Oral Health and Aging

Christie-Michele Hogue
Jorge G. Ruiz
Editors

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Age-Related Changes in Oral Health

Ezekiel Ijaopo and Christie-Michele Hogue

This chapter reviews common age-related changes in oral health that affect the structures and functions of the oral cavity and how they may predispose older adults to the development of a variety of oral pathologies. We will address some of the limitations and challenges in the study of age-related changes in oral health. Clinicians and investigators often overlook age-related changes in oral health due to the wrong perception that these problems are inconsequential or non-life-threatening. Further evidence of this oversight is in the limited number of cross-sectional, longitudinal studies and randomized controlled trials that have been conducted. When available, existing studies have included relatively small sample sizes or shorter follow-up periods. Another consideration when discussing age-related changes is that oral conditions may not necessarily reflect the effects of the aging but rather the effects of chronic diseases, lifestyle, environmental, and social determinants. These factors may negatively impact oral health by accelerating the effects of aging on the oral cavity.

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1 Age-Related Changes in Oral Structures and Function

The development of oral structures is a complex process that began during the embryonic stage. The main structures in the oral cavity include the lips, soft and hard palates, oral mucous membranes, teeth, gingiva, tongue, salivary glands, and bones of the upper (maxilla) and lower (mandible) jaws. These structures provide a framework that supports the oral cavity and play critical roles in the physiologic processes of tasting, speaking, chewing, (mastication), and swallowing (deglutition) which will impact the process of digestion and articulation. Table 1 summarizes the main age-related changes in the structures and functions of the oral cavity.

2 Oral Mucous Membranes

The oral mucosa becomes smooth and dry with aging. Several studies [1, 3] have described age-related changes in the oral mucosa that include the thinning of the oral epithelium which results from reduction in the thickness of epithelial ridges and a decrease in salivary secretion. Arteriosclerotic changes with progressive obliteration of the capillaries and a reduction of cell metabolism are the main causes of oral mucosa changes with aging. The connective tissue of the oral mucosa also becomes atrophic with loss of elasticity. Similarly, nerves and end organs in the oral mucosa may also be affected by age, thus leading to a gradual loss of sensitivity to thermal, chemical, and mechanical stimuli [3].

As stated earlier, environmental factors may contribute to some of the observed changes in the oral cavity. Evidence shows that exposure of the lining of the oral mucosa to a variety of environmental factors may resemble many of the changes attributed to aging. While few age-related structural changes occur in the surface epithelia, there is mixed evidence regarding age-related changes in epithelial thickness, rates of tissue turnover, and metabolic activity [25]. Indeed, it can be challenging to differentiate normal aging changes in the oral mucosa from the variable effects of lifestyle, genetics, and environmental factors on these oral structures.

An observational study that included 38 cadavers from Japanese adults ranging in age from 62 to 98 years investigated age-related changes in the buccal mucous membranes. Serial sections of the buccal mucous membrane in the vicinity of the anguli oris were observed under a light microscope. The investigators identified five age-related changes: (1) a significant decrease in the thickness of the buccal mucous membrane; (2) a disappearance of the functional arrangement of collagenous and elastic fibers in the lamina propria and submucous membrane, accompanied by prominent fibrosis; (3) a reduction in the number and distribution of blood vessels in the mucous membrane; (4) fat infiltration and fibrosis of the small salivary glands; and (5) a decrease in the thickness of the tunica muscularis [2]. Limitations of this study are the cross-sectional nature of the data and the technical limitations of postmortem examinations which may limit the interpretation of age-related changes.

Table 1 Age-related changes in the structure and function of the oral cavity

Oral cavity structures and functions	Changes with aging	Predispose to oral pathologies
Structure		
Oral mucous membranes	↑ epithelial thinning [1] ↑ atrophy of connective tissue [2] ↑ dry, thin, and smooth oral mucosal surfaces [1, 3] ↓ thickness of epithelial ridges [3] ↓ elasticity [1, 2]	Oral cancers Oral candidiasis Oral lichen planus Chronic aphthous stomatitis Oral hairy leukoplakia Pemphigus vulgaris
Teeth	↑ enamel hardness and brittleness [4] ↑ wearing of occlusal surface [1, 5] ↓ thickness of mantle dentine and globular dentine [6] ↑ cemental irregularities [7] ↑ secondary dentine deposition/ calcification [4]	Dental caries Tooth loss Chewing dysfunction
Periodontium	↓ fibroblast density of periodontal ligament tissue [8] ↓ quality and quantity of collagen [9] ↑ alveolar bone resorption [10] ↑ thinning of gingival epithelium [7] ↓ vascularity and mitotic activity [9] ↓ keratinization of gingival epithelium [7] ↑ resorption and apposition of cementum [7]	Gingivitis Chronic periodontitis Periodontitis as a manifestation of systemic diseases Necrotizing periodontal diseases Periodontal abscess
Salivary glands	↑ replacement of parenchyma by fibrous and/or adipose tissue [7, 11, 12] ↓ acinar volume (acinar atrophy) [11, 13] ↓ salivary secretions [12]	Xerostomia Swallowing disorders Sialolithiasis Sialadenitis Tumors Sjogren's syndrome
Tongue	↓ filiform papillae [1] ↓ thickness of epithelium [14] ↓ epithelium of lingual mucosa [15] ↓ lingual muscle diameter [14] ↑ lingual gland acinar atrophy [14]	Glossitis Geographic tongue Fissured tongue Taste dysfunctions Oral candidiasis Oral cancers
Function		
Masticatory function	↓ thickness of the masseter muscle [16, 17] ↓ masticatory performance [18] → functional feeding skills [19]	Chewing dysfunction
Swallowing function	↑ (prolonged) initiation of swallowing [20] ↓ maximal tongue strength [21, 22] ↓ tongue motor function and tongue pressure [23] ↑ rigidity of the esophageal wall [24] ↓ esophageal contractility [24]	Swallowing dysfunction

3 Teeth

With increasing age, the teeth show wearing of the enamel, chipping and fracture lines, and thinning of the enamel that may cause stain of the dentin, leading to a darker appearance of the teeth. The pulp chamber and canals become reduced in size due to the deposition of secondary dentin [4]. Other studies have reported the wearing away of the occlusal surface and proximal contour of the enamel, making the teeth more vulnerable to damage and decay [1, 5]. Other changes include the appearance of a small, polished facet on the cusp tip or ridge or a slight flattening of the incisal edges. In addition, there is a reduction in the cuspal height with inclination and flattening of the proximal contour of the enamel. The shortening of the length of the dental arch may be due to reduction in the mesiodistal diameters of the teeth through proximal attrition [1, 26]. Tooth loss appears to be one of the main reasons why older people have difficulty with chewing. One study aimed to determine the age-related changes in pulp cell density, pulp area, and dentinal thickness with age. Incisors (50), canines (39), premolars (51), and molars (7) extracted from 60 patients, aged 10–59 years, were analyzed histomorphometrically for cell density (presence of odontoblasts, subodontoblasts, and pulp core fibroblasts) and dentinal thickness. The analyses revealed that with increasing age, dentinal thickness increases in both the crown and root aspects of the teeth, while the density of odontoblasts, subodontoblasts, and pulp fibroblasts decreases. However, the degree of age-related changes in the teeth appeared to be asymmetrical: the decreases in the root were more pronounced than those in the crown [6].

3.1 Edentulism

Edentulism, is the permanent absence of natural teeth in the dental arch. Edentulism, or the complete loss of teeth, represents a debilitating and irreversible condition and is the final outcome of a multifactorial process encompassing patient-related and environmental factors [27]. Data from the National Health and Nutrition Examination Survey (NHANES) (2005 through 2008) were used to estimate dentate status and prevalence of untreated dental disease by age (50–64 years, 65–74 years, and ≥75 years). The investigators gathered information on persons' reports of fair or poor general health, chronic disease status, race/ethnicity (non-Hispanic Whites, non-Hispanic Blacks, and Hispanics), and income levels. In this cohort of older adults, tooth loss was highest among persons aged 75 years and older. When compared with persons aged 50–64 years, persons aged 75 years and older were three times more likely to be edentulous (32% vs 10%), and, among the dentate, persons aged ≥75 years had four fewer teeth on average (18 vs 22). A significant number of older adults had untreated dental disease. Individuals aged ≥75 years were nearly 50% more likely to have untreated root caries than persons aged 50–64 years (16% vs 11%) [28]. Another survey study conducted among 308 older adults >65 years old living in large rural

communities of Colorado, USA, examined factors associated with tooth loss. This study demonstrated that rural residents of racial and ethnic minority groups along with people who had levels of education below high school had fewer teeth than their urban peers and were at higher risk of becoming edentulous at older ages [29]. A more recent study, based again on data from NHANES, analyzed data obtained from 1999–2004 and 2009–2014. It revealed a lower incidence of age-related tooth loss in adults aged 50 years and older in the 2009–2014 cohort as compared with the earlier 1999–2004 cohort (11% vs 17%) indicating an improvement in the oral health status of older individuals over time. However, this decrease was not observed among poor and disadvantaged groups. Complete tooth retention improved from 14% to 21% between 1999–2004 and 2009–2014 for persons aged 50 years and older. The improvements in teeth retention were mostly attributed to better public health measures in the last decade including exposure to fluoride and better preventive practices [30]. This evidence suggests that social determinants of health including poor lifestyle choices, access to appropriate dental care, poverty, and lack of education [31, 32] may work in association with age-related changes in the teeth to cause edentulism in older adults.

4 Salivary Glands

Salivary glands have many roles in the oral cavity. In addition to producing and secreting digestive fluids, salivary glands are responsible for producing the saliva that lubricates the mouth, protects the teeth against bacteria, makes foods moist, and aids in the digestion of food by helping with the formation of the alimentary bolus in preparation for the process of swallowing. There are three main pairs of salivary glands: parotid, submandibular, and sublingual. Salivary glands undergo degenerative changes with normal aging, including a reduced number of acini and infiltration of fatty and fibrous tissue that may contribute to reductions in salivary secretion [11–13]. However, there is mixed evidence on whether salivary flow rate declines with aging. While some authors have described reduced levels of salivary flow rates with aging, including an increase in the ionic concentrations of saliva [11, 12], others report that salivary flow rates are unchanged with aging [13].

One observational study examined salivary flow rates and saliva composition in healthy individuals ranging in age from 18 to 89 years. Saliva samples were collected in unstimulated conditions followed by sialometrical and sialochemical analyses. The study showed three main findings:

(a) Older people have significantly reduced and altered salivary secretion as compared with younger people. Although the salivary concentrations of some chemicals increased with aging, the total values of most salivary components decreased.
(b) Over one half of the older individuals reported idiopathic oral sensorial complaints (OSCs) including taste disturbances, burning mouth syndrome, or xerostomia.

(c) Older individuals reporting OSCs were more likely to use prescription drugs, highlighting again the difficulties in studying age-related changes.

The authors concluded that a reduction in salivary function and alteration in salivary composition are mostly age-related [33]. More longitudinal studies are needed that investigate age-related alterations in salivary gland morphology and function and on whether or not salivary flow rate decreases with increasing age. For a more in-depth discussion on xerostomia, please refer to the chapter "Xerostomia and Hyposalivation".

5 Tongue-Lip Motor Function (TLMF)

The tongue-lip motor function is an essential component of the innate oral-motor skills underpinning the ability to move the muscles of the facial structures, namely, the mouth, jaw, tongue, and lips. This function is fundamental for speech and feeding skills, such as sucking, biting, swallowing, and chewing. TLMF achieves this functionality by controlling muscle tone, strength, coordination, and range of motion. In older adults with missing teeth, the tongue may also play an important role in compensating for alterations in masticatory function [34]. An experimental study conducted on animals investigated age-related changes in the intrinsic lingual muscle fibers. The main age-related findings were a decreased in the number of rapid-contracting muscle fibers and an increased in the proportion of slow-contracting muscle fibers. The authors reported that shifts in muscle composition from faster to slower myosin heavy chain (MyHC) fiber types may contribute to age-related changes in swallowing duration. The decreasing muscle fiber size in transverse and verticalis muscles may add to reductions in the maximum isometric tongue pressure found in older individuals [35].

One study explored the relationship between tongue motor skills and masticatory performance in dentate older adults and denture wearers. Investigators examined 30 healthy, normal adults with teeth, 10 normal older adults with teeth, and 20 edentulous adults wearing complete dentures that were constructed following similar methods and materials. They assessed tongue motor skills via an ultrasound system and used a sieving method to evaluate masticatory performance. The study showed age-related decreases in tongue motor skills and masticatory performance [18]. Although the outcome from this study revealed that tongue-lip motor function deteriorates with increasing age, other studies have argued that these skills are not age-dependent. One longitudinal study investigated whether functional oral-motor skills change with age by measuring the functional feeding skills and oral praxis abilities of 79 healthy adults aged 60–97 years who were followed up for up to four decades. The investigators administered the Modified Functional Feeding Assessment (FFAm) subscale of the Multidisciplinary Feeding Profile (MFP) and the Oral Praxis Subtest (OPS) of the Southern California Sensory Integration Test. The results showed that older people maintained functional feeding skills throughout the

four decades of the study. Individuals in their 70s and 80s experienced difficulties with a variety of food textures including soft, hard, fibrous, and tough skins [19]. It is, however, important to exercise caution when interpreting these results as several factors could have influenced the findings. The investigators measured random portions of muscle fibers from each muscle cross section rather than including all fibers within that particular muscle. Analyzing the complete muscle cross sections may have improved the accuracy and perhaps provided different data. Two other studies examined the maximal tongue strength during swallowing and chewing in healthy adults. The first study enrolled 51 dentate adults with a mean age of 25 years. The investigators evaluated tongue and lip functions by measuring the maximum tongue pressure and oral diadochokinesis with a multiple sieving method using peanuts to evaluate chewing ability [36]. The second study assessed 80 healthy young (aged 20–39 years) and older adults (aged ≥65 years) recruited from the community. They used the Iowa Oral Performance Instrument to measure maximal tongue strength and tongue strength during swallowing [22]. The first study showed that chewing ability was significantly correlated with maximum tongue pressure. The second study revealed that compared to older adults, the maximal tongue strength was significantly higher in the younger adult age group.

Although the evidence from these studies is still inconclusive on how age-related changes in tongue-lip motor function affect swallowing and masticatory functions, there is consistent evidence that tongue motor function, tongue pressure, and maximal tongue strength decrease with aging.

6 Oral Microbiome

Oral microbes are essential components of the oral cavity. The term "microbiome" represents the ecological community of symbiotic, commensal, and pathogenic microorganisms that closely share our body space. Although they are often ignored, they play crucial roles as determinants of health and disease [37]. In fact, after the gut, the oral cavity has the second largest and diverse microbiota providing a habitat for over 700 species of bacteria, fungi, viruses, and protozoa. The oral microbiome is essential to maintaining oral and systemic health [38]. Aging changes including the chronic state of low-grade inflammation or "inflammaging" may interact with the oral microbiota of older adults increasing the susceptibility of older adults to several infectious and degenerative disease processes [39].

