3	1	1	1	1	1	1	1	0	1	0
<1	1	1	1	1	1	1	1	1	0	0
<1	1	1	1	1	1	1	0	1	1	1
<1	1	1	1	1	1	1	1	0	0	0
<1	1	1	1	1	1	0	1	1	1	1
<1	1	1	1	1	0	1	1	1	1	1
<1	1	0	1	1	1	1	1	1	1	1
<1	1	1	0	1	1	1	1	1	1	1
<1	1	1	1	0	1	1	1	1	1	1
<1	1	1	1	1	1	0	1	1	1	0
<1	1	1	1	1	0	1	1	0	1	0
<1	0	1	1	1	1	1	1	1	1	1
<1	1	0	1	1	1	1	0	1	1	1
<1	1	1	0	0	1	1	1	1	1	0
<1	1	1	0	1	1	1	1	0	1	0
<1	1	1	0	1	1	1	1	1	1	0
<1	1	1	1	0	0	1	1	1	0	1
<1	1	1	1	0	0	1	1	1	1	0
<1	1	1	1	0	1	1	1	1	0	0
<1	1	1	1	0	1	1	1	1	1	0
<1	1	1	1	1	0	0	1	1	1	0
<1	1	1	1	1	0	1	0	0	0	0
<1	1	1	1	1	0	1	0	0	1	0
<1	1	1	1	1	1	0	1	0	0	0
<1	1	1	1	1	1	0	1	0	1	0
<1	1	1	1	1	1	0	1	1	0	0
<1	1	1	1	1	1	1	0	0	1	0
<1	1	1	1	1	1	1	0	1	1	0
<1	1	1	1	1	1	1	1	0	1	1
100%										

*Where variables are: (1) race/ethnicity and nativity, (2) occupation, (3) flossing, (4) smoking, (5) education, (6) health insurance, (7) dental visits, (8) food insecurity, (9) diabetes, and (10) income.

Appendix 3.2. Differences in the baseline characteristics between the missing and complete case samples from 2013-2018 NHANES participants ages 50+ years

%	Total		
	Missing obs.	Complete case sample	p-value
Has complete tooth loss (Dependent variable)	9.7	10.1	0.704
Most recent dental visit			0.914
Within the past 12 months	64.8	64.8	
Between 1-5 years	21.7	21.2	
More than 5 years, or never	13.5	14.1	
Level of education			0.834
High school or less	37.8	38.1	
Some college	30.0	30.9	
College graduate	32.3	31.0	
Income level			0.285
<$20,000	21.7	16.7	
$20,000-$74,999	45.1	45.5	
$75,000-99,999	11.9	11.3	
$100,000+	21.2	26.4	
Food security			0.305
Full food security	77.1	78.9	
Marginal food security	10.2	8.1	
Low food security	8.3	7.3	
Very low food security	4.4	5.8	
Gender			0.953
Female	53.0	52.9	
Male	47.0	47.1	
Race/ethnicity & nativity			<0.001
U.S.-born Hispanic	4.1	3.6	
Foreign-born Hispanic	10.8	5.7	
Non-Hispanic White	62.9	73.8	
Non-Hispanic Black	13.0	9.5	
Non-Hispanic Asian	6.1	4.2	
Other race or multiracial	3.1	3.2	
Length of stay in the U.S.			<0.001
U.S.-born	79.2	86.2	
non-U.S. born, <15 yrs	1.6	1.5	
non-U.S. born, 15+ yrs	19.3	12.3	

Appendix 3.2 continued

Occupation status			0.396
Employed	43.2	46.1	
Not employed	20.0	17.9	
Retired	36.8	36.0	
Health insurance status			0.1571
Private	66.1	70.2	
Public	25.9	22.1	
No insurance	8.0	7.7	
Has diabetes	20.7	19.3	0.3266
Daily flossing			0.8296
0 days	30.3	29.9	
1 to 6 days	31.8	32.9	
7 days	38.0	37.2	
Smoking status			0.1022
Never smoked	56.6	51.4	
Former smoker	29.7	33.5	
Current smoker	13.8	15.1	
N	1,164	6,697	

*Percentages for analytic sample used sampling weights to reflect the national U.S. older adult population; above data are not imputed.

**p-values indicate significant differences in the characteristics between missing and analytic samples; calculated by weighted F-tests.

Appendix 3.3. Tests for correlation between food security and income: Odds ratios for complete tooth loss (n= 7,861)

	Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI
Level of education						
High school or less	6.34**	(4.49, 8.97)	9.22**	(6.74, 12.63)	6.26**	(4.47, 8.78)
Some college	2.75**	(1.92, 3.92)	3.63**	(2.61, 5.05)	2.72**	(1.91, 3.87)
College graduate (reference)						
Income level						
<$20,000	6.21**	(4.07, 9.48)			5.86**	(3.85, 8.92)
$20,000-$74,999	2.96**	(1.95, 4.49)			2.91**	(1.94, 4.36)
$75,000-99,999	1.44	(0.81, 2.56)			1.43	(0.80, 2.54)
$100,000+ (reference)						
Food security						
Full food security (reference)						
Marginal food security			1.38+	(1.02, 1.87)	1.03	(0.74, 1.43)
Low food security			1.63*	(1.21, 2.20)	1.16	(0.86, 1.57)
Very low food security			1.97*	(1.36, 2.85)	1.22	(0.83, 1.80)
Gender						
Female (reference)						
Male	1.11	(0.92, 1.33)	1.04	(0.87, 1.23)	1.10	(0.91, 1.34)
Race/ethnicity & nativity						
U.S.-born Hispanic	0.40**	(0.29, 0.56)	0.43**	(0.31, 0.60)	0.40**	(0.29, 0.54)
Foreign-born Hispanic	0.41**	(0.30, 0.56)	0.44**	(0.33, 0.60)	0.40**	(0.30, 0.54)
Non-Hispanic White (reference)						
Non-Hispanic Black	0.99	(0.78, 1.24)	1.14	(0.91, 1.43)	0.98	(0.78, 1.22)
Non-Hispanic Asian	0.60+	(0.38, 0.93)	0.63+	(0.40, 0.98)	0.60+	(0.38, 0.95)
Other race or multiracial	1.60+	(1.01, 2.51)	1.71+	(1.09, 2.69)	1.57	(0.99, 2.47)
Constant	0.01**	(0.01, 0.02)	0.02**	(0.02, 0.03)	0.01**	(0.01, 0.02)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.4. Tests for correlation between food security and income: Zero-inflated negative binomial (ZINB) estimates for tooth counts (n= 7,861)

	Model 1		Model 2		Model 3	
Counts outcome: Teeth present	Coef.	95% CI	Coef.	95% CI	Coef.	95% CI
Level of education						
High school or less (reference)						
Some college	0.08**	(0.06, 0.11)	0.09**	(0.06, 0.12)	0.08**	(0.05, 0.11)
College graduate	0.16**	(0.13, 0.19)	0.19**	(0.16, 0.22)	0.15**	(0.12, 0.18)
Income level						
<$20,000 (reference)						
$20,000-$74,999	0.10**	(0.07, 0.14)			0.09**	(0.05, 0.14)
$75,000-99,999	0.18**	(0.14, 0.23)			0.17**	(0.12, 0.22)
$100,000+	0.20**	(0.16, 0.24)			0.19**	(0.15, 0.23)
Food security						
Full food security (reference)						
Marginal food security			-0.08*	(-0.12, 0.03)	-0.03	(-0.08, 0.01)
Low food security			-0.10**	(-0.13, -0.07)	-0.05*	(-0.09, -0.02)
Very low food security			-0.10**	(-0.15, -0.05)	-0.03	(-0.08, -0.01)
Gender						
Female (reference)						
Male	-0.01	(-0.03, 0.01)	-0.01	(-0.03, 0.01)	-0.01	(-0.03, 0.01)
Race/ethnicity & nativity						
U.S.-born Hispanic	0.02	(-0.01, 0.05)	0.02	(-0.01, 0.05)	0.03	(-0.01, 0.05)
Foreign-born Hispanic	0.08**	(0.04, 0.11)	0.08**	(0.04, 0.11)	0.09**	(0.06, 0.12)
Non-Hispanic White (reference)						
Non-Hispanic Black	-0.08**	(-0.10, -0.05)	-0.09**	(-0.02, 0.04)	-0.07**	(-0.10, -0.04)
Non-Hispanic Asian	0.01	(-0.02, 0.04)	0.01	(-0.02, 0.04)	0.01	(-0.01, 0.04)
Other race or multiracial	-0.06	(-0.13, 0.01)	-0.07+	(-0.14, -0.01)	-0.06	(-0.12, 0.01)
Constant	2.93**	(2.89, 2.97)	3.06**	(3.03, 3.09)	2.95**	(2.91, 2.99)
Binary logistic regression component: Complete tooth loss						
Level of education						
High school or less (reference)						
Some college	-0.76**	(-0.95, -0.58)	-0.76**	(-0.95, -0.58)	-0.76**	(-0.95, -0.58)
College graduate	-1.77**	(-2.12, -1.43)	-1.77**	(-2.12, -1.43)	-1.77**	(-2.12, -1.43)
Income level						
<$20,000 (reference)						
$20,000-$74,999	-0.69**	(-0.93, -0.45)	-0.69**	(-0.93, -0.45)	-0.69**	(-0.93, -0.45)
$75,000-99,999	-1.40**	(-1.92, -0.88)	-1.40**	(-1.92, -0.88)	-1.40**	(-1.92, -0.88)
$100,000+	-1.76**	(-2.20, -1.32)	-1.76**	(-2.20, -1.32)	-1.76**	(-2.20, -1.32)

Appendix 3.4 continued

Constant	-0.92**	(-1.10, -0.75)	-0.92**	(-1.10, -0.75)	-0.92**	(-1.10, -0.75)
lnalpha	-2.96**	(-3.21, -2.71)	-2.89**	(-3.13, -2.66)	-2.97**	(-3.22, -2.71)
alpha	0.05**	(0.04, 0.07)	0.06**	(0.04, 0.07)	0.05**	(0.04, 0.07)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.5. Odds ratios of complete tooth loss and variation by SES x age and gender x age interactions

	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)
Level of education				
High school or less	3.9** (0.6)	7.4** (3.4)	4.1** (0.6)	4.2** (0.6)
Some college	2.5** (0.4)	4.4* (2.1)	2.7** (0.4)	2.7** (0.4)
College graduate (reference)				
Income level				
<$20,000	4.3** (0.7)	3.7** (0.6)	10.1** (5.3)	3.7** (0.6)
$20,000-$74,999	2.5** (0.4)	2.2** (0.4)	4.9* (2.6)	2.2** (0.4)
$75,000-99,999	1.2 (0.3)	1.2 (0.3)	2.4 (1.6)	1.2 (0.3)
$100,000+ (reference)				
Gender				
Female (reference)				
Male	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	1.0 (0.2)
Age category				
50-59 years (reference)				
60-69 years		3.8* (1.9)	5.2* (2.9)	1.8** (0.3)
70-79 years		7.6** (3.8)	10.0** (5.8)	3.6** (0.6)
80+ years		7.2** (3.9)	15.6** (9.4)	4.1** (0.7)
Education*Age				
High school or less*60-69 years		0.5 (0.3)		
High school or less*70-79 years		0.5 (0.2)		
High school or less*80+ years		0.6 (0.4)		
Some college*60-69 years		0.6 (0.3)		
Some college*70-79 years		0.5 (0.3)		
Some college*80+ years		0.6 (0.4)		
Income*Age				
<$20,000*60-69 years			0.3+ (0.2)	
<$20,000*70-79 years			0.4 (0.2)	
<$20,000*80+ years			0.2+ (0.1)	
$20,000-$74,999*60-69 years			0.4 (0.3)	
$20,000-$74,999*70-79 years			0.4 (0.2)	
$20,000-$74,999*80+ years			0.3 (0.2)	
$75,000-$99,999*60-69 years			0.6 (0.4)	
$75,000-$99,999*70-79 years			0.4 (0.3)	
$75,000-$99,999*80+ years			0.4 (0.4)	

Appendix 3.5 continued

Gender*Age				
Male*60-69 years				1.3 (0.3)
Male*70-79 years				1.1 (0.3)
Male*80+ years				1.3 (0.3)
Constant	0.2** (0.0)	0.1** (0.0)	0.1** (0.0)	0.1** (0.0)
Observations	6,727	6,727	6,727	6,727
AIC	4951.5	4748.8	4747.8	4745.5
BIC	4999.2	4857.8	4877.2	4834.1
-2 Log Likelihood	-2662.2	-2358.4	-2354.9	-2359.7
df	7	16	19	13
Pseudo R2	0.073	0.114	0.115	0.114

Likelihood Ratio Test: Model 1 is the reduced model

	Mod1 vs Mod2	Mod1 vs Mod3	Mod1 vs Mod4
LR chi2	4.1	227.7	218.0
Prob > chi2	0.670	<0.001	<0.001

** p<0.001, * p<0.01, + p<0.05

Model 1: Control for education + income + gender

Model 2: Control for education + income + gender + age*education

Model 3: Control for education + income + gender + age*income

Model 4: Control for education + income + gender + age*gender

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Above data are not imputed; complete case sample used in these sensitivity analyses (n=6,727).

Appendix 3.6. Sequential logistic regression models of adults ages 50+ years (n= 6,697): Odds ratios for complete tooth loss by 5 models of predictors (using non-imputed data)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Level of education										
High school or less	3.94**	(2.97, 5.24)	3.94**	(2.96, 5.34)	4.40**	(3.30, 5.87)	4.30**	(3.21, 5.75)	2.42**	(1.76, 3.33)
Some college	2.49**	(1.85, 3.37)	2.49**	(1.84, 3.37)	2.42**	(1.78, 3.27)	2.44**	(1.80, 3.30)	1.92**	(1.37, 2.69)
College graduate (reference)										
Income level										
<$20,000	4.30**	(3.09, 6.00)	4.26**	(3.03, 5.99)	4.11**	(2.92, 5.79)	3.00**	(2.11, 4.28)	1.42	(0.95, 2.11)
$20,000-$74,999	2.51**	(1.81, 3.48)	2.52**	(1.82, 3.50)	2.41**	(1.73, 3.35)	2.01**	(1.44, 2.81)	1.12	(0.77, 1.62)
$75,000-99,999	1.22	(0.76, 1.95)	1.22	(0.76, 1.95)	1.22	(0.76, 1.96)	1.19	(0.69, 1.80)	0.99	(0.58, 1.69)
$100,000+ (reference)										
Food security										
Full food security (reference)										
Marginal food security			0.89	(0.71, 1.11)	0.98	(0.78, 1.23)	1.01	(0.80, 1.28)	0.84	(0.64, 1.10)
Low food security			1.04	(0.84, 1.29)	1.22	(0.98, 1.52)	1.26+	(1.01, 1.58)	0.96	(0.74, 1.24)
Very low food security			1.09	(0.86, 1.39)	1.16	(0.91, 1.48)	1.24	(0.96, 1.60)	0.92	(0.68, 1.22)
Gender										
Female (reference)										
Male					1.10	(0.95, 1.28)	1.14	(0.99, 1.33)	0.60**	(0.50, 0.72)
Race/ethnicity & nativity										
U.S.-born Hispanic					0.34**	(0.24, 0.48)	0.35**	(0.25, 0.49)	0.43**	(0.30, 0.64)
Foreign-born Hispanic					0.35**	(0.27, 0.44)	0.39**	(0.31, 0.51)	0.56**	(0.42, 0.75)
Non-Hispanic White (reference)										
Non-Hispanic Black					0.84	(0.70, 1.00)	0.88	(0.73, 1.06)	0.82	(0.66, 1.01)
Non-Hispanic Asian					0.40**	(0.28, 0.57)	0.44**	(0.31, 0.63)	0.50*	(0.34, 0.75)
Other race or multiracial					1.24	(0.86, 1.80)	1.31	(0.90, 1.91)	1.44	(0.92, 2.27)
Occupation status										
Employed (reference)										