The oropharyngeal microbiome of older people may promote the growth of several microorganisms including enterobacteria, pseudomonads, staphylococci, and yeasts that in older individuals with weakened immunity or deteriorated general health may become opportunistic pathogens [40]. Whether through the influence of the natural aging process or facilitated by the effects of disease, the bionomics of the oral cavity are likely to change, leading to alterations in the makeup of the oral microbiome. A survey study examined the relationship between the oral and gut microbiota. The findings demonstrated higher similarity between the microbiota of

the gut and the subgingival plaque in older adults than in younger individuals [41]. A Japanese study investigated changes in the gut microbiota composition of age groups ranging from newborns to centenarians. They found a higher proportion of *Bacteroidetes* and *Proteobacteria* species in individuals older than 70 years. The authors postulated that nutrients in the gut might play an important role in changing the gut microbiota composition with age [42]. In addition to aging, the oral and gut microbiota may be affected by changes in dietary habits, lifestyle, immunologic reactivity, exposure to certain medications (i.e., antibiotics, proton pump inhibitors), and the increased incidence of chronic multimorbidity in the older adult population which can potentially contribute to dysbiosis of the oral microbiome which in turn may predispose older adults to oral and systemic pathologies [43–46].

Research into the role of the oral microbiome in aging and disease is rapidly evolving. Studies using diverse research techniques, lack of standardization, and small sample sizes have produced findings that are often inconsistent. Future research with larger sample sizes along with improved techniques and standardization are needed to generate more consistent results.

7 Masticatory Function

The ability to chew food particles ensures an adequate nutritional status critical for oral health and quality of life [47–50]. Optimal chewing ability will be highly dependent on the number of functional teeth, number of missing teeth, and whether the individual uses dental prostheses. The chewing ability of an individual will have direct and indirect impact on general health and may serve as an indicator of the overall oral health of an individual [51].

A cross-sectional study investigated the relationship between aging and tooth loss on the quantity and quality of masseter muscle among 112 participants, aged 20–90 years old, who were cognitively intact and independent in their activities of daily living. The study excluded participants with a lack of molar occlusal support, diseases that could affect muscle function, and presence of temporomandibular disorders. The investigators used ultrasound to measure masseter muscle thickness (MMT), an indicator of muscle quantity, and masseter muscle echo intensity (MMEI), a measure of muscle quality. Findings revealed that aging was associated with lower quantity and quality of the masseter muscle [17]. While preservation of natural dentition or prosthetic treatment may be effective at maintaining masseter muscle function in females, males may require resistance exercise training to maintain the same level of function. In another cross-sectional study, 547 community-dwelling older persons (246 men and 301 women, mean age 73.8 ± 6.2 years) underwent a comprehensive annual geriatric health examination. Their chewing ability was evaluated by masseter muscle tension palpation, differences of masseter muscle thickness measured with ultrasound, occlusal force, self-reported chewing ability, and number of remaining and functional teeth. The study showed that masseter muscle thickness and occlusal force were significantly different between males

and females [52]. Another study found that masseter muscle thickness in dentate older adults at rest and during contraction was significantly higher than that found in edentulous older individuals [53]. By aiding chewing ability, masseter muscle thickness may represent an indicator of good oral health-related quality of life.

Although it has been argued that feeding skills are usually unaffected with normal aging, available evidence shows a decreased thickness of the masseter muscle and an increased acinar atrophy of lingual glands with normal aging. In addition, the prolonged initiation of swallowing and decreased masticatory performance reported with age may predispose older adults to swallowing and chewing dysfunction. These age-related changes may cause detrimental effects on the dietary habits of older individuals by limiting the intake of foods rich in vitamins, minerals, fiber, and protein while increasing the consumption of sugary and easy-to-chew, less nutritious foods [54–56]. These dietary habits may in turn contribute to nutritional deficiencies, ultimately increasing the risk for malnutrition and poor quality of life in older adults [57]. For a more in-depth discussion on these topics, please refer to chapters "Nutrition and Oral Health" and "Swallowing, Dysphagia, and Aspiration Pneumonia".

8 Conclusions

Available evidence revealed that age-related structural and functional changes in the oral cavity occur with normal aging in older people. The structural changes range from increased epithelial thinning of the oral mucosa membranes; dry, thin, and smooth oral mucosal surfaces; increased enamel hardness and brittleness; wearing of occlusal surface; and cemental irregularities. Similarly, the periodontium undergoes increased resorption and apposition of cementum and increased thinning of gingival epithelium along with decreased keratinization. With aging, salivary glands also experience more replacement of parenchyma by fibrous and/or adipose tissue and decreased acinar volume along with decreased saliva production. However, available studies are inconclusive on whether the salivary flow rate decreases with normal aging. Decreased thickness of the masseter muscle and increased acinar atrophy of lingual glands with normal aging affect masticatory function and result in altered perception of food taste, respectively. These age-related changes may predispose older individuals to malnutrition, disease, and poor quality of life.

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Epidemiology of Oral Health Conditions in the Older Population

W. Murray Thomson and Moira B. Smith

Oral epidemiological research makes inferences about oral health and ill-health in the source population from measurements conducted on representative samples. The purpose of this chapter is to provide an overview of what is currently known of the epidemiology of oral health and disease in older people using data from epidemiological studies.

1 Thinking About Old Age and Oral Health

Old age is more than just a chronological concept; the age at which a person is considered "old" is arbitrary and varies globally. While 65 years has traditionally been the accepted threshold for old age in most Western societies, the greater longevity accrued in recent decades means that it is an administrative threshold (enabling access to retirement benefits and other services) more than a chronological or social one. Low- and middle-income countries have relatively younger populations, and so their threshold for old age is typically 60 years; it is also the age used when considering the global older population.

It is important to bear in mind that older people have not appeared de novo. They have been shaped by their journey along the life course, having been subjected to age effects (maturation and then senescence), period effects (exposures

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occurring at particular times), and cohort effects (generation-specific characteristics). Ettinger summarized these well: "Elderly (sic) individuals are a complex combination and expression of their individual genetic predispositions, lifestyles, socialization and environments, all of which affect their health beliefs and, consequently, their health behavior. To understand an individual, one must evaluate the social, cultural, economic and chronologically specific cohort experiences which have shaped his/her life" [1]. Older people comprise the most heterogenous of any of the life stage groups (childhood, adolescence, adulthood, and old age), and we cannot lump all older people together and make generalizations about their oral health. Recognizing this diversity and to more accurately reflect the changes that typically occur as people age, the older population may be divided into the subgroups of "young-old" (65–74), "middle-old" or "old" (75–84), and "oldest-old" (85+) [2].

How might this work in practice? Consider, for example, a situation where we are interpreting findings from an oral health survey of people aged 65 years and older that we conducted in 2020. We recorded their dentition and periodontal status. Our sample ranges in age from 65 to 95 years. For reporting purposes, we have categorized age into the four age groups of 65–74, 75–84, 85–94, and 95+ years. Comparisons of dentition status across those age groups will show noteworthy and not entirely unpredictable differences in tooth loss and Decayed, Missing, or Filled Teeth (DMFT) scores. After all, both tooth loss and dental caries are chronic, cumulative conditions which increase in severity as we age. However, what we cannot do is state with any confidence that the accumulated disease experience observed in the oldest age group would be what we would observe in the youngest age group if we were to replicate the survey in three decades' time. This is because of differences arising from the abovementioned period and cohort effects.

Figure 1 illustrates the challenges. Those who were 95 in 2020 would have been 45 in 1970; by contrast, those aged 65 years in 2020 were only 15 in 1970. Their behaviors, beliefs, and norms would have been very different, as would their life trajectories over the subsequent decades. The same applies to their exposures, whether adverse or beneficial. For example, fluoride toothpaste, widely credited for the most precipitous fall in dental caries experienced in recent decades, was introduced in the early 1970s. While those aged 65 years in 2020 would have spent three quarters of their lives exposed to it, their 95-year-old counterparts would have used it for only half of their lives, and that would be reflected in their DMFT scores (as well as in their cumulative tooth loss). Such differences are depicted in Table 1, which presents nationally representative data from a survey of older New Zealanders, conducted in 2012 [3]. While the date of the survey differs from 2020, the differences are marked enough to illustrate the principle well. The observed differences between the oldest group and those aged 65–74 years are generational in nature, yet we tend to aggregate them together, considering those aged 65 years or more as "older people."

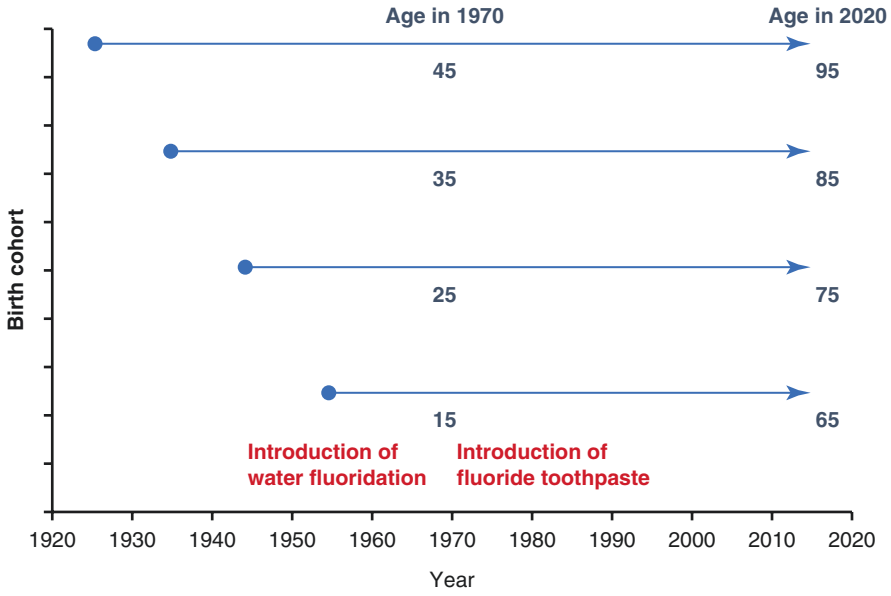

Fig. 1 Cohort differences in respect to dental caries among older adults

Table 1 Age group differences in dentition status in 2012 among older New Zealanders[a] (brackets contain 95% CI)

	Age group (years)			
	65–74	75–84	85–94	95+
% dentate	42.9 (36.8, 49.2)	41.8 (37.8, 45.8)	36.0 (32.2, 40.0)	29.9 (23.5, 37.1)
Mean no. of teeth	19.6 (18.2, 21.0)	16.9 (16.0, 17.7)	15.1 (14.3, 15.9)	14.9 (12.7, 17.2)
Mean DMFT	21.6 (20.4, 22.9)	23.6 (22.9, 24.2)	25.3 (24.7, 25.8)	25.0 (23.4, 26.6)
Mean DT	2.1 (1.6, 2.7)	2.0 (1.6, 2.3)	2.4 (2.0, 2.9)	1.9 (1.1, 2.7)
Mean MT	12.2 (11.0, 13.4)	14.9 (14.1, 15.8)	16.7 (15.9, 17.5)	17.0 (14.8, 19.3)
Mean FT	7.3 (5.9, 8.7)	6.7 (5.9, 7.5)	6.1 (5.4, 6.9)	6.0 (4.2, 7.9)

Abbreviations: *DMFT* Decayed, Missing, or Filled Teeth, *DT* decayed teeth, *MT* missing teeth, *FT* filled teeth

[a]Source of data: see CBG Health Research Ltd [3]

2 Sociodemographic Changes

Rising life expectancy and falling birth rates have meant that, in almost all countries, populations comprise more older people, and a greater share of older people, than ever before. What is more, almost all societies are aging at unprecedented rates [4, 5]. By 2050, the proportion of the global population aged over 60 years is

projected to more than double, rising from 1 billion in 2019 to 2.1 billion. In some regions, such as North America and Europe, almost one in four people will be "older" [5]. Longer life expectancies also mean that populations will comprise a substantial proportion of "oldest-old" people. In many countries, that age category is the fastest growing of all older age groups. The number of people aged 85 years or older is expected to triple in the period from 2019 to 2050, to make up almost one quarter of all older people. Rates of aging also vary regionally. While the older populations in many industrialized countries, most notably Japan, have been aging for some time, the most rapid shifts in population distribution are projected to occur in developing countries, in which four in five of the world's older people will live [5].

Population aging presents health, social, and economic systems with myriad challenges in meeting older people's complex dental and medical needs, in protecting and promoting their health and well-being, and in reducing the years lived with disability and poor quality of life. While Western societies have had some time to consider how to address these challenges, low- and middle-income countries' rapid acceleration of aging, and a lack of capacity and resources to cope with these changes, means that they are less well-prepared to respond and face imminent and substantial pressures [6]. It is thought that the health, social, and economic implications—for individuals and society alike—of the demographic changes are so substantial that population aging will be a hallmark of the twenty-first century [5]. Consequently, there has been a burgeoning of gerontological research aimed at understanding the demographic, geographic, sociocultural, and political influences on the associated dental and medical phenomena.

3 Health Differences by Gender, Ethnicity, and Socioeconomic Position

Marked differences by gender among older populations are evident [7, 8]. Most notably, women live approximately 5 years longer than men, the gap being greater among countries with higher levels of development [5, 9]. Unsurprisingly, then, women make up more than half of older populations and an even larger share of the oldest-old subgrouping [5]. However, the gender longevity gap appears to be narrowing (especially in more developed countries), a consequence of a reduction in gender differences in tobacco and alcohol consumption. While men's rates of tobacco and alcohol consumption have typically been higher than women, they are now falling; women's uptake of tobacco and alcohol also occurred later than men. Improvements in the treatment of cardiovascular disease, which is more prevalent in men than women, have further contributed to the convergence of men's and women's life expectancies [8, 10].

Aside from living longer, women are disadvantaged in almost all other aspects of health [7]. In many societies, women (of all ages) do not have the same access as men to several key determinants of health, including education, paid employment and other economic opportunities, and health services. Not only do the consequences of such inequities and disadvantage accumulate through the life course and persist into older age but they also exist and have an impact in old age. In some countries, sources of social support and income for older people, such as pensions and care assistance, may be inadequate or non-existent; these situations especially impact women. Consequently, many older women (especially those in low- and middle-income countries) live in or close to poverty, and typically have poorer health and health-related quality of life, and live longer with disability than men [7, 11]. Older women also live with greater levels of dependency than men, and fewer can live independently [12]. Disparities in health and social support between older men and women, particularly those living in developing countries, are exacerbated by prevailing gender-related cultural norms, such as women's lack of financial autonomy, capacity to own property, and the realization of other rights and freedoms [7].

Ethnic differences in health and well-being among older populations are also evident. Indigenous older people and those in "minority" ethnic groups typically have poorer access to health services, social supports, income, and other key determinants of health than non-indigenous and majority ethnic groups. They also experience racial prejudice and discrimination. In turn, their health and well-being are poorer; they have higher prevalence of chronic conditions, multimorbidity, levels of disability, and lower life expectancy and poorer quality of life than their non-indigenous peers and those of majority ethnicities [13–15]. Addressing these disparities is critical in maintaining and improving the health and well-being of future older generations, given that the proportion and absolute numbers of these groups among most populations are expected to rise [4, 16].