Appendix 3.6 continued

Not employed							1.63**	(1.30, 2.04)	1.26	(0.98, 1.62)
Retired							2.15**	(1.77, 2.62)	1.90**	(1.51, 2.39)
Health insurance status										
Private (reference)										
Public							1.32*	(1.11, 1.57)	1.14	(0.93, 1.39)
No insurance							0.74+	(0.56, 0.99)	0.51**	(0.37, 0.70)
Has diabetes										
No (reference)										
Yes									1.15	(0.95, 1.40)
Daily flossing										
0 days									20.97**	(14.70, 29.92)
1 to 6 days									1.36	(0.86, 2.16)
7 days (reference)										
Smoking status										
Never smoked (reference)										
Former smoker									1.58**	(1.28, 1.94)
Current smoker									1.67**	(1.32, 2.12)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									1.81**	(1.45, 2.26)
More than 5 years, or never									3.85**	(3.09, 4.79)
Constant	0.02**	(0.01, 0.03)	0.02**	(0.01, 0.03)	0.03**	(0.02, 0.04)	0.02**	(0.02, 0.04)	0.01**	(0.00, 0.01)
AIC	4939.63		4943.42		4818.08		4721.77		3474.57	
BIC	4980.49		5004.71		4920.22		4851.14		3651.61	
-2 Log Likelihood	-2463.82		-2462.71		-2394.04		-2341.88		-1711.29	
df	6		9		15		19		26	
Pseudo R2	0.0730		0.0734		0.0992		0.1187		0.3560	

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; complete case sample used in these sensitivity analyses (n=6,697).

Appendix 3.7 Checking for overdispersion within full model of covariates using zero-inflated negative binomial (ZINB) regression

	Total sample		Age 50-59		Age 60-69		Age 70-79		Age 80+	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.04*	(0.02, 0.06)	0.03+	(0.00, 0.06)	0.01	(-0.03, 0.05)	0.10*	(0.04, 0.16)	-0.04	(-0.12, 0.05)
College graduate	0.09**	(0.06, 0.11)	0.08**	(0.05, 0.11)	0.07*	(0.03, 0.11)	0.14**	(0.07, 0.20)	0.03	(-0.07, 0.12)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.07**	(0.04, 0.09)	0.01	(-0.02, 0.05)	0.05+	(0.01, 0.10)	0.08+	(0.02, 0.15)	0.08	(-0.02, 0.17)
$75,000-99,999	0.10**	(0.06, 0.13)	0.01	(-0.04, 0.05)	0.09*	(0.03, 0.16)	0.14*	(0.04, 0.24)	-0.01	(-0.18, 0.17)
$100,000+	0.12**	(0.09, 0.15)	0.03	(-0.02, 0.07)	0.13**	(0.07, 0.19)	0.14*	(0.06, 0.23)	0.15+	(0.02, 0.28)
Food security										
Full food security (reference)										
Marginal food security	-0.02	(-0.05, 0.01)	-0.01	(-0.05, 0.02)	-0.02	(-0.07, 0.03)	-0.09+	(-0.18, 0.01)	-0.15	(-0.29, 0.01)
Low food security	-0.02	(-0.05, 0.01)	-0.01	(-0.04, 0.03)	-0.08*	(-0.13, -0.02)	-0.01	(-0.10, 0.09)	-0.17	(-0.35, 0.02)
Very low food security	-0.01	(-0.04, 0.04)	-0.05+	(-0.10, -0.01)	0.01	(-0.06, 0.06)	-0.06	(-0.19, 0.07)	-0.02	(-0.29, 0.25)
Gender										
Female (reference)										
Male	0.03*	(-0.01, 0.05)	0.03+	(0.01, 0.05)	0.01	(-0.02, 0.04)	0.06+	(0.01, 0.11)	0.10+	(0.02, 0.17)
Race/ethnicity & nativity										
U.S.-born Hispanic	0.02	(-0.01, 0.06)	0.02	(-0.02, 0.07)	0.01	(-0.05, 0.05)	0.02	(-0.08, 0.11)	0.03	(-0.16, 0.23)
Foreign-born Hispanic	0.04+	(0.01, 0.07)	0.06*	(0.03, 0.10)	0.02	(-0.03, 0.06)	0.05	(-0.03, 0.14)	-0.05	(-0.23, 0.13)
Non-Hispanic White (reference)										
Non-Hispanic Black	-0.06**	(-0.08, -0.03)	-0.03	(0.06, 0.01)	-0.07*	(-0.11, -0.03)	-0.14**	(-0.21, -0.07)	-0.12	(-0.25, 0.01)
Non-Hispanic Asian	0.03+	(0.01, 0.07)	0.03	(-0.01, 0.06)	0.04	(-0.02, 0.09)	0.01	(-0.08, 0.09)	-0.11	(-0.29, 0.07)
Other race or multiracial	-0.04	(-0.10, 0.02)	0.05	(-0.02, 0.11)	-0.16*	(-0.28, -0.05)	-0.18+	(-0.32, -0.03)	-0.11	(-0.41, 0.20)

Appendix 3.7 continued

Health insurance status										
Private (reference)										
Public	-0.02+	(-0.05, -0.01)	-0.03	(0.07, 0.01)	0.01	(-0.04, 0.04)	-0.03	(-0.08, 0.02)	-0.06	(-0.15, 0.02)
No insurance	0.04*	(0.01, 0.08)	-0.01	(-0.05, 0.02)	-0.01	(-0.06, 0.05)	-0.01	(-0.15, 0.15)	0.04	(-0.33, 0.40)
Occupation status										
Employed (reference)										
Not employed	-0.04*	(-0.07, -0.02)	-0.05**	(-0.08, -0.03)	-0.03	(-0.07, 0.01)	-0.01	(-0.12, 0.09)	0.05	(-0.14, 0.23)
Retired	-0.11**	(-0.13, -0.08)	-0.03	(-0.09, 0.03)	-0.01	(-0.05, 0.02)	0.03	(-0.04, 0.09	0.05	(-0.09, 0.18)
Has diabetes										
No (reference)										
Yes	-0.07**	(-0.09, -0.05)	-0.07**	(-0.10, -0.04)	-0.05*	(-0.08, -0.01)	-0.04	(-0.09, 0.02)	-0.10+	(-0.18, -0.01)
Daily flossing										
0 days (reference)										
1 to 6 days	0.18**	(0.16, 0.20)	0.11**	(0.08, 0.14)	0.17**	(0.13, 0.21)	0.20**	(0.13, 0.27)	0.22**	(0.12, 0.32)
7 days	0.18**	(0.15, 0.20)	0.10**	(0.07, 0.13)	0.17**	(0.13, 0.21)	0.23**	(0.17, 0.30)	0.23**	(0.14, 0.32)
Smoking status										
Never smoked (reference)										
Former smoker	-0.08**	(-0.10, -0.06)	-0.06**	(-0.09, -0.03)	-0.06*	(-0.10, -0.03)	-0.13**	(-0.18, -0.07)	-0.10+	(-0.17, -0.02)
Current smoker	-0.13**	(-0.16, -0.10)	-0.15**	(-0.19, -0.12)	-0.18**	(-0.22, -0.13)	-0.10	(-0.20, 0.01)	-0.40*	(-0.65, -0.15)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years	-0.05**	(-0.07, -0.02)	-0.02	(-0.04, 0.01)	-0.04	(-0.07, 0.01)	-0.09*	(-0.15, -0.03)	-0.14*	(-0.24, -0.05)
More than 5 years, or never	-0.08**	(-0.11, -0.05)	-0.02	(-0.06, 0.01)	-0.04	(-0.09, 0.01)	-0.20**	(-0.29, -0.12)	-0.22*	(-0.34, -0.09)
Constant	2.95**	(2.92, 3.00)	3.12**	(3.06, 3.17)	2.96**	(2.89, 3.03)	2.78**	(2.66, 2.89)	2.77**	(2.60, 2.96)

Appendix 3.7 continued

Binary logistic regression component: Complete tooth loss										
Level of education										
High school or less (reference)										
Some college	-0.46**	(-0.62, -0.29)	-0.48+	(-0.89, -0.06)	-0.32+	(-0.60, -0.03)	-0.47*	(-0.79, -0.16)	-0.61*	(-1.00, -0.22)
College graduate	-1.37**	(-1.66, -1.09)	-1.79**	(-2.72, -0.87)	-1.37**	(-1.89, -0.86)	-1.25**	(-1.73, -0.77)	-1.63**	(-2.25, -1.01)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-0.54**	(-0.69, -0.38)	-0.71**	(-1.09, -0.33)	-0.34+	(-0.61, -0.07)	-0.77**	(-1.06, -0.48)	-0.40+	(-0.75, -0.04)
$75,000-99,999	-1.27**	(-1.64, -0.89)	-1.37*	(-2.23, -0.51)	-0.85*	(-1.48, -0.22)	-1.49**	(-2.21, -0.76)	-0.76	(-1.77, 0.25)
$100,000+	-1.46**	(-1.79, -1.12)	-2.22**	(-3.26, -1.18)	-1.15**	(-1.70, -0.59)	-1.41**	(-2.04, -0.79)	-0.79+	(-1.50, -0.07)
Constant	-1.03**	(-1.15, -0.91)	-1.73**	(-2.01, -1.45)	-1.31**	(-1.53, -1.10)	-0.40*	(-0.63, -0.17)	-0.44*	(-0.71, -0.16)
lnalpha	-2.60**	(-2.66, -2.53)	-3.80**	(-4.01, -3.59)	-2.63**	(-2.75, -2.52)	-2.24**	(-2.39, -2.11)	-1.97**	(-2.15, -1.80)
alpha	0.07**	(0.07, 0.08)	0.02**	(0.02, 0.03)	0.07**	(0.06, 0.08)	0.11**	(0.09, 0.12)	0.14**	(0.12, 0.17)
Likelihood-ratio test of alpha=0										
chibar2	2442.39		140.08		813.13		666.96		543.42	
Pr>=chibar2	<0.001		<0.001		<0.001		<0.001		<0.001	
N	6,694		2,203		2,306		1,362		823	

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018

Above data are not imputed; complete case sample used in these sensitivity analyses (n=6,697).

Appendix 3.8. Sequential hurdle models of tooth counts in adults ages 50+ years (n=7,861): Zero-inflated negative binomial (ZINB) regression results

	Model 1		Model 2		Model 3		Model 4		Model 5	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.08**	(0.05, 0.11)	0.08**	(0.05, 0.10)	0.08**	(0.05, 0.11)	0.08**	(0.05, 0.10)	0.06**	(0.03, 0.09)
College graduate	0.15**	(0.12, 0.18)	0.15**	(0.12, 0.18)	0.15**	(0.12, 0.18)	0.15**	(0.12, 0.18)	0.11**	(0.08, 0.14)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.10**	(0.07, 0.14)	0.09**	(0.05, 0.14)	0.09**	(0.05, 0.14)	0.07*	(0.03, 0.12)	0.06*	(0.02, 0.10)
$75,000-99,999	0.18**	(0.14, 0.23)	0.17**	(0.12, 0.22)	0.17**	(0.12, 0.22)	0.14**	(0.08, 0.19)	0.10**	(0.05, 0.15)
$100,000+	0.20**	(0.17, 0.24)	0.19**	(0.15, 0.23)	0.19**	(0.15, 0.23)	0.14**	(0.10, 0.19)	0.10**	(0.06, 0.14)
Food security										
Full food security (reference)										
Marginal food security			-0.03	(-0.08, 0.01)	-0.03	(-0.08, 0.01)	-0.04	(-0.09, 0.01)	-0.02	(-0.06, 0.02)
Low food security			-0.04+	(-0.08, -0.01)	-0.05*	(-0.09, -0.02)	-0.06*	(-0.09, -0.03)	-0.03+	(-0.06, -0.01)
Very low food security			-0.03	(-0.07, 0.01)	-0.03	(-0.08, 0.01)	-0.04	(-0.08, 0.01)	-0.01	(-0.05, 0.04)
Gender										
Female (reference)										
Male					-0.01	(-0.03, 0.01)	-0.02	(-0.04, 0.01)	0.02+	(0.01, 0.04)
Race/ethnicity & nativity										
U.S.-born Hispanic					0.03	(-0.01, 0.05)	0.02	(-0.01, 0.05)	0.02	(-0.01, 0.05)
Foreign-born Hispanic					0.09**	(0.06, 0.12)	0.08**	(0.05, 0.12)	0.06*	(0.03, 0.09)
Non-Hispanic White (reference)										
Non-Hispanic Black					-0.07**	(-0.10, -0.04)	-0.08**	(-0.10, -0.05)	-0.06**	(-0.09, -0.03)
Non-Hispanic Asian					0.01	(-0.01, 0.04)	0.01	(-0.02, 0.04)	0.01	(-0.02, 0.04)
Other race or multiracial					-0.06	(-0.12, 0.01)	-0.06	(-0.13, 0.01)	-0.04	(-0.11, 0.02)
Health insurance status										
Private (reference)										
Public							-0.04*	(-0.06, -0.01)	-0.02+	(-0.05, -0.01)

Appendix 3.8 continued

No insurance							-0.02	(-0.07, 0.02)	0.01	(-0.03, 0.05)
Occupation status										
Employed (reference)										
Not employed							-0.05*	(-0.08, -0.02)	-0.03*	(-0.06, -0.01)
Retired							-0.09**	(-0.11, -0.06)	-0.08**	(-0.11, -0.06)
Has diabetes										
No (reference)										
Yes									-0.07**	(-0.10, -0.03)
Daily flossing										
0 days (reference)										
1 to 6 days									0.15**	(0.12, 0.19)
7 days									0.14**	(0.11, 0.17)
Smoking status										
Never smoked (reference)										
Former smoker									-0.07**	(-0.09, -0.06)
Current smoker									-0.14**	(-0.18, -0.11)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.03+	(-0.06, -0.01)
More than 5 years, or never									-0.07*	(-0.11, -0.02)
Constant	2.92**	(2.89, 2.96)	2.94**	(2.90, 2.98)	2.95**	(2.91, 2.99)	3.03**	(2.97, 3.09)	2.99**	(2.93, 3.05)
Binary logistic regression component: Complete tooth loss										
SES variables										
Level of education										
High school or less (reference)										
Some college	-0.76**	(-0.95, -0.58)	-0.76**	(-0.94, -0.58)	-0.83**	(-1.02, -0.64)	-0.81**	(-0.99, -0.62)	-0.50**	(-0.70, -0.31)