Similarly, the prevalence rates for chronic diseases, multimorbidity, cognitive decline, and disability are higher among older adults living in more deprived areas than in those living in wealthier neighborhoods [8, 17, 18]. Deprivation also accelerates decline in older people [17]; those living in the least deprived areas live up to 10 years longer than their counterparts in poorer areas [8]. For a more in-depth discussion on the topic of health disparities, please refer to the chapter "Health Disparities in Oral Health".

4 Chronic Conditions, Multimorbidity, and Disability

Globally, the prevalence of non-communicable diseases—and deaths resulting from them—is overtaking that of communicable diseases. A substantial proportion of the global burden of chronic disease is attributable to those aged over 60 years [19, 20], and the slow progression and long duration of chronic conditions, combined with

greater life expectancy, means that older people are disproportionately burdened by mental, neurological, and musculoskeletal disorders, diabetes, cardiovascular and chronic respiratory diseases, and cancer [21]. What is more, multimorbidity—the co-occurrence of two or more chronic conditions—is high among older people; over half to almost all older people have multiple chronic conditions [22, 23]. The number of conditions a person has increases with age and greater deprivation [22–24], and multimorbidity prevalence is higher among women than men. Other limitations associated with older age include compromised vision, poorer nutrition, more falls and other accidents, hearing loss, and speaking difficulties (the latter two make communication more challenging).

For the older person, chronic conditions (and multimorbidity) are associated with greater risk of disability, poorer quality of life, and greater rate of hospitalizations, use of health and social services, and mortality [22–24]. There is also the likelihood of greater dependency on others for functioning, ranging from support to undertake activities of daily living (such as housework and shopping) through to assistance with self-care or full personal care. For societies, these lead to greater use of health and social services and, in turn, substantive burdens on social and health resources [21, 24]. Given that older people are expected to live longer with chronic conditions and disability, it is thought that the costs associated with their long-term care needs will be substantial and exceed those directly associated with health care [21].

5 Dementia

One of the unforeseen features of greater longevity has been considerable growth in the incidence of dementia. Approximately 5–8% of those over 60 worldwide have dementia, with Alzheimer's diseases accounting for approximately two-thirds of all cases [25]. Concurrent with projections of population aging, the number of people with dementia is expected to rise rapidly, from 50 million in 2019 to 152 million in 2050, the majority living in low- and middle-income countries [23]. Although not a normal part of aging, dementia incidence rises sharply from age 75 [25].

Dementia is characterized by cognitive decline and loss of independence in daily functioning and is a leading cause of disability and dependency among older people. The consequences of dementia are profound, are wide-ranging, and are both direct and indirect, not only for the person with the disease but also for their caregivers and family members. Dementia also has substantial societal social and economic impacts; addressing dementia costs low- and middle-income countries 0.2% of GDP, while it accounts for 1.4% of the GDP in high-income countries [25]. For a more in-depth discussion on the topic of dementia, please refer to chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health".

6 Frailty

Frailty is a clinically recognizable state of greater vulnerability, resulting from age-associated declines in physiologic reserve and function across multiple organ systems, such that the ability to cope with everyday or acute stressors is compromised. It is commonly associated with aging [26]. Its prevalence is high among older people, higher among women than men, and increases with age [27]. While it is distinct from multimorbidity, it shares features with chronic conditions and similarly increases the risk of disability, hospitalization, and death. Of those aged over 50 years, 12–24% are frail and a further half are prefrail [28]. For a more in-depth discussion on the topic of frailty, please refer to the chapter "Frailty and Oral Health".

7 Ageism

Population aging places considerable burdens on social and health-care systems and communities [21]. Assumptions that all older people are frail, disabled, and dependent, and therefore a burden on society and families, prevail, and ageism and discrimination against older people exist. Consequently, in many societies, older people are an often overlooked and excluded population group whose needs and rights are not sufficiently addressed.

There are differences in the rate at—and level to—which people decline as they age. Some decline rapidly and substantially, while others remain cognitively and physically intact throughout life, and older people are important members of society. Many continue to contribute to (and are active agents in) communities and societal development. Not only do they have extensive and valuable life experience, skills, and knowledge but they also participate politically and socially, and some continue in paid work, thus also making important economic contributions. Many older people (particularly women) engage in informal, unpaid work, volunteering for community organizations, and caring for grandchildren or an aging spouse.

8 Active Aging

To address the needs and rights of older people and advance their health and well-being, in recent decades, global [29] and national [30] strategies have been developed that aim to promote active aging, "the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" [29]. Emphasis is placed on the implementation of actions that support older people's independence and autonomy and to ensure that people remain unencumbered by ill health, poor quality of life, and disability as they age.

Where older people live is a key feature of active aging, determined by cultural, economic, political, and health factors. As populations become more urbanized, family structures and functions also change. Generations of families are now more likely to be living separately, with older relatives being cared for less and less by their family. In Western societies in particular, older people are encouraged to "age in place," that is, to remain in their own homes for as long as possible as they age. Aging in place has benefits for the older person's quality of life and social connectedness, and it can reduce care-related costs for health systems [31]. Despite older people spending 2.5–3 years, on average, with considerable care needs, the majority will continue to live in the community in their own homes [12], possibly with support for their care, either from family members or more increasingly from support workers. Nevertheless, some older people will require more intensive support provided in residential care facilities, the rate of use depending on countries' attitudes to the care of older people, economic resources, and supply of such facilities [32]. Approximately 5% of the older population reside in aged residential care facilities [33], for 2 years, on average [32], although up to half of the older population are likely to use such facilities for care at some point in the late stages of their life [34]. As the number of older people aging in place rises, those entering aged care facilities are predominantly the oldest-old, those with the greatest cognitive decline, the very frail, and those with the most complex care needs [34–37].

9 The Common Oral Conditions Affecting Older People

The most common oral conditions among older people are tooth loss, dental caries, periodontitis, dry mouth, and oral mucosal lesions [38–40]. Those are chronic noncommunicable conditions which increase in severity with age because of their cumulative nature, and all can compromise older people's quality of life.

9.1 Tooth Loss

Almost all older people have lost at least one tooth on their journey through life, and most of that tooth loss has occurred because of dental caries or periodontitis [41]. Before thinking about the occurrence of tooth loss, however, it is useful to make a distinction between edentulism (the state of having had all the natural teeth removed) and the more common incremental loss of teeth (but short of the full dentition) which tends to occur throughout life. People who are edentulous have at some stage made the decision (or had it made for them) to undergo complete removal of their remaining dentition. The decision to make that transition is as much a social one as it is a clinical one [42, 43], and there are marked inequities by socioeconomic position and accumulation of adversity through the life course [44, 45]. In industrialized countries, edentulism prevalence has fallen markedly over the past few decades.

Regarded as an undesirable, "biographically disruptive" endpoint which perhaps reflects the collective failure of both self-care and the dental care system [46], the transition to edentulism can also mark the end of decades of misery and eating problems [47]. The influence of the dental system and prevailing social norms on tooth loss rates in older people was underlined in findings from a comparison of oral status in older people in a Western society (New Zealand) and one rooted in the Confucian tradition (China), whereby tooth retention among the latter was considerably greater, not only in their lower edentulism prevalence but also in a higher proportion with a functional dentition and in the higher mean number of teeth present among dentate individuals [48]. The authors pointed out that those dissimilarities represent differences in not only access to—and use of—dental care but also sociocultural differences in norms and values.

Incremental tooth loss is now far more common than edentulism, among adults of all ages. The most important reason for it is dental caries, with trauma and periodontitis making minor contributions, although the latter becomes more important with increasing age [41, 49]. There appears to be no readily identifiable life stage at which the bulk of tooth loss takes place, although, given the chronic, cumulative nature of its main cause, it would be expected that perhaps the tooth loss increment rate might stay reasonably constant with age, and this has been confirmed by several reports from prospective cohort studies of older people [47, 50]. Its less predictable nature means that incremental tooth loss can pose more of a prosthodontic challenge, given that its sequelae can include the drifting or over-eruption of the remaining teeth. Most descriptions of tooth loss among older adults have focused on indicators such as the edentulous proportion, the mean number of restored and missing teeth, and the proportion with a functional dentition (usually defined as having 21 or more remaining teeth [51]). While those indicators remain useful, they lack the detail required for a more nuanced understanding of the remaining dentition. Recently published estimates from a national survey of dependent older adults in New Zealand have shown that their residual dentitions vary considerably, and having a complete dentition is rare [52]. Those residual dentition patterns come about through influences which range from the pathological through to the societal; what is observed in old age is the outcome of a lifetime's steady accumulation of adverse and beneficial exposures.

9.2 Dental Caries

It is now well-recognized that dental caries is a disease that continues through life and that, other than the greater susceptibility of the deciduous dentition (due to its lower mineralization), the typical annual caries increment is constant through life, at about one new surface per year in the average person [53]. That holds in old age, where coronal caries continues to predominate [54, 55]. However, where the caries increment has been shown to increase considerably is after admission to aged residential care, where it is more than double that observed among community-dwelling older people, and more than twice as high again among those with dementia [56].

There is no shortage of anecdotal reports from clinicians of dentitions deteriorating rapidly in such circumstances. For a more in-depth discussion on the topic of caries, please refer to the chapter "Management of Caries in Older Adults".

9.3 Periodontitis

Most dentate older people show evidence of periodontitis, with moderate levels of attachment loss apparent in most [57]. While a substantial minority have more advanced attachment loss [58], relatively few sites are affected. The attachment loss manifests mainly as gingival recession. A complicating factor when considering periodontitis in older people is that their experience of incremental tooth loss means that the remaining dentition is the "healthy survivors," and so their lifetime periodontitis experience is likely to be underestimated from a contemporary clinical dental examination. This makes the interpretation of periodontal epidemiological data on older people particularly difficult. For a more in-depth discussion on the topic of periodontal disease, please refer to the chapter "Management of Periodontal Disease in Older Adults".

9.4 Dry Mouth

The term "dry mouth" covers both salivary gland hypofunction (SGH) and xerostomia. With the former, someone has low salivary flow, while the latter involves the subjective sensation of dry mouth. The degree of concordance between the two aspects of dry mouth remains unclear, and it is likely that much of the occurrence of xerostomia may be due to differences in saliva quality rather than quantity [59]. Not only is dry mouth common but its prevalence is highest among older people, with more than one in five affected [60].

People who have Sjögren's syndrome (1% of the population) or who have undergone radiotherapy for head/neck cancer (0.1% of the population) can suffer from severe chronic dry mouth, but medications are by far the most important risk factor for chronic dry mouth, responsible for more than 95% of cases [59]. Older people take a lot of medications: polypharmacy is common [60]. Determining the effects of medications on salivary flow and subjective dry mouth is challenging because not only may a particular drug exert its effect at more than one step in the salivary secretion pathway but the strength of that effect is determined by dose, duration, metabolism, and the concurrent effects of other drugs which are being taken [60]. Epidemiological investigations of associations between medications and dry mouth have found many drugs to be risk factors, but those most consistently identified as such have been antidepressants, diuretics, anti-anginal, bronchodilators, and antihistamines. Polypharmacy continues to complicate such investigations, but people

taking many different medications have higher rates of dry mouth, regardless of the actual preparations being taken.

Dry mouth has been shown to affect sufferers' quality of life [61], and they also have higher rates of dental caries [62]. Managing dry mouth remains a difficult and challenging process, mostly empirical in nature. For a more in-depth discussion on the topic of dry mouth, please refer to the chapter "Xerostomia and Hyposalivation".

9.5 Oral Mucosal Lesions

While lesions of the oral mucosa are common among older people, population-based estimates are scarce. In the USA, the most recent estimates come from the third NHANES study (conducted from 1988 to 1994), where one or more oral mucosal lesions were observed in 39.4% of 60–69-year-olds and 42.6% of those aged 70 years or older [63]. More recent estimates come from New Zealand's 2009 national oral health survey [64], where one-third of those aged 65 years or older had at least one oral mucosal lesion. Almost all of those were relatively harmless, arising from local trauma or chronic infection (such as denture stomatitis). Given its catastrophic personal implications, oral cancer should always be considered, of course, given that most cases of oral cancer are diagnosed in older people.

The terms "oral precancer" and "oral cancer" cover several oral mucosal lesions. The former term is generally applied to lesions such as leukoplakia, lichen planus, and erythroplakia; these are acknowledged to have malignant transformation potential. Erythroplakia is very rare but is the most sinister of those, invariably featuring dysplastic epithelium. The term "oral cancer" most commonly refers to oral squamous cell carcinoma [65]. It is a condition for which the death-registration ratio is comparable to those of breast cancer and cervical cancer and exceeds that of melanoma [66]. Tobacco use (whether smoked, chewed, or rinsed as a "tuibur" solution [67]) is the most well-known risk factor. It also has a synergistic effect with heavy alcohol use [68]. Human papilloma virus (HPV) has also been implicated in the occurrence of oropharyngeal cancer, particularly among younger adults [69], but it will be intriguing to observe what happens as that population enters old age.

10 Conclusions

Most countries are faced with the challenge of older people with more teeth. Such an unprecedented situation is challenging for health systems which (for the most part) are not ready for it. Epidemiological investigations of older people's oral health provide essential information for understanding the nature and extent of that challenge. A life course perspective is essential to interpreting and understanding the data.

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Nutrition and Oral Health

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There are synergistic and multifaceted associations between diet, nutrition, and oral health. As the "gateway to the gastrointestinal tract," a healthy functioning mouth is essential for individuals to eat and drink. Diet can directly impact oral soft and hard tissues, and, conversely, the integrity of the mouth can affect biting, chewing, and swallowing. If the impact is prolonged, the risk for micronutrient deficiencies and malnutrition increases, potentially increasing the risk for compromised systemic health. Soft tissue integrity can be negatively impacted by nutrient deficiencies, infection(s), surgery, and medication(s). Changes to soft or hard tissue including tooth loss with or without replacement can negatively impact food, fluid intake, nutritional status, and in turn can further compromise oral health.

Screening to detect factors influencing the ability to consume a healthy diet and risk for micronutrient deficiencies and malnutrition as well as factors influencing the ability to consume foods and fluids can help identify older adults needing intervention early and prevent or mitigate the severity of problems. The primary aims of this chapter are to describe nutrition risk factors within the context of validated approaches to nutrition risk screening of older adults; describe associations between diet, nutrition, and tooth loss and dentures; and address interventions to improve the functional ability to eat in the face of tooth loss and replacement. The other chapters of this text cover additional topics that can also influence nutritional status including chapter "Age-Related Changes in Oral Health", and as such, they are not covered herein. Similarly, content covered in the chapters on dysphagia (chapter "Swallowing, Dysphagia, and Aspiration Pneumonia"), hyposalivation (chapter "Xerostomia and

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Hyposalivation"), oral, infectious, and systemic diseases (chapter "Systemic Disease That Influence Oral Health"), alterations in mental status (chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health"); and long-term care settings (chapter "Oral Care in Long-Term Care Settings"), includes factors that impact diet and nutritional status. While there are no screening tools that are specific to predict the impact on nutritional status due to oral disease, infections, and altered soft or hard tissue function or integrity, clinicians should consider the location(s) of the problem, whether it is acute or chronic, and patient self-reported and clinician anticipated impact on food and fluid consumption in determining risk for problems with diet that require patient education and/or referral. If such factors are not addressed in a timely and comprehensive manner, changes in diet may ultimately negatively impact nutritional status and risk for malnutrition.