Appendix 3.8 continued

College graduate	-1.77**	(-2.12, -1.43)	-1.77**	(-2.10, -1.43)	-1.83**	(-2.17, -1.50)	-1.81**	(-2.15, -1.47)	-1.16**	(-1.53, -0.80)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-0.69**	(-0.93, -0.45)	-0.66**	(-0.93, -0.40)	-0.70**	(-0.97, -0.43)	-0.54**	(-0.81, -0.27)	-0.30+	(-0.59, -0.02)
$75,000-99,999	-1.40**	(-1.92, -0.88)	-1.37**	(-1.91, -0.83)	-1.41**	(-1.96, -0.86)	-1.15**	(-1.70, -0.60)	-0.40	(-0.94, 0.14)
$100,000+	-1.76**	(-2.20, -1.32)	-1.73**	(-2.20, -1.30)	-1.77**	(-2.19, -1.35)	-1.41**	(-1.87, -0.95)	-0.39	(-0.95, 0.17)
Constant	-0.92**	(-1.10, -0.75)	-0.96**	(-1.23, -0.68)	-0.88**	(1.16, -0.59)	-1.58**	(1.87, -1.28)	-1.57**	(2.08, -1.05)
Food insecurity										
Food security										
Full food security (reference)										
Marginal food security			-0.03	(-0.35, 0.28)	0.03	(-0.30, 0.36)	0.08	(-1.28, -0.59)	-0.15	(-0.54, 0.24)
Low food security			0.03	(-0.28, 0.33)	0.15	(-0.15, 0.45)	0.21	(-0.11, 0.52)	-0.25	(-0.67, 0.17)
Very low food security			0.17	(-0.21, 0.55)	0.20	(-0.18, 0.59)	0.24	(-0.16, 0.65)	-0.12	(-0.56, 0.32)
Constant			-0.96**	(-1.23, -0.68)	-0.88**	(1.16, -0.59)	-1.58**	(1.87, -1.28)	-1.57**	(2.08, -1.05)
Frequency of dental visits										
Most recent dental visit										
(reference)										
Between 1-5 years									0.84**	(0.51, 1.17)
More than 5 years, or never									1.71**	(1.35, 2.06)
Constant									-1.57**	(2.08, -1.05)
lnalpha	-2.94**	(-3.18, -2.69)	-2.94**	(-3.19, -2.69)	-2.97**	(-3.22, -2.71)	-3.01**	(-3.27, -2.75)	-3.22**	(-3.51, -2.93)
alpha	0.05**	(0.04, 0.07)	0.05**	(0.04, 0.07)	0.05**	(0.04, 0.07)	0.05**	(0.04, 0.06)	0.04**	(0.03, 0.05)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.9. Sequential hurdle models of tooth counts in adults ages 50 to 59 years (n=2,540): Zero-inflated negative binomial (ZINB) regression results

	Model 1		Model 2		Model 3		Model 4		Model 5	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.07**	(0.03, 0.11)	0.07*	(0.03, 0.10)	0.08**	(0.04, 0.11)	0.07**	(0.04, 0.11)	0.06*	(0.02, 0.09)
College graduate	0.14**	(0.11, 0.18)	0.14**	(0.10, 0.17)	0.14**	(0.11, 0.18)	0.14**	(0.10, 0.18)	0.10**	(0.06, 0.14)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.06+	(0.01, 0.10)	0.04	(-0.01, 0.09)	0.04	(-0.01, 0.09)	0.01	(-0.04, 0.06)	-0.01	(-0.05, 0.04)
$75,000-99,999	0.11*	(0.05, 0.17)	0.08+	(0.02, 0.15)	0.08+	(0.02, 0.15)	0.04	(-0.04, 0.12)	0.01	(-0.05, 0.08)
$100,000+	0.13**	(0.08, 0.17)	0.10**	(0.05, 0.15)	0.10**	(0.05, 0.15)	0.05	(-0.01, 0.12)	0.02	(-0.03, 0.07)
Food security										
Full food security (reference)										
Marginal food security			-0.04	(-0.09, 0.01)	-0.05+	(-0.10, -0.01)	-0.04	(-0.08, 0.01)	-0.03	(-0.07, 0.01)
Low food security			-0.05	(-0.10, 0.01)	-0.06+	(-0.12, -0.01)	-0.05	(-0.10, 0.01)	-0.03	(-0.08, 0.01)
Very low food security			-0.05+	(-0.11, -0.01)	-0.06+	(-0.11, -0.01)	-0.05	(-0.10, 0.01)	-0.03	(-0.08, 0.03)
Gender										
Female (reference)										
Male					0.01	(-0.02, 0.03)	0.01	(-0.03, 0.03)	0.02	(-0.01, 0.05)
Race/ethnicity & nativity										
U.S.-born Hispanic					0.03	(-0.01, 0.06)	0.03	(-0.01, 0.06)	0.02	(-0.02, 0.05)
Foreign-born Hispanic					0.11**	(0.06, 0.15)	0.11**	(0.07, 0.15)	0.07*	(0.03, 0.12)
Non-Hispanic White (reference)										
Non-Hispanic Black					-0.04+	(-0.07, -0.01)	-0.04+	(-0.07, -0.01)	-0.04+	(-0.07, -0.01)
Non-Hispanic Asian					0.03+	(0.01, 0.07)	0.04+	(0.01, 0.07)	0.02	(-0.01, 0.06)
Other race or multiracial					0.01	(-0.05, 0.07)	0.01	(-0.05, 0.07)	0.03	(-0.03, 0.09)
Health insurance status										
Private (reference)										
Public							-0.05**	(-0.10, -0.01)	-0.04	(-0.08, 0.01)

Appendix 3.9 continued

No insurance							-0.05**	(-0.10, 0.01	-0.03	(-0.07, 0.02)
Occupation status										
Employed (reference)										
Not employed							-0.04*	(-0.07, -0.01)	-0.03+	(-0.06, -0.01)
Retired							0.02	(-0.03, 0.07)	0.01	(-0.04, 0.06)
Has diabetes										
No (reference)										
Yes									-0.09*	(-0.14,-0.03)
Daily flossing										
0 days (reference)										
1 to 6 days									0.09*	(0.04, 0.14)
7 days									0.10**	(0.05, 0.15)
Smoking status										
Never smoked (reference)										
Former smoker									-0.05**	(-0.07, -0.02)
Current smoker									-0.15**	(-0.20, -0.11)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.01	(-0.03, 0.02)
More than 5 years, or never									-0.01	(-0.06, 0.06)
Constant	3.04**	(3.00, 3.08)	3.07**	(3.02, 3.13)	3.06**	(3.00, 3.12)	3.12**	(3.04, 3.19)	3.12**	(3.03, 3.20)
Binary logistic regression component: Complete tooth loss										
SES variables										
Level of education										
High school or less (reference)										
Some college	-0.52+	(-0.94, -0.10)	-0.52+	(-0.94, -0.11)	-0.70*	(-1.13, -0.27)	-0.74*	(-1.19, -0.28)	-0.54+	(-0.99, -0.10)