1 Nutrition Risk Factors and Screening Tools Used with Older Adults

Nutrition risk factors are any factors that elevate the chances of getting a disease or having a certain outcome or condition [1]. For the purposes of this chapter, nutrition and oral health risk factors will refer to any factor that may increase an older adult's risk for difficulty eating or drinking which can lead to inadequate nutrient intake, micronutrient deficiencies, or malnutrition. There are nutrition risk screening tools for older adults [2–8]; however, the integrity or function of the oral cavity as a risk factor is only addressed to a small extent in the Mini Nutritional Assessment (MNA) [2, 3]. Common nutrition screening factors are addressed in the next section. Consideration of factors affecting the integrity and function (mandibular opening, biting, chewing, swallowing, lip seal) of the mouth (including pain, saliva, soft tissue, nerves, muscles, joints, teeth) that may in turn affect food and fluid consumption is important both in regard to provider examination and patient self-report as part of comprehensive care [9]. The findings can be integrated with any of the nutrition screening tools addressed herein to determine interventions to maximize patient response to treatment and systemic health.

1.1 Weight Status and Change

Unintentional weight change, either loss or gain, may reflect a change in appetite or ability to eat and/or drink, alterations in energy needs due to a systemic issue, an eating disorder, or food insecurity. With unintentional weight loss, losses in both fat and muscle mass may occur. Body compositional changes seen in aging include loss of muscle mass and an increase in body fat mass. This process may be expedited in the face of decreased mobility either due to voluntary or involuntary causes [10].

Asking patients about their weight history is valuable to establish a basis for comparison. Both actual and usual weights are used to calculate percent weight change [(Actual − Usual)/Usual × 100]. A 5–10% unintentional weight loss in 3–6 months is considered a risk factor for malnutrition according to the Malnutrition Universal Screening Tool (MUST) [5], while the Mini Nutritional Assessment (MNA) [2, 3] considers a 3 kilograms or more loss of weight in the preceding 3 months a risk factor for malnutrition. Unintentional weight gain can reflect a change in health status, diet, or a decline in physical activity. If the gain is due to excess fluid accumulation, such as in edema or ascites, prompt medical attention is needed to determine the cause and treat the fluid excess.

Evaluation of weight and weight change over time is inexpensive, noninvasive, and rapid. Body mass index (BMI) reflects weight in proportion to height; it does not differentiate between fat and muscle mass. Hence, even a person with no weight change may have a shift in the proportion of muscle and fat mass that will not be reflected in the BMI. Weight status classifications are based on BMI [underweight, normal, overweight, obesity (class I or II), and extreme obesity (class III)] and can be used to identify risk for cardiometabolic diseases as well as mortality. BMI can be calculated using applications from the National Institutes of Health and the Centers for Disease Control and Prevention (http://www.nhlbi.nih.gov/guidelines/obesity/BMI/bmicalc.htm, and https://www.cdc.gov/healthyweight/assessing/index.html).

1.2 Medical, Surgical, and Dental History

Patient history of acute or chronic diseases provides insights into factors that may influence oral integrity and subsequently oral intake. Oral manifestations of diabetes including increased risk of oral infectious diseases, burning tongue, xerostomia, and compromised wound healing can negatively affect appetite, eating ability, and intake [11, 12]. Infections can impact glycemic control and ultimately nutritional status.

Other systemic diseases not specific to older adults that can affect nutritional status and diet include autoimmune diseases such as Crohn's disease, rheumatoid arthritis, Sjögren's syndrome, systemic lupus erythematosus, scleroderma, and pemphigus vulgaris. In these diseases, both functional and sensory abilities may be altered either by virtue of the impact of the disease on muscle and joint pain or function, sensory impacts due to oral lesions or altered cranial nerve function, or the medications used to treat the systemic conditions. Xerostomia and hyposalivation which may be due to medications or Sjögren's syndrome increase the risk for oral infectious diseases and mucosal injury. Joint pain such as in the temporomandibular joint can limit mandibular opening and the ability to bite and chew. While these factors may not be included specifically in nutrition risk screening or assessment tools, they are essential for health professionals to consider.

Most cancers can affect nutritional status as well as the integrity of the oral cavity. In particular, upper gastrointestinal tract (GI) cancers from the mouth through

the esophagus can impact nutrition via the disease itself causing altered energy and nutrient needs, location, and extent of surgeries and treatments. Radiation to the mouth can alter sensory and functional abilities and may, depending on the extent, cause hyposalivation and xerostomia. Chemotherapies can cause oral infections including stomatitis, along with anorexia, nausea, and vomiting. Surgical resections depending on the location, extent, and any need for oral devices such as a palatal obturator can have short- and long-term impacts on eating and drinking ability.

1.3 Oral Risk Factors

The integrity and function (mandibular opening, biting, chewing, swallowing, lip seal) of the mouth (including pain, saliva, soft tissue, nerves, muscles, joints, teeth) are not addressed in the majority of nutrition screening tools. However, failure to consider these factors as part of the assessment of the older adult, in terms of both physical examination and patient interview, can impact the plan of care and may result in missing contributing causal factors to risk for or presence of malnutrition. Readers are urged to consider the impact of material covered in other sections and chapters as part of their nutrition screening.

1.4 Dietary Intake

Changes in dietary intake of foods and fluids merit consideration as part of nutrition screening. Simple questions about whether food intake has changed or declined due to appetite, masticatory or swallowing problems, or gastrointestinal disorders and, if so, the extent and timeframe of the decline or change help to identify the severity of the problem. In some circumstances, the clinician may choose to further assess dietary intake to determine eating patterns, energy and nutrient intake, and diet quality. Diet assessment methods commonly used include dietary recalls and food frequencies. With any approach, there is the potential for over- and underreporting of error [13].

Dietary recalls refer to asking the patient to "recall" everything they consumed (foods and fluids) either on a typical day or the preceding 24 hours. With this approach, one documents the pattern, specific food(s) and fluid(s), and portion sizes. Dietary recall data can be analyzed using a nutrient analysis web application to determine total energy intake, macro- and micronutrients, and food groups. In contrast, food frequency questionnaires (FFQs) assess patient consumption of foods and fluids over a period of time such as a week, a month, or a year [14]. Validated FFQs exist and are typically used in epidemiological studies. The use of FFQs in clinical settings is limited as they may not reflect short-term changes in intake or eating and drinking patterns. There are other approaches to dietary intake assessment; the National Cancer Institute *Dietary Assessment Primer* [14] provides greater detail on these approaches.

1.5 Nutrition Screening and Assessment Tools

Nutrition screening refers to the identification of patient characteristics that are associated with nutritional problems [15]. It is intended to identify whether further comprehensive nutrition assessment should be conducted prior to intervention. Validated tools for nutrition assessment and screening specific to older adults which can be used in a variety of settings include the Mini Nutritional Assessment in the complete and short forms (MNA, MNA-SF) and the self-administered version (Self-MNA), the Malnutrition Screening Tool (MST), the Malnutrition Universal Screening Tool (MUST), and the Nutritional Risk Screening 2002 (NRS 2002). These tools are compared in Table 1. The choice of the tool to use is dependent on the intent (screening or diagnosis), population (some tools have only been validated in specific countries), care setting, time, and user.

The MNA family of tools originated with the validation of the MNA in 1994 in its full and complete form [16]. The MNA forms are specific to adults aged 65 years and older in any care setting. The original 18-item MNA (https://www.mna-elderly.com/forms/MNA_english.pdf) is intended as a nutrition assessment tool; it addresses food intake, BMI, weight loss, diet, activities of daily living, mobility, psychological stress or acute disease, neuropsychological problems, medications, presence of decubiti, and mid-arm and calf circumferences. Of note, the change in food intake question specifically asks whether the change is due to difficulty chewing or swallowing, appetite loss, or digestive problems. It is intended to be used by healthcare professionals to determine if patients have normal nutritional status or are at risk of or have malnutrition.

The MNA Short-Form (MNA-SF) (https://www.mna-elderly.com/forms/mini/mna_mini_english.pdf) was validated in 2001 [17] and 2009 [3] against the original

Table 1 Validated nutrition screening and assessment tools [2–8]

	MNA	MNA-SF	MST	MUST	NRS 2002
Unintentional weight loss	X	X	X	X	X
Change in intake due to oral function and appetite	X	X	X (only appetite)		X
Acute disease	X	X		X	
Cognition	X	X			
Mobility	X	X			
BMI or calf circumference	X	X		X	X
Medications	X				
Decubiti	X				
Mode of feeding	X				
Mid-arm circumference	X				
Specific to older adults	X	X			X has a correction score

BMI body mass index, *MNA* Mini Nutritional Assessment, *MNA-SF* Mini Nutritional Assessment Short-Form, *MST* Malnutrition Screening Tool, *MUST* Malnutrition Universal Screening Tool, *NRS 2002* Nutrition Risk Screening 2002

MNA. It is designed as a nutritional status screening tool for use by any healthcare professional to determine the risk of malnutrition in older adults. The two validation studies reflect its original validation [17] with BMI, and then in 2009, the validation included the use of calf circumference as an alternative to BMI when it is not available [3]. The six items include the same questions as the original MNA in regard to intake, unintentional weight loss, mobility, psychological stress/acute disease, neuropsychological problems, and BMI (or calf circumference).

The 2013 validated Self-MNA (https://www.mnaelderly.com/forms/Self_MNA_English_Imperial.pdf) can be used by older adults to self-assess their risk for malnutrition [18]. The Self-MNA asks for self-assessment of decline in food intake (but does not evaluate the specific cause of the decline), weight loss, mobility status, stress or severe illness, dementia, and BMI. The tool is limited by its self-evaluative nature and whether a person can self-identify as having dementia or experiencing the other symptoms evaluated.

The Malnutrition Screening Tool (MST), like the MNA Short-Form, was validated with adults in acute, rehabilitation, and long-term care settings, including inpatients with cancer in ambulatory care settings [4, 6]. It is designed for use by healthcare professionals as well as consumers to identify the risk for malnutrition. It asks about weight loss (intentional or unintentional and extent) and change in appetite.

The Malnutrition Universal Screening Tool (MUST) was validated in community, long-term care, and acute care settings in Australia, the United Kingdom, and the European Union with adults to identify risk for malnutrition [5, 7]. It can be used by any healthcare professional and includes the evaluation of BMI, unintentional weight loss over the previous 3–6 months, and acute illness with or without lack of intake in the preceding 5 days. Without an accurate weight or self-reported weight, a recalled weight can be used. If height measurement is not feasible, knee height may be used.

The Nutritional Risk Screening 2002 (NRS 2002) was validated in Denmark for use with hospitalized patients to identify risk for malnutrition [8]. It includes a correction factor in the scoring system for patients who are 70 years of age or older. The use of the tool is limited to adults in acute care settings; it classifies patients as having "undernutrition" to varying extents based on the presence of an unintentional weight loss, change in intake, and BMI.

2 Associations Between Tooth Loss and Replacement, Diet, and Nutritional Status in Older Adults

Tooth loss, with or without replacement with dentures, can lead to compromised oral function and changes in biting, chewing, and swallowing ability [19]. The quantity and distribution of the remaining teeth and the type, fit, and location of dentures all influence masticatory ability, food choices, diet quality, and nutritional status [19–24]. Associations between these factors reported in the research are

heterogeneous due to variability in the methods used to assess diet, nutritional status, tooth loss, and denture type(s). Tada et al. found that those who are missing all or some of their natural teeth are more likely to have impaired ability to bite and chew compared with those who are fully dentate [20]. Having fewer natural teeth and poorer occlusion and mastication are associated with poorer food diversity and diet quality, as well as lower intakes of energy, vegetables, fruits, fiber, protein, dairy, carbohydrates, fat (especially polyunsaturated fatty acids), and micronutrients including vitamins A, C, D, E, K, beta carotene, thiamine, riboflavin, niacin, B6, folate, B12, pantothenic acid, calcium, sodium, potassium, phosphorus, magnesium, iron, zinc, selenium, and copper [24–42].

Likewise, denture type and pattern may also impact nutrient intake; however, research findings vary in part due to the types of tools used to assess intake and denture type and pattern [43]. Individuals with implant-supported dentures (ISD) consume more vegetables, B12 and animal proteins, fiber, calcium, and iron and have less difficulty masticating raw, hard, and fibrous foods as compared to those who wear other types of dentures [44–47]. However, other researchers have not demonstrated significant differences in food and nutrient intake based on denture type [26, 48, 49]. Individuals with ill-fitting dentures, or those who remove their dentures while eating, are more likely to have poorer diet quality and avoid more foods than those who consistently wear their dentures for eating [26, 50–52]. A simple yet often overlooked question with patients is whether they use their dentures for eating.

Aside from changes in overall quantity of nutrient intake, difficulty biting and chewing can lead to the selection of softer foods that require less masticatory effort and that may be richer in carbohydrate and calories in place of nutrient-dense foods that may be harder to chew [33, 38, 53]. Such changes in diet can ultimately result in changes in weight and nutritional status [28, 29, 38, 54, 55]. Older adults with poorer occlusion and compromised masticatory ability are significantly more likely to be both underweight or have lower BMI values [54–60] and to be overweight/obese or have higher BMI values [28, 54, 56, 61–63], when compared to those with more teeth and better occlusion, placing them at higher risk of malnutrition. Longitudinal studies have found that complete edentulism is a significant risk factor for both weight loss [64] and gain [53].

However, others have not found significant associations between tooth loss and changes in weight or weight status [38, 65, 66] or replacement with dental prostheses and changes in weight or weight status [46, 54, 67, 68] which contributes to the lack of definitive findings. The variation in these findings may be due in part to the heterogeneity in study design and populations. Regardless, screening for changes in nutrient intake and weight status that may occur in association with tooth loss and replacement can help prevent malnutrition [69].

The MNA is the most commonly used nutrition screening tool reported in research that assesses the associations between tooth loss, replacement, and malnutrition risk [70–80]. However, this body of research is heterogeneous in that the studies measure dental status differently, which make the results somewhat difficult to compare. When the nutritional status of participants with complete edentulism

has been compared to participants with partial edentulism, most studies have found significant positive associations between complete edentulism and increased risk of malnutrition [71–74].

Associations between functional dentition [81, 82] and the risk of malnutrition have also been documented. Those without functional dentition are at a higher risk of malnutrition than those with functional dentition [70, 80]. Others have only reported trends [79] or found significant findings but only in unadjusted models for this association [76]. Yet other research findings do not support significant differences in nutritional status based on the number of remaining teeth or occlusal status [75, 77, 78]. While the findings of these individual studies are heterogeneous, Zelig et al. completed a meta-analysis and found that older adults who were fully edentulous or lacked functional dentition were 21% more likely to be at risk of or have malnutrition than older adults who were partially dentate or with functional dentition [21].

Older adults with removable partial or full dentures are at greater risk of malnutrition than those with complete posterior occlusion [83] or implant-supported dentures [44]. Some have found that the replacement of missing teeth with dentures can improve nutritional status [84–87]. However, replacement of older dentures with newer complete dentures has not been shown to significantly improve MNA scores and reduce malnutrition risk [68, 88]. Dentures do not provide the same masticatory ability as natural teeth. Changes in eating behaviors and dietary patterns take time, education, and adjustment and may be difficult to attain.

Ikebe et al. found that adults in the poorest quintile of masticatory ability were approximately two times more likely to be underweight and those in the lowest quintile of occlusal force were almost two times more likely to be overweight [55]. These findings shed some light on the heterogeneity of this body of research and suggest that in relation to their effect on nutritional status, functional ability (masticatory and occlusal force) may be equally or more important than morphology (number of teeth and presence and type of dentures). Thus, rehabilitation to improve oral function and masticatory ability combined with education and interventions to improve nutritional status are warranted for older adults with tooth loss.

3 Dietary Interventions for Older Adults With Tooth Loss With or Without Dentures

Older adults experience both adaptive and maladaptive behaviors as they adjust to tooth loss and replacement [89–92]. Individuals with tooth loss may take more time to eat, chew food longer, and chew on the side of the mouth that has better occlusion. Intervention to minimize risk for declines in the intake of energy or nutrient and maximize adaptive behaviors can also help individuals consume a healthy dietary pattern and enjoy a better quality of life.

Simply telling patients to “eat soft foods” is insufficient as it is open to interpretation and some soft foods like white bread readily absorb saliva and form a bolus and are hard to swallow. In contrast, cooked, cut, or chopped foods may be easier to

bite and chew initially, and thus the degree of "softness" may be better stated "as tolerated." Advising patients to use their knives and forks as "teeth" and to cut foods to minimize biting and chewing is also useful.

According to the World Health Organization (WHO), consuming a healthy diet throughout the lifespan is essential for preventing malnutrition and chronic disease [93, 94]. A healthy diet emphasizes vegetables, fruits, legumes, nuts, and whole grains and includes low-fat dairy products and lean protein sources like fish and poultry [93–96]. Preference is given to unsaturated fat sources, such as olive, canola, sunflower, or soybean oils, as well as fish, nuts, and avocados. Intake of sugar, sweets, sugar-sweetened beverages, trans and saturated fats including red meats and tropical oils, sodium, and processed foods is discouraged [93–96]. Within this framework, clinicians can guide patients toward adaptation of healthier dietary choices based on personal and cultural food preferences, food availability, and budgetary constraints to reduce the potential for maladaptive behaviors [93, 94].

Maladaptive behaviors include the avoidance of difficult to chew foods, like raw vegetables and fruits, hard or fibrous nuts, grains, and meat products, and increased consumption of foods that are higher in fat (i.e., mayonnaise), sugar (i.e., ice cream), or other carbohydrate sources (i.e., mashed potatoes) [89–92]. Approaches to replace maladaptive with adaptive behaviors have been developed for older adults with tooth loss and with dentures [89–92].

4 Guidance for Healthcare Providers and Older Adults with Tooth Loss

Zelig et al. found that older adults with tooth loss employed adaptive strategies to compensate for chewing difficulty [89]. These included modifications in food texture selection and cooking methods, such as choosing foods that are naturally easier to bite and chew, like overripe fruits, and cooking foods until they acquire a softer consistency. Other compensatory strategies include chopping, mashing, peeling, shredding, and grinding foods or adding fats and gravies to make foods softer, moister, and easier to chew. Table 2 provides tips for oral health and other healthcare providers to use with older adults experiencing tooth loss to help them eat better and enhance their eating experience.

5 Guidance for Healthcare Providers and Older Adults with Dentures

Replacement of missing teeth with removable partial or full dentures (RPD, FD) also impacts the eating experience. While dentures replace teeth, functional ability to bite and chew foods varies depending on many factors including type(s) of

Table 2 Guidance for eating healthier with tooth loss [89]

Tips to improve fruit and vegetable intake
Choose softer fruits and vegetables like bananas or avocados
Peel or remove hard-to-chew skin
Cut or chop into bite-sized pieces
Cook to a softer consistency
Blend or puree into a smoothie or a cold soup
Buy canned (without added salt or sugar) or frozen as needed
Tips to improve whole grain intake
Choose cooled whole grains like oatmeal, brown rice, quinoa, or couscous
Cut bagels and rolls into smaller pieces
Cook pasta and rice until soft
Allow cereals to soften in milk or other liquid
Toast lightly and add a spread like butter or cream cheese
Have sips of fluids while eating to add moisture
Tips to improve protein intake
Choose easy-to-eat and drink, protein-rich foods like ground meat or poultry, fish or seafood, eggs, cooked beans, tofu, or dairy products like cottage cheese, cow or other dairy or non-dairy alternative milks, yogurts, and cheese
Remove hard-to-chew skin
Cook foods that will shred or flake easily like fish, shredded or pulled beef, chicken, or pork, or vegetable protein alternatives
Cook to a softer consistency or until tender; try a slow cooker
Add sauces and gravies to moisten
Use a knife and fork or mini-food chopper to cut foods into bite-sized pieces
Tips to become more comfortable eating around others
Share eating challenges with family and friends so you can enjoy eating with them
Plan meals with family and friends where everyone can eat the same thing
When going to a party or event, eat first or bring something you can eat just in case there are no foods you can tolerate
Leave yourself enough time to eat
Go to restaurants where the menu includes foods you can eat, and don't be afraid to ask how foods are prepared, and specify how you would like them cooked

dentures, location (maxillary or mandibular), age, and fit [19, 43]. Ideally, denture fit and stability should be evaluated while observing a patient eating. Observation of mandibular movement while attempting to bite and chew foods permits the examiner to check for movement, noise, and function of the denture(s) as well as food pocketing. Adults with dentures should be asked if they use them for eating, and, if not, they should be questioned on why in order to determine potential causes and solutions. Consideration of patient complaints of difficulty biting, chewing, and swallowing with or without dentures is critical. This information can be used for the dental and diet treatment plans.

Dietary guidelines for those wearing dentures recommend that individuals start slow and progress gradually, *as tolerated* [97]. At least initially, it is best to avoid dry foods that fall apart in the mouth like rice, muffins, and nuts. On the day of and initially 1–3 days following insertion, some patients may need to eat easy-to-masticate items. This helps minimize the need to bite or chew while maintaining

nutrient quality of food along with sensory qualities like taste and smell. Chopping and cooking a variety of vegetables to make a vegetable soup, mashing them to the consistency of mashed potatoes, or cooking any vegetables until they are fork-tender allows for consumption of a greater variety of vegetables to enhance flavor and increase the nutrient value.

Cut-up and peeled raw soft fruits and vegetables, grains, and protein products should come next, followed by progression to raw, whole items, *as tolerated*. Using a knife and fork to cut food into bite-sized pieces so that the teeth don't have to do the work can help. Trying to chew foods at corners of the mouth can take the pressure off the front teeth which are generally used to bite. Fluids should also be encouraged to help moisten food.

Adjusting to dentures takes time. A progressive diet plan can ease the adjustment and allow the patients to consume foods they enjoy and that are healthy. Hard, crunchy, and tough foods like crusty breads, tough stringy meats (e.g., steaks, ribs), nuts, and seeds may be challenging, and soft, sticky foods like white bread and some soft rolls may be very difficult. Similarly, peanut and other nut butters can be difficult to manage with dentures. Chewing gum is generally discouraged [97].

Individuals who wear dentures also benefit from modification of food choices and consistencies, in addition to instruction on how to improve denture stability and function while eating [91, 92]. Table 3 provides a guide for oral health and other healthcare providers for use with older adults who wear dentures to help them eat better and enhance their eating experience.

6 Conclusions

A healthy mouth is a key component to being able to consume a healthy diet. Changes to soft and hard tissues and cranial nerves that affect oral sensations and movement have the potential to affect food and fluid choices and nutrient and energy intake and ultimately increase the risk for malnutrition. The extent to which the risk for malnutrition occurs may be mitigated by early identification of risk factors, followed by the provision of appropriate interventions. An interprofessional team including medical, oral health, and diet and nutrition professionals working together to provide screening and appropriate referrals between professions can promote optimal patient-centered care.

Nutrition screening and identification of factors that affect the ability to eat and drink can be identified early as part of the initial patient evaluation by oral healthcare professionals. Dietitians can integrate oral screening into their physical examination as part of nutrition assessment. Diet education may be provided by a dentist or hygienist, physician, physician assistant, nurse, or a credentialed dietitian, depending on the setting. In settings without a credentialed dietitian, a referral can be provided to one for medical nutrition therapy. A synergistic approach to patient care by all members of the interprofessional team can help to maximize oral, systemic, and nutritional health as well as quality of life.

Table 3 Guidance for eating following denture provision [91, 92, 97]

Tips for diet progression following provision of new dentures:
Day #1: May need to eat chopped, minced, pureed, or blenderized foods; smoothies, soups, puddings
Days #2–3: Choose soft or cut-up foods as tolerated Animal and vegetable protein sources: cook until soft[a], cut into small pieces, moisten with gravy or sauces Dairy and non-dairy alternatives: milk, yogurt, spreads, cheeses, hot/cold cereal with milk, smoothies Fruits and vegetables: soups, smoothies; peel and cook until mashable or fork-tender as tolerated Grains: mashed potatoes, oatmeal, cream of wheat, pastas
Days #4–5: Progress to raw cut-up foods as tolerated Peel and cut or chop raw fruits and vegetables Use a knife and fork to cut food into bite-sized pieces
Foods to avoid (at least initially)
Dry foods that fall apart in the mouth like rice, quinoa, grains, biscuits, crackers, and muffins Hard, crunchy, tough-to-chew foods like crusty breads, stringy meats, nuts, and seeds Soft, sticky foods like white bread and soft rolls and nut butters Foods that may get stuck like seeds and pulp or other foods that break into small pieces Chewing gum and hard candies
Other tips for eating well with dentures[b]
Cut food using a knife and fork and take small bites Chew foods at corners of the mouth to take the pressure off the front teeth Balance the bite force on both sides of the mouth Fluids should also be encouraged to help moisten food Choose softer[a] foods as tolerated Cook foods to a softer[a] consistency Modify the way the food is prepared and consumed Practice good oral hygiene after meals and snacks
Troubleshooting pain or discomfort and denture instability
Use fixatives as needed under the guidance of an oral healthcare professional Follow up with a dentist for denture adjustment as needed

[a]The narrative describes how to interpret the word "soft"
[b]See Table 2 for further discussion of appropriate food modifications for patients with tooth loss and replacement

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Swallowing, Dysphagia, and Aspiration Pneumonia

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Abbreviations

BOHSE	Brief Oral Health Status Examination
CN	Cranial nerve
DHI	Dysphagia Handicap Index
DIGEST	Dynamic Imaging Grade of Swallowing Toxicity
EAT-10	Eating Assessment Tool-10
FESS	Fiberoptic endoscopic evaluation of swallowing
GOHAI	Geriatric Oral Health Assessment Index
GUSS	Gugging Swallowing Screen
IDDSI	International Dysphagia Diet Standardization Initiative
LTC	Long-term care
MBSImP	Modified Barium Swallow Impairment Profile

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MBSS	Modified barium swallow study
MPS	Mucosal-Plaque Index
OHAT	Oral Health Assessment Tool
OHrQoL	Oral health-related quality of life
PEM	Protein-energy malnutrition
ROAG	Revised Oral Assessment Guide
SLP	Speech-language pathologist
SLS	Sodium lauryl sulfate-free
SSQ	Sydney Swallowing Questionnaire
THROAT	The Holistic and Reliable Oral Assessment Tool
TOR-BSST	Toronto Bedside Swallowing Screening Test
UES	Upper esophageal sphincter
VFS	Videofluoroscopic swallowing study
VFSS	Videofluoroscopic examination of swallow

1 What Is Swallowing?

1.1 Swallowing Definition

Swallowing is defined as the process of moving material through the oral cavity, pharynx, and esophagus and into the stomach through a series of muscular actions [1]. Swallowing is an overly complex neuromuscular act which requires motor and sensory coordination as well as organized interaction of cortical, subcortical, brain stem, and peripheral systems [2, 3]. Despite this, healthy individuals swallow an average of 500 times a day [4]. There are two types of swallowing: volitional and spontaneous [2]. Volitional swallowing is initiated under a conscious and awake condition such as during mealtimes with an intention to swallow [2]. Spontaneous swallowing is thought to be an involuntary mechanism that facilitates clearance of secretions from the mouth and pharynx and supports oral health and airway protection [4–8]. Spontaneous swallowing occurs unconsciously or without intention such as during sleeping or between mealtimes and is initiated when the salivary volume reaches a critical threshold [2, 7, 9].

Previous work has identified that as the volume of saliva increases in the oral cavity, humans will respond by spontaneously swallowing more frequently. Studies exploring resting swallowing frequency in healthy adults have identified a highly variable rate of 24–61 swallows/hour [9]. It is not clear if this variability is influenced by the volume of saliva secreted into the oral cavity or if there are other factors that may contribute. Reduction in the rate of spontaneous swallowing has been associated with increased pharyngeal secretions which increase the risk of chest infection in health compromised individuals [4–8].

2 Swallow Physiology

2.1 Liquid Swallowing: Four Sequence Model of Swallowing

Swallow physiology is divided into four sequential phases: (1) oral preparatory phase, (2) oral phase, (3) pharyngeal phase, and (4) esophageal phase [1, 10–12]. These phases are not discrete from one another but rather often overlap.

2.1.1 Oral Preparatory Phase of Swallowing

During the oral preparatory phase, liquid is taken into the oral cavity, and it is held on the tongue surface against the hard palate. The liquid is coated by and integrated with saliva to form a lubricated mass, which is referred to as a "bolus," that has suitable size and consistency for swallowing [10–14]. To prevent the loss of a portion of the bolus, the oral cavity is sealed anteriorly by the upper and lower lips and posteriorly by the contact of the dorsum of the tongue and the soft palate [1, 12, 15, 16].

2.1.2 Oral Phase of Swallowing

The oral phase of swallowing is initiated after the bolus is adequately formed [16]. During the oral phase, the bolus is held between the elevating and retracting tongue and the hard palate and propelled posteriorly via sequential contact of the tongue against the hard palate from front to back [10]. The oral phase ends when the tail of the bolus fully enters the oropharyngeal region.