Appendix 3.9 continued

College graduate	-1.56+	(-2.72, -0.39)	-1.56+	(-2.76, -0.37)	-1.74*	(-2.91, -0.57)	-1.78*	(-2.96, -0.60)	-0.96	(-2.13, 0.22)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-0.94**	(-1.43, -0.45)	-0.93*	(-1.54, -0.32)	-0.96*	(-1.55, -0.37)	-0.58	(-1.23, 0.07)	-0.48	(-1.15, 0.19)
$75,000-99,999	-2.04*	(-3.31, -0.76)	-2.02*	(-3.34, -0.71)	-2.10*	(-3.40, -0.79)	-1.66+	(-2.97, -0.35)	-0.97	(-2.29, 0.35)
$100,000+	-3.28**	(-4.92, -1.63)	-3.26**	(-4.90, -1.62)	-3.38**	(-5.00, -1.76)	-2.89*	(-4.64, -1.14)	-2.07+	(-3.81, -0.34)
Constant	-1.50**	(-1.98, -1.02)	-1.51*	(-2.33, -0.70)	-1.10+	(-2.01, -0.19)	-1.78*	(-2.88, -0.69)	-1.50+	(-2.90, -0.11)
Food insecurity										
Food security										
Full food security (reference)										
Marginal food security			-0.17	(-0.78, 0.45)	-0.09	(0.75, 0.56)	-0.29	(-0.90, 0.33)	-0.46	(-1.04, 0.13)
Low food security			0.17	(0.34, 2.01)	0.32	(-0.53, 1.16)	0.12	(-0.70, 0.93)	-0.09	(-0.90, 0.72)
Very low food security			0.04	(-0.88, 0.95)	0.40	(-0.86, 0.94)	-0.16	(-1.02, 0.69)	-0.22	(-1.13, 0.69)
Constant			-1.51*	(-2.33, -0.70)	-1.10+	(-2.01, -0.19)	-1.78*	(-2.88, -0.69)	-1.50+	(-2.90, -0.11)
Frequency of dental visits										
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.03	(-0.68, 0.63)
More than 5 years, or never									0.55	(-0.01, 1.10)
Constant									-1.50+	(-2.90, -0.11)
lnalpha	-4.41**	(-5.51, -3.31)	-4.45**	(-5.60, -3.30)	-4.58**	(-5.86, -3.31)	-4.69**	(-6.09, -3.29)	-5.98*	(-10.37, -1.58)
alpha	0.01**	(0.01, 0.04)	0.01**	(0.01, 0.04)	0.01**	(0.01, 0.04)	0.01**	(0.01, 0.04)	0.01*	(0.01, 0.21)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.10. Sequential hurdle models of tooth counts in adults ages 60 to 69 years (n=2,746): Zero-inflated negative binomial (ZINB) regression results

	Model 1		Model 2		Model 3		Model 4		Model 5	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.07*	(0.02, 0.12)	0.06*	(0.02, 0.11)	0.06*	(0.02, 0.11)	0.06*	(0.02, 0.10)	0.04	(-0.01, 0.08)
College graduate	0.16**	(0.11, 0.20)	0.14**	(0.10, 0.19)	0.15**	(0.10, 0.20)	0.14**	(0.09, 0.19)	0.10**	(0.06, 0.15)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.13**	(0.07, 0.19)	0.10*	(0.03, 0.17)	0.09*	(0.02, 0.16)	0.08+	(0.01, 0.15)	0.04	(-0.04, 0.12)
$75,000-99,999	0.20**	(0.14, 0.27)	0.16**	(0.09, 0.24)	0.15**	(0.08, 0.23)	0.13*	(0.05, 0.21)	0.08	(-0.01, 0.17)
$100,000+	0.23**	(0.16, 0.30)	0.19**	(0.11, 0.27)	0.18**	(0.09, 0.27)	0.16*	(0.07, 0.25)	0.10+	(0.01, 0.19)
Food security										
Full food security (reference)										
Marginal food security			-0.03	(-0.12, 0.05)	-0.04	(-0.12, 0.05)	-0.03	(-0.11, 0.05)	-0.02	(-0.09, 0.04)
Low food security			-0.13*	(-0.21, -0.06)	-0.14**	(-0.21, -0.07)	-0.12*	(-0.19, -0.05)	-0.11*	(-0.18, -0.04)
Very low food security			-0.10	(-0.21, 0.01)	-0.10	(-0.20, 0.01)	-0.08	(-0.18, 0.03)	-0.03	(-0.12, 0.05)
Gender										
Female (reference)										
Male					-0.05*	(-0.08, -0.01)	-0.05*	(-0.08, -0.01)	-0.01	(-0.04, 0.02)
Race/ethnicity & nativity										
U.S.-born Hispanic					0.01	(-0.04, 0.06)	0.01	(-0.04, 0.06)	-0.01	(-0.05, 0.05)
Foreign-born Hispanic					0.05	(-0.01, 0.10)	0.06+	(0.01, 0.11)	0.03	(-0.01, 0.08)
Non-Hispanic White (reference)										
Non-Hispanic Black					-0.09*	(-0.15, -0.04)	-0.09*	(-0.15, -0.03)	-0.07+	(-0.13, -0.01)
Non-Hispanic Asian					0.02	(-0.02, 0.07)	0.03	(-0.02, 0.08)	0.02	(-0.02, 0.07)
Other race or multiracial					-0.23+	(-0.42, -0.04)	-0.22+	(-0.42, -0.03)	-0.19+	(-0.38, -0.01)
Health insurance status										
Private (reference)										
Public							-0.01	(-0.05, 0.02)	-0.01	(-0.04, 0.03)

Appendix 3.10 continued

No insurance							-0.07	(-0.15, 0.01)	-0.05	(-0.14, 0.04)
Occupation status										
Employed (reference)										
Not employed							-0.06	(-0.13, 0.01)	-0.04	(-0.10, 0.03)
Retired							-0.01	(-0.06, 0.03)	-0.01	(-0.06, 0.03)
Has diabetes										
No (reference)										
Yes									-0.03	(-0.08, 0.01)
Daily flossing										
0 days (reference)										
1 to 6 days									0.12**	(0.06, 0.18)
7 days									0.10**	(0.05, 0.15)
Smoking status										
Never smoked (reference)										
Former smoker									-0.08**	(-0.11, -0.04)
Current smoker									-0.20**	(-0.29, -0.12)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.05	(-0.11, 0.01)
More than 5 years, or never									-0.10+	(-0.17, -0.02)
Constant	2.89**	(2.84, 2.95)	2.95**	(2.87, 3.02)	2.98**	(2.90, 3.06)	3.02**	(2.93, 3.11)	3.04**	(2.93, 3.14)
Binary logistic regression component: Complete tooth loss										
SES variables										
Level of education										
High school or less (reference)										
Some college	-0.82**	(-1.17, -0.47)	-0.80**	(-1.17, -0.44)	-0.85**	(-1.24, -0.46)	-0.83**	(-1.24, -0.41)	-0.36	(-0.81, 0.09)

Appendix 3.10 continued

College graduate	-2.54**	(-3.40, -1.68)	-2.52**	(-3.40, -1.64)	-2.58**	(-3.46, -1.69)	-2.56**	(-3.45, -1.67)	-1.67**	(-2.51, -0.83)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-0.36+	(-0.72, -0.01)	-0.21	(-0.57, 0.14)	-0.25	(-0.59, 0.10)	-0.04	(-0.44, 0.35)	0.24	(-0.25, 0.73)
$75,000-99,999	-0.54	(-1.47, 0.39)	-0.33	(-1.24, 0.59)	-0.37	(-1.29, 0.55)	-0.10	(-1.08, 0.88)	0.76	(-0.22, 1.74)
$100,000+	-1.00*	(-1.74, -0.26)	-0.77+	(-1.53, -0.01)	-0.84+	(-1.59, -0.09)	-0.60	(-1.36, 0.16)	0.71	(-0.31, 1.74)
Constant	-1.15**	(-1.40, -0.90)	-1.39**	(-1.75, -1.02)	-1.44**	(-1.86, -1.01)	-1.68**	(-2.18, -1.18)	-2.30**	(-3.16, -1.44)
Food insecurity										
Food security										
Full food security (reference)										
Marginal food security			0.18	(-0.35, 0.72)	0.25	(-0.29, 0.79)	0.16	(-0.43, 0.75)	0.15	(-0.40, 0.70)
Low food security			0.17	(-0.30, 0.64)	0.27	(-0.19, 0.73)	0.23	(-0.26, 0.72)	-0.01	(-0.48, 0.46)
Very low food security			0.70+	(0.18, 1.23)	0.74*	(0.20, 1.29)	0.65+	(0.09, 1.21)	0.08	(-0.54, 0.70)
Constant			-1.39**	(-1.75, -1.02)	-1.44**	(-1.86, -1.01)	-1.68**	(-2.18, -1.18)	-2.30**	(-3.16, -1.44)
Frequency of dental visits										
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									1.13**	(0.60, 1.66)
More than 5 years, or never									2.09**	(1.50, 2.68)
Constant									-2.30**	(-3.16, -1.44)
lnalpha	-2.93**	(-3.27, -2.59)	-2.96**	(-3.31, -2.60)	-3.02**	(-3.40, -2.65)	-3.04**	(-3.42, -2.66)	-3.26**	(-3.68, -2.83)
alpha	0.05**	(0.04, 0.08)	0.05**	(0.04, 0.07)	0.05**	(0.03, 0.07)	0.05**	(0.03, 0.07)	0.04**	(0.03, 0.06)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.11. Sequential hurdle models of tooth counts in adults ages 70 to 79 years (n=1,586): Zero-inflated negative binomial (ZINB) regression results