2.1.3 Pharyngeal Phase of Swallowing

When the head of the bolus passes any point between the anterior faucial arches and the point where the base of the tongue crosses the ramus of the mandible, the pharyngeal swallow is triggered [1, 10, 17]. Sequential neuromuscular events occur once the pharyngeal swallow is initiated [1, 10, 15, 17]. The velum is moved superiorly and posteriorly to contact the posterior and lateral wall of the pharynx to close off the nasopharynx. This prevents materials from entering the nasal cavity. The hyoid bone is pulled superiorly and anteriorly by the suprahyoid muscles [16]. Simultaneously, the larynx is moved toward the hyoid bone by the thyrohyoid muscle. The anterior and superior displacement of the hyolaryngeal complex contributes to closure of the airway [1, 10, 17]. The airway is closed at three levels: (1) the true vocal folds; (2) the laryngeal entrance including the false vocal folds, the arytenoid cartilages tilting

forward to the epiglottic base, and thickening of the epiglottic base; and (3) the deflection of the epiglottis. Airway closure is critical for preventing materials from entering the airway. The anterior displacement of the hyolaryngeal complex, relaxation of the cricopharyngeal muscle, and intrabolus pressure contribute to the upper esophageal sphincter (UES) opening [18]. The opening of the UES allows the bolus to enter the esophagus [1, 15]. Then, the space between the base of the tongue and posterior pharyngeal wall sequentially collapses from the top to bottom to propel the bolus inferiorly when the bolus tail reaches the level of the base of the tongue.

2.1.4 Esophageal Phase of Swallowing

The esophageal phase of swallowing is initiated when the bolus enters the esophagus at the UES [1, 16]. When the bolus passes through the UES, the bolus is carried down to the stomach by a sequential peristaltic wave through the lower esophageal sphincter [1, 15].

2.2 Solid Food Swallowing: Process Model of Feeding

The process model of feeding divides swallow physiology into five stages: (1) stage I transport, (2) food processing, (3) stage II transport, (4) pharyngeal stage, and (5) esophageal stage [15, 19]. The pharyngeal and esophageal stages in this model are identical to those of the four- phase model for liquid swallowing.

2.2.1 Stage I Transport

After the solid food is placed in the oral cavity, the food is moved posteriorly to the post-canine region by the tongue. Then, the food is moved laterally to be placed onto the occlusal surface of the lower teeth for mastication [15, 19].

2.2.2 Food Processing

During food processing, the solid food is masticated and mixed with saliva until the food becomes suitable and safe for swallowing [15, 19, 20]. The properties of masticated bolus, such as particle size, bolus hardness, springiness, adhesiveness, and cohesiveness, may be used to determine when the bolus is ready for swallowing [20].

2.2.3 Stage II Transport

The masticated food is placed on the tongue surface, and it is propelled posteriorly. Then, the food is accumulated in the upper oropharynx and/or valleculae, which is referred to as "bolus aggregation," before it is propelled into the pharynx and beyond [15, 19]. This is also an example of overlap between the phases of swallowing given that the pharyngeal phase of the swallow may be initiated with a portion of the solid bolus that was adequately masticated while food processing with the rest of the solid bolus continues.

The purpose of mastication is to process food in the oral cavity into a bolus that can be transported through the oropharynx, swallowed safely, and then easily digested [21, 22]. During mastication, ingested food particles are mechanically reduced in size through the process of lingual particle selection as well as fragmentation between the occlusal surfaces of the teeth [23]. Factors such as total occlusal area, opposing occlusal contacts, bite force, number of teeth, and coordination between the movement of the jaw, tongue, and cheeks during manipulation of the food particles play an important role in effective mastication [22–24].

The secretion of saliva is critical for effective mastication, bolus formation, and bolus transport, and both the volume and composition of saliva contribute significantly to these functions [25]. The water in saliva is used to moisten the food particles, allowing the salivary amylase to access available starch and initiate chemical digestion [26]. Saliva contains mucins (primarily MUC5B and MUC7) that contribute to a slimy, viscoelastic coating of all surfaces in the oral cavity which is an important lubricant between opposing oral surfaces during mastication, swallowing, and speaking [27]. The salivary mucins bind masticated food into a coherent and slippery bolus that can easily be transported through the oropharynx [21]. The secretions rich in mucins can lubricate, stretch, and bond to one another to form tangled grids or webs known as spinnbarkeit that coat the epithelial surfaces of the mouth and pharynx. When food is mixed with the mucin-rich secretions, they serve to minimize shear stresses and potentially increase the extensional viscosity of the bolus allowing for less effort during mastication and improved pharyngeal transport with less post-swallow residue [28]. Even though mucins seem to play a critical role in mastication of solid food boluses, saliva secreted from the parotid glands during alimentation typically has the lowest concentrations of mucins and is also the least viscoelastic [27]. It has been hypothesized that parotid secretions may change the pH of saliva during bolus formation, which may consequently affect shear forces [29], but this process is not well understood, and it is unclear whether there is a threshold concentration of mucins or ideal viscoelasticity that results in optimal bolus formation and transport.

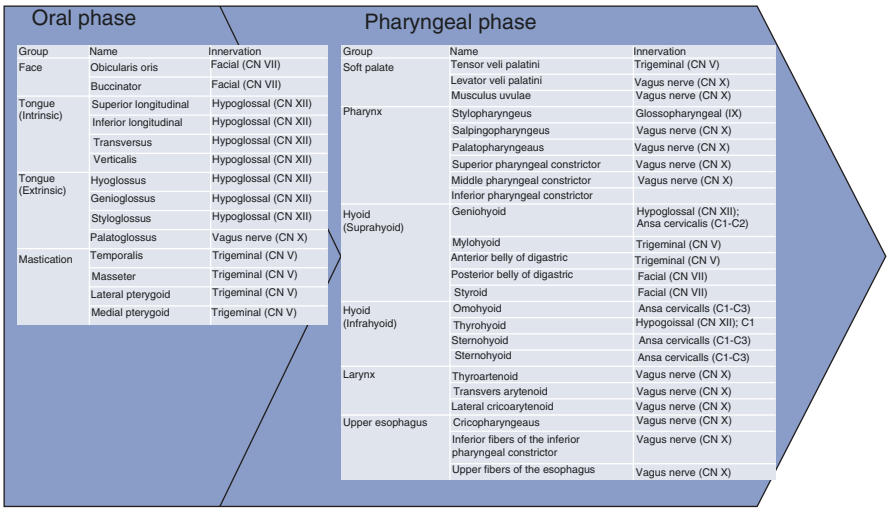
3 Swallowing Anatomy

3.1 Swallowing Musculature

Swallowing involves the precise coordination of more than 30 muscles in the face, oral cavity, pharynx, larynx, and esophagus [16]. Most of the muscles that participate in swallowing are striated muscles except for those in the middle and distal esophagus. The middle and distal esophagus are partially and completely comprised of smooth muscles [16]. Muscular movements during swallowing are controlled by the trigeminal (CN V), facial (CN VII), glossopharyngeal (CN IX), vagus (CN X), and hypoglossal (CN XII) nerves as well as the ansa cervicalis (C1–C3) and the pharyngeal plexus with fibers from the cranial division of accessory nerve (CN XI) [11, 16, 30]. The muscles involved during the oral phase include the muscles of the face, tongue (intrinsic and extrinsic tongue muscles), and mastication. The muscles involved during the pharyngeal phase include the muscles of the soft palate, pharyngeal musculature, hyoid (suprahyoid and infrahyoid), larynx, and upper esophagus [16, 31]. Figure 1 summarizes the muscles involved in swallowing.

3.2 Swallowing Neurophysiology

Swallowing requires the complex interaction of voluntary and involuntary neuronal networks including the cortical, subcortical, brain stem, and peripheral nervous system [2, 3]. There are sensory fibers that respond to temperature, touch, and pressure



Group	Name	Innervation
Face	Obicularis oris	Facial (CN VII)
	Buccinator	Facial (CN VII)
Tongue (Intrinsic)	Superior longitudinal	Hypoglossal (CN XII)
	Inferior longitudinal	Hypoglossal (CN XII)
	Transversus	Hypoglossal (CN XII)
	Verticalis	Hypoglossal (CN XII)
Tongue (Extrinsic)	Hyoglossus	Hypoglossal (CN XII)
	Genioglossus	Hypoglossal (CN XII)
	Styloglossus	Hypoglossal (CN XII)
	Palatoglossus	Vagus nerve (CN X)
Mastication	Temporalis	Trigeminal (CN V)
	Masseter	Trigeminal (CN V)
	Lateral pterygoid	Trigeminal (CN V)
	Medial pterygoid	Trigeminal (CN V)

Group	Name	Innervation
Soft palate	Tensor veli palatini	Trigeminal (CN V)
	Levator veli palatini	Vagus nerve (CN X)
	Musculus uvulae	Vagus nerve (CN X)
Pharynx	Stylopharyngeus	Glossopharyngeal (IX)
	Salpingopharyngeus	Vagus nerve (CN X)
	Palatopharyngeaus	Vagus nerve (CN X)
	Superior pharyngeal constrictor	Vagus nerve (CN X)
	Middle pharyngeal constrictor	Vagus nerve (CN X)
	Inferior pharyngeal constrictor	
Hyoid (Suprahyoid)	Geniohyoid	Hypoglossal (CN XII); Ansa cervicalis (C1-C2)
	Mylohyoid	Trigeminal (CN V)
	Anterior belly of digastric	Trigeminal (CN V)
	Posterior belly of digastric	Facial (CN VII)
	Styroid	Facial (CN VII)
Hyoid (Infrahyoid)	Omohyoid	Ansa cervicalls (C1-C3)
	Thyrohyoid	Hypogoissal (CN XII); C1
	Sternohyoid	Ansa cervicalls (C1-C3)
	Sternohyoid	Ansa cervicalls (C1-C3)
Larynx	Thyroartenoid	Vagus nerve (CN X)
	Transvers arytenoid	Vagus nerve (CN X)
	Lateral cricoarytenoid	Vagus nerve (CN X)
Upper esophagus	Cricopharyngeaus	Vagus nerve (CN X)
	Inferior fibers of the inferior pharyngeal constrictor	Vagus nerve (CN X)
	Upper fibers of the esophagus	Vagus nerve (CN X)

Fig. 1 Musculature and innervation in the oral and pharyngeal phase of swallowing. (Adapted from Shaw and Martino [16])

as well as chemoreceptors or taste receptors in the oropharynx [32]. Sensory information is sent to the trigeminal nerve (CN V), facial nerve (CN VII), glossopharyngeal nerve (IX), and vagus nerve (CN X) and then transferred to various nuclei in the brain stem [32, 33]. The swallowing central pattern generator is located within the medulla oblongata in the brain stem [32, 33] and contains two swallow-related neuron groups which are the dorsal swallowing group within and around the nucleus tractus solitarius and the ventral swallowing group around the nucleus ambiguus [3, 33, 34].

Peripheral as well as supra-medullary inputs travel to the dorsal swallowing group. The dorsal swallowing group sends the motor signals to the ventral swallowing group and transmits the outputs to motor neuron pools [33, 34]. Studies with functional magnetic resonance imaging indicate multiple bilateral subcortical as well as cortical areas are activated during swallowing [35, 36]. The areas that are consistently active during swallowing include the primary sensory cortex, primary motor cortex, anterior cingulate cortex, and insular cortex [35, 36]. However, further studies are needed to clarify the supratentorial neural mechanisms of swallowing.

4 What Is Dysphagia?

4.1 Dysphagia Definition

Swallowing difficulty is called dysphagia. Dysphagia is characterized by any difficulty moving food, liquid, secretions, or medications from the mouth to the stomach [12, 37]. Dysphagia may result from any illnesses that cause neurological, anatomical, or physiological abnormalities or dysfunctions of swallow-related structures such as the oral cavity, larynx, pharynx, and esophagus [12, 38].

4.2 Prevalence of Dysphagia

The exact prevalence of dysphagia is unknown given that it varies widely in the literature [38]. This variability could be in part due to differences in the swallowing measures and definitions of dysphagia [39]. Additionally, the prevalence of dysphagia varies depending on the type and severity of the diseases that are causing dysphagia (e.g., dementia type and head and neck cancer stage and site) as well as treatment modalities for the diseases [39].

4.3 Signs and Symptoms of Dysphagia

Signs and symptoms of dysphagia include coughing, nasal regurgitation, choking of food, clearing throat, sensation of food sticking in the throat and/or chest, recurrent pneumonia, unexplained weight loss, and gurgly or wet voice [1, 14, 40, 41]. Patients with dysphagia may or may not self-report swallowing difficulties.

4.4 Types of Swallowing Impairments

Characteristics of swallowing impairments vary among patients. However, there are some typical swallowing impairment types that a patient may exhibit in each swallow phase [32].

4.4.1 Oral Phase Impairments

Weakness or dysfunction of the tongue, lips, and other muscles in the oral cavity and/or loss of or reduced oral sensation may result in swallowing impairments during the oral phase of swallowing. These impairments include reduced lip closure, absent or prolonged oral preparation, reduced tongue control, incomplete tongue-palate contact, difficulty chewing, reduced taste, and swallow apraxia [1, 14, 32]. Reduced lip closure may result in drooping or food falling from the oral cavity anteriorly [1, 42]. Reduced tongue control may result in premature loss of the bolus into the pharynx [41, 43].

4.4.2 Pharyngeal Phase Impairments

Swallowing impairments during the pharyngeal phase include delayed triggering of the pharyngeal swallow, absence of the pharyngeal response, reduced laryngeal closure, epiglottic dysfunction, reduced tongue base and posterior pharyngeal wall contact, reduced velopharyngeal closure, and reduced laryngopharyngeal sensation [12, 15, 32, 40, 41, 44]. Reduced velopharyngeal closure may result in nasal regurgitation. Delayed triggering of the pharyngeal swallow may result in penetration (entry of liquid or food into the airway above the true vocal folds) or aspiration (entry of liquid or food into the airway below the true vocal folds) *prior* to initiation of the pharyngeal phase of the swallow and associated airway closure [44]. Reduced laryngeal closure, hyolaryngeal excursion, and laryngopharyngeal sensation may lead to aspiration/penetration *during* or *at the height of* the pharyngeal phase of the swallow [32]. Reduced hyolaryngeal excursion and tongue base and posterior pharyngeal wall contact may result in pharyngeal residue (liquid or food left in the oropharynx after swallowing) that leads to penetration/aspiration *after* conclusion of the pharyngeal phase [41].

4.4.3 Esophageal Phase Impairments

Swallowing impairment during the esophageal phase will occur if patients have reduced upper esophageal sphincter (UES) opening, reduced duration of UES opening, and/or impaired esophageal peristalsis which may result in intraesophageal stasis and pharyngoesophageal reflux [1, 14, 32]. Zenker's diverticulum is an

outpouching of mucosa at the level of UES [45, 46]. During swallowing, the diverticulum is filled with liquid or food, and then it is emptied after the swallow. The material in the diverticulum may enter the airway and cause aspiration *during* or *after* the swallow [46, 47]. Esophageal stricture is an abnormal narrowing of the esophagus that can be caused through neoplasm, fibrosis, or inflammation [48–50].

5 Risk Factors for Dysphagia

5.1 Risk Factors for Dysphagia in Older Adults

Older adults commonly experience normal age-related changes to swallowing anatomy and biomechanics, also known as "presbyphagia," that increase their susceptibility to dysphagia—increased time to initiate a swallow, reduced volume of the pharynx, reduced salivary secretion, and increasing rates of dental problems [51–62]. These changes are not considered pathological as many older adults are able to swallow safely, suggesting that functional reserve may allow older adults to compensate for age-related swallowing changes [63]. However, age has been identified as an independent risk factor for dysphagia in several studies including studies of community-dwelling older adults [64], as well as those in the hospital [65] or living in long-term care settings [66]. Age, therefore, is clearly an important factor related to dysphagia, and this may be due in part to the age-associated increase in the incidence of conditions and diseases that are known to be significant risk factors for developing dysphagia.