	Model 1		Model 2		Model 3		Model 4		Model 5	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.10*	(0.05, 0.16)	0.10*	(0.04, 0.16)	0.09*	(0.03, 0.15)	0.08*	(0.03, 0.14)	0.07+	(0.02, 0.12)
College graduate	0.19**	(0.13, 0.25)	0.18**	(0.11, 0.24)	0.17**	(0.11, 0.24)	0.16**	(0.10, 0.23)	0.12**	(0.06, 0.18)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.16**	(0.08, 0.25)	0.14*	(0.06, 0.23)	0.13*	(0.04, 0.22)	0.13*	(0.04, 0.21)	0.10+	(0.01, 0.19)
$75,000-99,999	0.27**	(0.16, 0.37)	0.24**	(0.14, 0.34)	0.22**	(0.12, 0.32)	0.22**	(0.12, 0.32)	0.17*	(0.07, 0.26)
$100,000+	0.22**	(0.13, 0.31)	0.19**	(0.11, 0.27)	0.17**	(0.09, 0.26)	0.17**	(0.08, 0.25)	0.12*	(0.03, 0.21)
Food security										
Full food security (reference)										
Marginal food security			-0.14*	(-0.24, -0.04)	-0.13+	(-0.23, -0.02)	-0.12+	(-0.23, -0.02)	-0.07	(-0.18, 0.02)
Low food security			-0.06	(-0.20, 0.09)	-0.04	(-0.19, 0.11)	-0.03	(-0.18, 0.11)	0.02	(-0.12, 0.16)
Very low food security			-0.11	(-0.30, 0.08)	-0.11	(-0.29, 0.08)	-0.09	(-0.26, 0.09)	-0.03	(-0.20, 0.14)
Gender										
Female (reference)										
Male					-0.03	(-0.07, 0.01)	-0.03	(-0.07, 0.01)	0.04	(-0.01, 0.09)
Race/ethnicity & nativity										
U.S.-born Hispanic					-0.05	(-0.13, 0.02)	-0.05	(-0.13, 0.02)	-0.02	(-0.10, 0.06)
Foreign-born Hispanic					-0.02	(-0.11, 0.07)	0.01	(-0.09, 0.11)	0.02	(-0.08, 0.12)
Non-Hispanic White (reference)										
Non-Hispanic Black					-0.22**	(-0.30, -0.15)	-0.21**	(-0.29, -0.14)	-0.17**	(-0.25, -0.10)
Non-Hispanic Asian					-0.07	(-0.14, 0.01)	-0.05	(-0.12, 0.02)	-0.04	(-0.12, 0.04)
Other race or multiracial					-0.13	(-0.26, 0.01)	-0.12	(-0.27, 0.02)	-0.13	(-0.27, 0.01)
Health insurance status										
Private (reference)										
Public							-0.04	(-0.09, 0.01)	-0.03	(-0.07, 0.01)

Appendix 3.11 continued

No insurance							-0.21	(-0.44, 0.02)	-0.20	(-0.41, 0.01)
Occupation status										
Employed (reference)										
Not employed							-0.02	(-0.11, 0.07)	0.03	(-0.06, 0.12)
Retired							0.01	(-0.06, 0.06)	0.02	(-0.04, 0.08)
Has diabetes										
No (reference)										
Yes									-0.02	(-0.08, 0.04)
Daily flossing										
0 days (reference)										
1 to 6 days									0.23**	(0.16, 0.30)
7 days									0.22**	(0.16, 0.28)
Smoking status										
Never smoked (reference)										
Former smoker									-0.11**	(-0.16, -0.05)
Current smoker									-0.16+	(-0.28, -0.04)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.06	(-0.15, 0.02)
More than 5 years, or never									-0.18*	(-0.28, -0.07)
Constant	2.80**	(2.71, 2.89)	2.84**	(2.76, 2.93)	2.90**	(2.81, 2.98)	2.92**	(2.81, 3.02)	2.80**	(2.66, 2.94)
Binary logistic regression component: Complete tooth loss										
SES variables										
Level of education										
High school or less (reference)										
Some college	-0.79**	(-1.10, -0.47)	-0.77**	(-1.09, -0.45)	-0.81**	(-1.15, -0.47)	-0.79**	(-1.12, -0.45)	-0.44	(-0.93, 0.05)

Appendix 3.11 continued

College graduate	-1.53**	(-2.27, -0.80)	-1.45**	(-2.19, -0.71)	-1.49**	(-2.25, -0.74)	-1.49**	(-2.26, -0.72)	-0.50	(-1.21, 0.21)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-1.07**	(-1.49, -0.66)	-0.96**	(-1.37, -0.55)	-1.01**	(-1.49, -0.66)	-0.98**	(-1.41, -0.54)	-0.58	(-1.19, 0.03)
$75,000-99,999	-1.69*	(-2.62, -0.76)	-1.53*	(-2.47, -0.59)	-1.59*	(-2.49, -0.68)	-1.57*	(-2.45, -0.68)	-0.87	(-1.87, 0.13)
$100,000+	-1.59*	(-2.49, -0.68)	-1.40*	(-2.28, -0.52)	-1.38*	(-2.23, -0.52)	-1.35*	(-2.24, -0.47)	-0.31	(-1.23, 0.62)
Constant	-0.25	(-0.54, 0.04)	-0.49*	(-0.85, -0.13)	-0.57+	(-1.01, -0.13)	-0.42	(-1.10, 0.25)	-0.37	(-1.30, 0.56)
Food insecurity										
Food security										
Full food security (reference)										
Marginal food security			0.50+	(0.03, 0.96)	0.53+	(0.06, 1.00)	0.52+	(0.06, 0.98)	-0.13	(-0.73, 0.47)
Low food security			0.37	(-0.13, 0.88)	0.51+	(0.01, 1.02)	0.49+	(0.01, 0.97)	0.07	(-0.68, 0.81)
Very low food security			0.72+	(0.13, 1.31)	0.78+	(0.16, 1.41)	0.70+	(0.05, 1.35)	0.34	(-0.39, 1.08)
Constant			-0.49*	(-0.85, -0.13)	-0.57+	(-1.01, -0.13)	-0.42	(-1.10, 0.25)	-0.37	(-1.30, 0.56)
Frequency of dental visits										
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									1.19**	(0.61, 1.76)
More than 5 years, or never									2.03**	(1.44, 2.62)
Constant									-0.37	(-1.30, 0.56)
lnalpha	-2.39**	(-2.70, -2.08)	-2.41**	(-2.73, -2.09)	-2.46**	(-2.81, -2.11)	-2.48**	(-2.83, -2.12)	-2.71**	(-3.08, -2.33)
alpha	0.09**	(0.07, 0.13)	0.09**	0.07, 0.12)	0.09**	(0.06, 0.12)	0.08**	(0.06, 0.12)	0.07**	0.05, 0.10)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

Appendix 3.12. Sequential hurdle models of tooth counts in adults ages 80+ years (n=989): Zero-inflated negative binomial (ZINB) regression results

	Model 1		Model 2		Model 3		Model 4		Model 5	
Counts outcome: Teeth present	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Level of education										
High school or less (reference)										
Some college	0.07	(-0.01, 0.14)	0.07	(-0.01, 0.14)	0.06	(-0.02, 0.14)	0.05	(-0.03, 0.13)	0.02	(-0.06, 0.10)
College graduate	0.18**	(0.11, 0.25)	0.17**	(0.10, 0.23)	0.16**	(0.08, 0.23)	0.16**	(0.08, 0.23)	0.12*	(0.04, 0.20)
Income level										
<$20,000 (reference)										
$20,000-$74,999	0.16*	(0.05, 0.27)	0.13+	(0.02, 0.24)	0.12+	(0.01, 0.23)	0.11	(-0.01, 0.23)	0.08	(-0.03, 0.20)
$75,000-99,999	0.12	(-0.06, 0.29)	0.08	(-0.10, 0.26)	0.07	(-0.11, 0.25)	0.07	(-0.11, 0.26)	0.02	(-0.17, 0.20)
$100,000+	0.24*	(0.11, 0.36)	0.21*	(0.08, 0.33)	0.21*	(0.08, 0.33)	0.20*	(0.07, 0.33)	0.13	(-0.01, 0.26)
Food security										
Full food security (reference)										
Marginal food security			-0.19	(-0.44, 0.05)	-0.17	(-0.42, 0.09)	-0.17	(-0.42, 0.09)	-0.13	(-0.36, 0.10)
Low food security			-0.33+	(-0.59, -0.07)	-0.30+	(-0.55, -0.04)	-0.30+	(-0.55, -0.06)	-0.17	(-0.40, 0.07)
Very low food security			-0.27	(-0.62, 0.07)	-0.24	(-0.59, 0.12)	-0.23	(-0.58, 0.13)	-0.17	(-0.49, 0.16)
Gender										
Female (reference)										
Male					-0.02	(-0.09, 0.05)	-0.02	(-0.09, 0.06)	0.06	(-0.02, 0.13)
Race/ethnicity & nativity										
U.S.-born Hispanic					-0.01	(-0.15, 0.14)	0.01	(-0.13, 0.14)	0.08	(-0.05, 0.21)
Foreign-born Hispanic					-0.08	(-0.25, 0.08)	-0.06	(-0.23, 0.11)	-0.03	(-0.22, 0.15)
Non-Hispanic White (reference)										
Non-Hispanic Black					-0.27*	(-0.43, -0.10)	-0.26*	(-0.42, -0.09)	-0.19+	(-0.34, -0.04)
Non-Hispanic Asian					-0.18+	(-0.32, -0.04)	-0.17+	(-0.30, -0.04)	-0.05	(-0.21, 0.11)
Other race or multiracial					-0.03	(-0.29, 0.23)	-0.04	(-0.31, 0.22)	0.01	(-0.31, 0.33)
Health insurance status										
Private (reference)										
Public							-0.05	(-0.14, 0.04)	-0.02	(-0.10, 0.06)

Appendix 3.12 continued

No insurance							0.21	(-0.01, 0.44)	0.27	(-0.01, 0.56)
Occupation status										
Employed (reference)										
Not employed							0.06	(-0.14, 0.25)	0.03	(-0.15, 0.21)
Retired							0.05	(-0.09, 0.20)	0.04	(-0.11, 0.18)
Has diabetes										
No (reference)										
Yes									-0.12+	(-0.22, -0.02)
Daily flossing										
0 days (reference)										
1 to 6 days									0.25**	(0.12, 0.37)
7 days									0.22*	(0.09, 0.35)
Smoking status										
Never smoked (reference)										
Former smoker									-0.10*	(-0.17, 0.30)
Current smoker									-0.14	(-0.24, 0.07)
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									-0.10	(-0.22, 0.01)
More than 5 years, or never									-0.23*	(-0.39, -0.07)
Constant	2.74**	(2.63, 2.85)	2.79**	(2.68, 2.90)	2.83**	(2.71, 2.95)	2.80**	(2.64, 2.95)	2.74**	(2.54, 2.94)
Binary logistic regression component: Complete tooth loss										
SES variables										
Level of education										
High school or less (reference)										
Some college	-0.77**	(-1.16, -0.38)	-0.78**	(-1.16, -0.39)	-0.79**	(-1.18, -0.39)	-0.80**	(-1.20, -0.39)	-0.48	(-1.00, 0.03)

Appendix 3.12 continued

College graduate	-1.51**	(-2.12, -0.91)	-1.47**	(-2.06, -0.87)	-1.47**	(-2.05, -0.89)	-1.46**	(-2.02, -0.90)	-1.22*	(-2.02, -0.43)
Income level										
<$20,000 (reference)										
$20,000-$74,999	-0.48+	(-0.89, -0.06)	-0.39	(-0.82, 0.03)	-0.39	(-0.80, 0.02)	-0.37	(-0.82, 0.08)	-0.05	(-0.67, 0.56)
$75,000-99,999	-1.12	(-2.28, 0.04)	-1.05	(-2.21, 0.10)	-1.09	(-2.28, 0.11)	-0.99	(-2.23, 0.24)	-0.42	(-2.13, 1.28)
$100,000+	-1.18+	(-2.11, -0.25)	-1.09+	(-2.04, -0.13)	-1.07+	(-2.00, -0.15)	-1.03+	(-1.97, -0.09)	0.01	(-1.00, 1.00)
Constant	-0.45*	(-0.78, -0.12)	-0.59*	(-0.97, -0.21)	-0.80*	(-1.23, -0.37)	-1.64*	(-2.77, -0.51)	-1.97*	(-3.15, -0.79)
Food insecurity										
Food security										
Full food security (reference)										
Marginal food security			0.27	(-0.31, 0.84)	0.16	(-0.45, 0.76)	0.14	(-0.48, 0.76)	-0.24	(-1.16, 0.68)
Low food security			0.52	(-0.29, 1.34)	0.36	(-0.44, 1.16)	0.37	(-0.44, 1.17)	-0.41	(-1.74, 0.92)
Very low food security			1.15	(-0.24, 2.54)	1.02	(-0.51, 2.56)	1.01	(-0.51, 2.54)	0.42	(-1.12, 1.98)
Constant			-0.59*	(-0.97, -0.21)	-0.80*	(-1.23, -0.37)	-1.64*	(-2.77, -0.51)	-1.97*	(-3.15, -0.79)
Frequency of dental visits										
Most recent dental visit										
Within the past 12 months (reference)										
Between 1-5 years									0.83**	(0.39, 1.27)
More than 5 years, or never									2.35**	(1.73, 2.97)
Constant									-1.97*	(-3.15, -0.79)
lnalpha	-1.84**	(-2.06, -1.62)	-1.88**	(-2.10, -1.66)	-1.91**	(-2.15, -1.68)	-1.92**	(-2.16, -1.68)	-2.10**	(-2.33, -1.86)
alpha	0.16**	(0.13, 0.20)	0.15**	(0.12, 0.19)	0.15**	(0.12, 0.19)	0.15**	(0.12, 0.19)	0.12**	(0.10, 0.16)

** p<0.001, * p<0.01, + p<0.05

Source: The National Health and Nutrition Examination Survey (NHANES), 2013-2018; above data are weighted and imputed.

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