It is well-established that dysphagia is a symptom of many dysfunctions and disorders, including, but not limited to, stroke, Parkinson's disease, dementia, head and neck cancer, and brain injury [39]. Moreover, because the oropharynx is a shared pathway that supports ventilation as well as nutrition and hydration, diseases that impact the ventilatory system may also impact the process of deglutition. As such, dysphagia is a documented symptom of chronic respiratory diseases such as obstructive sleep apnea and chronic obstructive pulmonary disease [67, 68]. It is also commonly associated with laryngeal injury or deconditioning that may occur following endotracheal intubation and mechanical ventilation [69] and with the development of respiratory complications such as aspiration pneumonia that can further exacerbate existing respiratory disease [70].

Eating and swallowing requires an individual to address the meal, visually recognize food and drink, and respond with the appropriate motor movements that results in transportation of food and fluid to the mouth and then from the mouth to the stomach [37, 71, 72]. Given the important role that cognition plays in the process of eating and swallowing, it is not surprising that impaired cognitive function has been found to be a risk factor for dysphagia. Leder and group conducted a study with hospitalized participants and found that not being oriented to person, place, or time or being unable to follow single-step commands was associated with increased risk of aspiration [73]. Jo and group (2017) used a retrospective analysis of

hospitalized patients and identified that cognitive status was an important predictor of dysphagia after a first-time stroke [74].

Furthermore, in a study of long-term care residents aged 60 years and older, Yatabe and colleagues (2018) identified that edentulous residents with higher Mini-Mental State Examination scores tended to have lower odds of dysphagia risk [75].

While the prevalence of dysphagia tends to increase with advancing age [65, 76], increased risk of adverse health outcomes, including dysphagia, may not necessarily be a consequence of aging. Some older adults are at greater risk of experiencing poor health outcomes compared with similar aged peers [77]. In a systematic review conducted by Madhavan and colleagues (2016), the authors identified significant risk factors for dysphagia, one of which was physical frailty [64]. Frailty, a condition marked by cumulative decline across several physiological systems [78], is generally measured in two different ways: as a specific physical syndrome [79] and as a deficit accumulation [80]. Evidence examining the relationship between dysphagia and physical frailty and frailty as deficit accumulation suggests that the two conditions may frequently co-occur [81–85], resulting in negative health outcomes [85]. The relationship between physical frailty and dysphagia may be driven by sarcopenia, or age-associated decreased muscle mass and function of the tongue [86]. The tongue plays a critical role in preparing the bolus to be swallowed and moving the bolus through the oral cavity and pharynx and into the esophagus [87]. Reduced tongue strength has been found to be an independent predictor of sarcopenic dysphagia in older hospitalized patients [88], it has been associated with aspiration in healthy, community-dwelling older adults [86], and with increased dysphagia risk and mealtime duration for individuals living in long-term care [89, 90]. Furthermore, a meta-analysis conducted by Zhao and colleagues (2018) revealed that individuals with sarcopenia are four times more likely to develop dysphagia [91]. Individuals with frailty due to their reduced functional reserve may no longer be able to compensate for age-related swallowing changes and may experience an acute, but potentially transient, reduction of swallowing safety and/or efficiency [92]. Even a transient dysphagia in these individuals has the potential for the negative sequelae associated with dysphagia to add to the burden of disease and worsen any existing frailty. It is critical to identify dysphagia and manage it appropriately to reduce these negative outcomes as well as others, including higher total costs, increased non-routine discharges (discharge to a short-term hospital, long-term care facility, or home health), more medical complications, and increased risk of inhospital mortality [85]. For a more in-depth discussion on the topic of frailty, please refer to the chapter "Frailty and Oral Health."

5.2 Poor Oral Health as a Risk Factor for Dysphagia

Due to the complexity and the multifactorial nature of oral health, the relationship between dysphagia and oral health has been hypothesized and explored in different ways. For example, the concepts of salivary [93–95] and oral function [96, 97],

presence or absence of teeth [98], and oral hygiene [99] in relation to dysphagia have been discussed previously in the literature.

The oral cavity is the beginning of the digestive tract and contains numerous structures that function to deliver food and drink to the pharynx, including the teeth, orofacial muscles, lips, cheeks, and tongue. Missing teeth can decrease one's ability to masticate or chew [100], and tooth loss is also significantly associated with impaired water and saliva swallowing [98, 101].

Sarcopenia of the muscles of mastication may result in reduced bite force and jaw velocity and prolonged mastication duration, especially when eating tough foods such as meat. This may negatively impact nutritional status [53]. Dentures and tongue motor function have also been found to impact masticatory efficiency [102], which suggests that as tongue motor function declines with age, denture stability and retention may be compromised.

Other types of oral impairment have been identified as risk factors for dysphagia. Community-dwelling older adults may be two times more likely to self-report dysphagia if they have impaired oral function measured using a speech diadochokinesis task or the ability to repeat the /pa/ syllable as quickly as possible [97]. Reduced ability to complete diadochokinesis with the /pa/ syllable may be due to reduced lip force, which is associated with sarcopenic dysphagia in older hospitalized patients and may contribute to the downward turn of the lips and pooling of liquid at the labial commissures [88]. Impaired oral function may also impact functional oral intake.

Furuya and colleagues (2019) examined oral function in hospitalized patients with dysphagia and found that functional oral intake was significantly associated with level of consciousness, ability to independently complete activities of daily living, tongue coating, and posterior occlusal support [96]. Impaired oral hygiene has also been identified as a risk for dysphagia. Hida and colleagues (2021) examined oral cavity flora in community-dwelling older adults and identified that participants with colony-forming units of anaerobic *Prevotella* spp. were three times more likely to fail a water swallowing screening test [99].

5.3 Dysphagia as Risk Factor for Poor Oral Health

Older patients with dysphagia demonstrate poorer oral health than those without dysphagia. A study of 50 older patients with dysphagia revealed that this cohort had a higher prevalence of full edentulism, dental caries, gingivitis, and periodontitis compared to 15 older patients without dysphagia [103]. This same research group also conducted a study of 47 older patients with frailty (>70 years of age) in which they enrolled four groups: 17 patients with dysphagia and an acute episode of pneumonia, 14 patients with dysphagia and a history of pneumonia, 14 patients with dysphagia and no history of pneumonia, and 14 control participants without dysphagia [104]. Results showed that oral health was poor in all three groups (90% with periodontitis, 72% with caries). Total bacterial load was similar in all three

groups. However, colonization of respiratory pathogens was significantly higher in the two groups of patients with dysphagia (93% in both groups) compared to the non-dysphagic control group (67%).

These findings highlight the ways in which swallowing function and various aspects of oral health may interact and influence one another. Regular and efficient swallowing supports a healthy microbiome by clearing food debris, detached cells, and microbial waste products. Saliva prevents dysbiosis through its antimicrobial components, pH buffering, and continuous refreshing. Salivary mucins induce bacterial aggregation preventing bacteria from attaching to the oral epithelial cell surface and promoting removal upon swallowing. Impaired swallowing biomechanics that result in more frequent and larger volume aspiration events in combination with a dysbiotic oral environment increase the risk of adverse health outcomes. In fact, a recent study revealed that, while poor oral health and dysphagia were both independently associated with mortality risk, those patients with both showed the highest mortality risk (2.6 times higher than those without either impairment) [105].

6 Consequences of Dysphagia

6.1 Pneumonia

Pneumonia is considered a major cause of morbidity and mortality globally for older adults and has been estimated to cause up to 1.1 million in-hospital deaths [106] and significant financial costs [107, 108] to patients and healthcare systems. Aspiration pneumonia is the third and fifth leading cause of infectious death in individuals aged >85 years and >65 years, respectively [109]. Bacterial pneumonia has been classified into several different types, and the categorization reflects differences in how the pneumonia was contracted and the pathogens responsible for the pneumonia [110–116] (Table 1).

6.2 Aspiration Pneumonia

Aspiration pneumonia is a lung infection that is acquired when bacteria-laden foreign materials, such as food/liquid, secretions, or regurgitated contents of the stomach or esophagus, enter the lungs, resulting in bacterial colonization [117]. In a meta-analysis conducted by van der Maarel-Wierink and colleagues, they found a positive correlation between dysphagia and aspiration pneumonia, which supports the common belief that dysphagia with aspiration is the essential predisposing element for the development of aspiration pneumonia [118]. However, Langmore and colleagues (1998) were the first to draw a connection between the condition of the oral cavity and the occurrence of aspiration pneumonia [119]. While dysphagia was

Table 1 Types of pneumonia

Pneumonia type	Description	Pathogen
Community-acquired pneumonia	Any pneumonia contracted outside the hospital	*Haemophilus influenzae*, *Streptococcus pneumoniae*
Hospital-acquired pneumonia—nosocomial	Any pneumonia contracted by a patient in a hospital at least 48–72 hours after being admitted	*Staphylococcus aureus*
Hospital-acquired pneumonia—ventilator acquired	Any pneumonia contracted while on mechanical ventilation	*Pseudomonas aeruginosa*, *Staphylococcus aureus*
Healthcare-associated pneumonia	Any pneumonia contracted prior to hospital admission in patients with specific risk factors such as residing in long-term care, being immunocompromised, etc.	*Staphylococcus aureus*
Aspiration pneumonia	Any pneumonia contracted after bacteria-laden foreign materials, such as food/liquid, secretions, or regurgitated contents of the stomach or esophagus, enter the lungs, resulting in bacterial colonization	*Streptococcus pneumoniae*, *Staphylococcus aureus*, *Haemophilus influenzae*, and *Enterobacteriaceae* [117]

determined to be an important risk for aspiration pneumonia, it was not sufficient to cause pneumonia unless other risk factors were present. In that study, dependence for oral care and the number of decayed teeth were among the strongest predictors for pneumonia [120–122]. It is now accepted that there is a strong relationship between poor oral health and respiratory disease [123].

6.3 Malnutrition and Dehydration

Dysphagia is a risk factor for malnutrition in older adults [124–126]. A large secondary cross-sectional analysis of over 17,000 patients during hospitalization and in the nursing home setting revealed that those with dysphagia were at two times higher risk of malnutrition than those without dysphagia in the sample [127]. In one study examining patients with dysphagia (without tube feeding instigated), daily unsupported oral intake was found to be as low as 275 kcal (14.5% of estimated energy requirements) [128]. Protein-energy malnutrition (PEM) is a serious medical condition in which a person is not adequately receiving the correct amounts of protein/energy needed to sustain metabolic functions [129]. Individuals with dysphagia, especially those of advanced age, are at an increased risk for PEM and may experience a synergistic interaction between this nutritional vulnerability and reduced immune function that increases the chance for serious illness, including pneumonia onset [130]. The individual effects of poor oral health and dysphagia on food selection and nutrient intake may combine to exacerbate risk of malnutrition [131].

Similarly, individuals with dysphagia are at higher risk for dehydration. Patients with post-stroke dysphagia and modification of solid diets or on thickened liquids are significantly more likely to be dehydrated at discharge [132]. While thickened fluids and diet modification are often necessary for appropriate management of dysphagia, studies have shown that patients taking thickened liquids demonstrate decreased acceptance of the beverages [133]. One study of a group of patients post-stroke with comorbid dysphagia revealed that the intake of thickened fluids per day led to only 30% of the recommended 1500 mL/day [134].

6.4 Asphyxiation Risk

Asphyxiations of semisolid and solid foods are the cause of many deaths among older adults [135–137]. During 2007–2010 in the USA, 2214 deaths among persons aged >/= 65 years were attributed to choking on food [136]. These deaths were most associated with dementia (including Alzheimer's disease, Parkinson's disease, and pneumonitis) [136, 138]. Asphyxiation deaths can occur in all settings—hospital, nursing homes, at home, and in restaurants [139]. A maximum food sample size of 1.5 × 1.5 cm for hard and soft solid foods has been recommended by the International Dysphagia Diet Standardization Initiative (IDDSI) framework [140]. This particle size is small enough to pass completely into an adult trachea without obstructing it and has been shown to reduce the risk of asphyxiation [141, 142]. Issues related to inadequate oral health affecting masticatory efficiency, such as edentulism or low salivation, can increase the risk of asphyxiation due to poor bolus processing or breakdown to this necessary particle size [143].

6.5 Quality of Life for Oral Health and Swallowing

The ability to eat and swallow is critically important to maintaining the oral health-related quality of life of older adults. In a study conducted by Miura and colleagues (2010), they surveyed older adults and caregiver dyads and found that the most influential factors that impacted oral health-related quality of life (OHrQoL) were communication and dysphagia [144]. Dysphagia impacts OHrQoL in persons with neurodegenerative disease. In a study examining persons with Parkinson's disease, Barbe and colleagues (2016) found that many participants experienced xerostomia (49%), drooling (70%), and dysphagia (47%), and these symptoms significantly impacted oral health-related quality of life [145]. Dysphagia has also been found to mediate OHrQoL. Lu and group (2020) conducted a cross-sectional study of community-dwelling participants aged 65 years or older. They collected data on depression, dental status, oral dryness, masticatory performance, swallowing, physical function, and oral health-related quality of life and found that

perceived oral dryness had the strongest direct negative effect on OHrQoL. Dysphagia and masticatory performance strongly mediated the effect of xerostomia on OHrQoL [146].

7 Evaluation of Swallowing

There are two main swallowing evaluations: clinical evaluation and instrumental evaluation [40]. Instrumental evaluation includes videofluoroscopic examination of swallow (VFSS) and fiberoptic endoscopic evaluation of swallowing (FESS) [40, 147].

7.1 Clinical Evaluation

The purpose of the clinical evaluation is to identify whether (1) patients are at a high risk of dysphagia and (2) referral for further instrumental swallowing evaluations [148]. There is no current standard protocol for the clinical evaluation. Typically, speech-language pathologists first conduct a thorough review of the patient's medical history from the medical chart. During the process, current and past medical issues that may cause dysphagia, current and past medications that may cause dysphagia and xerostomia (dry mouth), respiratory status including recent pneumonia episodes, history of intubation, mechanical ventilation and tracheostomy tube, cognitive functions, conscious level, and nutrition status are reviewed [1, 14, 40]. After the review, physical examination is conducted. Physical examination includes the oral anatomy examination, oral motor control examination, and oral sensitivity examination. During the oral anatomy examination, any abnormality of the lips, jaw, tongue, soft and hard palates, uvula, oral cavity, and neck is identified [1, 41, 149]. Dental and secretion status also is examined. For the oral motor examination, range, accuracy, and rate of the movement of the lips, jaw, tongue, and soft palate as well as laryngeal function (vocal quality) are assessed [1, 41, 150]. Muscular control of the head and trunk also is examined. The oral sensitivity examination includes the assessment of light touch of the face, lips, tongue, and palate to identify whether there are any areas with reduced sensitivity [1, 41, 150]. After completing the physical examination, the patient's swallowing function is evaluated. First, swallowing of saliva is observed. Then, liquid and/or food of various volumes and consistencies is administered to observe the swallowing functions including oral control of the bolus, elevations of the larynx, vocal quality after the swallow, and presence of coughing and choking during and after a swallow [1, 14, 40, 41]. When any signs and symptoms of dysphagia and/or any abnormality that may cause dysphagia are identified during the clinical evaluation, a referral for an in-depth comprehensive instrumental swallowing evaluation is made [1].

7.2 Screening Tests

There are several validated swallowing screening tests available to clinicians. Swallowing screening provides quick determination of (1) the likelihood of a patient having dysphagia; (2) need for referral for further swallowing evaluation; (3) safety of oral feeding for the purpose of nutrition, hydration, and medication; and (4) needs for referral to nutritional support and/or other medical services [151]. Swallowing screening protocols for adult patients include patient-reported outcome measures, water swallow tests, and solid food tests [152].

7.2.1 Patient-Reported Outcome Measures

Patient-reported outcomes are self-administered questionnaire-based screening tools. Some examples are the Eating Assessment Tool-10 (EAT-10) [153], the Sydney Swallowing Questionnaire (SSQ) [154], and the Dysphagia Handicap Index (DHI) [155]. The questionnaire-based patient-reported outcomes rely on patient's recall and cognitive ability. However, it is important to note that patients often underreport their dysphagia symptoms [152].

7.2.2 Water Swallow Tests

The water swallow test involves presentation of liquid boluses [152]. Water swallow test protocols include the Toronto Bedside Swallowing Screening Test (TOR-BSST) [156, 157], 3-Ounce Water Swallow Test [158, 159], Yale Swallow Screening Test [160], Barnes-Jewish Hospital Stroke Dysphagia Screen [161, 162], Gugging Swallowing Screen (GUSS) [161, 162], and Volume-Viscosity Test [163–166]. Most water swallow tests are pass/fail. The patient is asked to swallow liquid during the test. The volume administered for a water test varies depending on the protocol. Signs of dysphagia such as coughing, choking, clearing throat, voice quality change, breathlessness, and drooling and/or inability to complete the test indicate that a referral for instrumental swallowing evaluation is required.

7.2.3 Solid Food Test

A solid food test involves presentation of solid food. The Test of Masticating and Swallowing Solids (TOMASS) was developed to assess swallowing efficiency of solid food [167]. The TOMASS is composed of two short questionnaires regarding dental condition and mouth dryness and a solid swallowing test. The patient is asked to eat a commercially available cracker during the test.

7.3 Instrumental Swallow Evaluations

The goals for a comprehensive instrumental swallow evaluation are (1) to identify abnormalities in swallow anatomy and physiology that are causing swallowing difficulties and (2) to determine best swallow treatment strategies [1, 147]. Both videofluoroscopic examination of swallow (VFSS) and fiberoptic endoscopic evaluation of swallowing (FESS) are considered diagnostic standard assessment methods for evaluation of swallowing [147].

7.3.1 Videofluoroscopic Examination of Swallow (VFSS)

The videofluoroscopic examination of swallow (VFSS), also called the modified barium swallow study (MBSS) or videofluoroscopic swallowing study (VFS), is a dynamic radiographic procedure that can provide real time visualization of all phases of swallowing [1, 168, 169]. During VFSS, patients are asked to swallow barium of various volumes and viscosities, and the oropharyngeal region is radiographically visualized [32, 40]. While standard VFSS protocols have been proposed in the literature, heterogeneity may be observed among clinicians and facilities. The VFSS enables clinicians to examine bolus flow throughout all the phases of swallowing [1, 169]. It also allows clinicians to assess swallowing biomechanical functions that cause abnormal bolus flow and detect the presence, timing, and severity of aspiration and penetration [1]. VFSS does involve radiation exposure [168, 170]; however, the amount is minimal during the procedure [168, 170, 171]. Bedridden patients who cannot be transported to a fluoroscopy suite and are unable to maintain a seated position are ineligible for VFSS [172, 173].

There are standardized, validated tools for interpretation of swallowing function and outcomes on VFSS imaging. The severity of penetration and aspiration is quantifiable on VFSS by using the penetration-aspiration scale [174]. Also, the amount of residue is quantifiable using pixel-based measurements [175]. The Dynamic Imaging Grade of Swallowing Toxicity (DIGEST) is a validated scale that provides an overall rating of the function of the pharyngeal phase of swallowing [176]. The DIGEST first measures the swallowing safety (penetration and aspiration) and swallowing efficiency (estimation of the pharyngeal residue amount) through VFSS. Then, a single summary grade for the pharyngeal swallowing function is provided based on the swallowing safety and efficiency results [176, 177]. The Modified Barium Swallow Impairment Profile (MBSImP®) has 17 physiologic components to assess swallow physiology across the oral, pharyngeal, and esophageal phases [42].

7.3.2 Fiberoptic Endoscopic Evaluation of Swallowing (FEES)

Fiberoptic endoscopic evaluation of swallowing (FEES) involves insertion of a fiberoptic endoscope through the patient's nose into the oropharynx to obtain superior visual images of the larynx and hypopharynx, including the vocal folds [147]. FEES is

portable and can be performed at bedside [172, 173, 178]. During a FEES examination, anatomical and physiological assessments of swallowing-related structural movements with liquid and solid boluses are conducted. Then, compensatory swallowing interventions (e.g., bolus modifications, postural changes, and behavioral changes) may be tested [172, 173, 178]. FEES does not involve radiation exposure [172]. FEES has higher sensitivity for detecting aspiration, penetration, and residue than VFSS [178]. However, FEES does not provide images of the oral cavity since an endoscope is placed transnasally [172]. Additionally, FEES does not visualize any swallow events that occur during the "white-out" period, when the pharynx collapses after the pharyngeal swallow is triggered [172]. Therefore, conclusions regarding swallowing impairment are based on the aspects of the swallow visualized before and after this period.

8 Prevention of Pneumonia

8.1 Daily Mouth Care for Individuals Intubated or with Dysphagia to Prevent Pneumonia

Daily mouth care for those who are experiencing impaired swallowing function is imperative to maintain oral health and OHrQoL [179, 180] and to reduce the risk of aspiration pneumonia [181]. The risk of aspiration pneumonia is reduced by minimizing bacterial colonization in the oral cavity and, in turn, minimizing bacteria in orogastric secretions. Bacterial colonization can occur on the teeth, tongue, fixed and removable prosthesis, and gingival and mucosal tissues. During intubation and mechanical ventilation, the endotracheal or tracheostomy tube is an additional structure for bacterial colonization [182, 183]. The following are daily mouth care considerations for individuals intubated or experiencing dysphagia post-extubation or for other reasons.

8.2 Daily Mouth Care Plans

Daily mouth care should be individualized and based on an oral health assessment [184]. Evidence suggests that following a step-by-step daily mouth care plan can reduce ventilator- associated or non-ventilator hospital-acquired pneumonia [185]. The following is an example of daily mouth care plan (Fig. 2).

8.3 Chlorhexidine

While once a standard of care, routine use of chlorhexidine gluconate in the oral cavity of mechanically ventilated patients has more recently come into question. Findings of a meta-analysis conclude that cardiac surgery patients whose oral care

Example

Oral Health Care Plan

Oral Health Assessment (OHA) Date: _____ (OHA) Review Date: _____

Oral Health Care Considerations

Problems: ☐ difficulty swallowing ☐ difficulty moving head ☐ difficulty opening mouth ☐ fear of being touched

Interventions: ☐ briding ☐ chaining ☐ hand over hand ☐ distraction (activity board/toy) ☐ rescue

☐ other _____

Daiy Activities of Oral Hygiene

	Morning	After Lunch	Night
Natural Teeth ☐ Yes ☐ No Cleaned by: ☐ Self ☐ Supervise ☐ i (Assist) Replace toothbrush (3 monthly) Date:	☐ clean teeth, gums, tongue	☐ rinse mouth with water ☐ antibacterial product (teeth & gums)	☐ clean teeth, gums, tongue
Denture ☐ Full ☐ Partial ☐ Upper ☐ Lower Inserted / removed by: ☐ Self ☐ Staff Cleaned by: ☐ Self ☐ Supervise ☐ Assist	☐ dean teeth, gums, tongue ☐ brush denture	☐ rinse mouth with water ☐ rinse denture ☐ antibacterial product (gums)	☐ clean teeth, gums, tongue ☐ brush denture with mild soap ☐ Leave dentures out overnight ☐ soak denture in cold water Disinfect dentures (weekly) Specify day:

Oral Hygiene Aids

☐ soft toothbrush ☐ modified toothbrush ☐ toothbrush grip ☐ denture brush ☐ spray bottle (labelled)

Oral Hygiene Care Products

☐ mild soap (denture) _____ ☐ antibacterial product _____ ☐ saliva substitute _____

☐ lip moisturiser _____ ☐ high fluoride (5000 ppm) toothpaste _____

Additional Oral Care Instruction

☐ antifungal gel _____ ☐ denture adhesive _____

☐ interproximal brush ☐ tongue scraper ☐ normal saline mouth toilet

Comments _____

Check daily, document and report to RN if:

- bad breath
- bleeding gums
- lip blisters/sores/cracks
- tongue for any coating/change in colour
- sore mouth or gums
- mouth ulcer
- swelling of face/mouth
- broken / lost denture
- difficulty eating
- refusal of oral care
- denture not named
- excessive food left in mouth
- broken teeth

Signed RN: _____ Date: _____

18 | Oral Health Care Plan

Fig. 2 Example of an oral care plan. (Lewis and Fricker [221])

regime included chlorhexidine had significantly fewer respiratory tract infections, when compared with a placebo (95% CI, [0.41–0.77]). However, there was no significant difference in ventilator-associated pneumonia among non-cardiac surgical patients, with or without the use of chlorhexidine.

Furthermore, there is evidence to suggest that chlorhexidine does not reduce the risk of ventilator-associated pneumonia, regardless of concentration (0.12–2%) or preparation (liquid versus gel) [186]. In addition, chlorhexidine appears to be associated with increased mortality rate [186–188].

8.4 Suctioning

8.4.1 Oral Suctioning

Continuous suctioning of oral secretions during mechanical ventilation may reduce the risk of ventilator-associated pneumonia, duration of mechanical ventilation, and length of intensive care unit (ICU) admission, though research is limited. A pilot randomized controlled trial (RCT) study compared continuous suctioning using a saliva ejector with 100 mmHG of suction to routine care that did not include continuous suctioning. The saliva ejector was placed adjacent to the buccal mucosa. Statistically significant differences were found between the experimental group, who received continuous suctioning, and control groups in the rate of ventilator-associated pneumonia (3 (23.1%) vs 10 (83.3%), $p = 0.003$); number of days of mechanical ventilation (3.2 (SD 1.3) vs 5.9 (SD 2.8), $p = 0.009$); and number of days of ICU stay (4.8 (SD 1.6) vs 9.8 (SD 6.3), $p = 0.019$) [189].

8.4.2 Deep Suctioning

Deep suctioning of oropharyngeal secretions beyond the oral cavity is also recommended. Sole et al. (2011) used a repeated measures, single-group design to explore the frequency of deep suctioning among orally intubated adults. A 21-cm-deep suctioning catheter was used, and the patient's backrest was elevated to 30°. The catheter was inserted to the depth required to retrieve the secretions. Deep suctioning was required every 2–4 hours, depending on the volume of secretions. The group receiving deep suctioning had significantly shorter hospital length of stay [190]; however, more research is needed to explore the impact of deep suctioning on prevention of aspiration pneumonia.

8.4.3 Suction Toothbrushing

Evidence surrounding suction toothbrushes is also limited. The impact of a suction toothbrush as compared to a manual toothbrush on the incidence of aspiration pneumonia among dependent adults with dysphagia living in long-term care (LTC)

has been explored in a pilot RCT. At the beginning of the study, participants received professional debridement, and the caregivers received training on daily mouth care. While statistically significant improvements in oral health were observed for all study participants between baseline and 1 month and the incidence of pneumonia for all study participants was significantly less compared to the general population within the LTC facility, no between-group differences were identified [191].

8.5 Toothbrushing

The best positioning for toothbrushing is sitting upright with the chin tucked downward and backward toward the chest. This helps to prevent aspiration and closure of the airway during swallowing. In the case of a stroke, the head should also be tilted toward the paralyzed side. If the person is unable to sit upright, toothbrushing can be performed with the person laying on their weaker side to allow for the oral secretions to flow out of the mouth. Suction, manual, or an electric toothbrush can be used, preferably with a small head and soft bristles [192–194].

8.6 Toothpaste

If a person is unable to expectorate voluntarily, a small pea-sized amount of fluoridated, nonfoaming (sodium lauryl sulfate-free [SLS]) toothpaste is recommended. After brushing, the remaining debris and excess moisture should be removed using a suction device or a moist thin face cloth or gauze to finger sweep in the buccal vestibule and the floor of the mouth. Rinsing the oral cavity after brushing is not recommended because the minimal amount of fluoridated toothpaste remaining is beneficial for caries prevention [192, 194].

8.7 Sample Protocol for Mechanically Ventilated Critically Ill Patients

A combination of oral hydration, lip moisturization, and toothbrushing is recommended for mechanically ventilated critically ill patients [195]. A non-petroleum, water-soluble lip moisturizer is preferred [193]. The proposed protocol for comprehensive oral care for mechanically ventilated critically ill patients is currently under investigation [196] (Table 2).

Table 2 Oral care bundle for mechanically ventilated critically ill patients

Comprehensive oral care Q12 hours	Equipment	Procedure
1. Oral assessment	• Flashlight • Tongue depressor • Gloves • Face shield	• Explain procedure to patient • Gently open mouth or use mouth prop • Inquire about mouth/throat pain (0–10 NRS) • Use CPOT tool to evaluate pain in non-verbal pt. • Treat pain prior to proceeding
2. Tooth brushing	• Yankauer • 12 or 14 French flexible catheter • Small soft-bristle or suction toothbrush • Sponge swabs • Sterile water • Gloves • Face shield	• Explain procedure to patient • Perform hand hygiene • Elevate HUB 30–45° as tolerated • Use oral prop to open mouth as needed • Oral suction with Yankauer or sterile flexible catheter to remove secretions that may migrate down airway • Moisten toothbrush with sterile water • Connect suction toothbrush to continuous suction if applicable • Brush accessible teeth and gums for 2 full minutes or 30 seconds per quadrant; brush in one continuous line LUQ > RUQ > RLQ > LLQ • Gently brush tongue
3. Mouth and lip moisturizer	• Swabs • Mouth moisturizer/ saliva replacement or sterile water • Gloves • Face shield	• Explain procedure to patient • Use oral prop to open mouth as needed • Use 1–3 swabs to apply moisturizer to oral mucosa, tongue, and lips
4. Deep oral suctioning	• Yankauer or flexible catheter • Gloves • Face shield	• Explain procedure to patient • Use oral prop to open mouth as needed • Deep oropharyngeal suction (above the cuff) to remove pooled secretions
Maintenance oral care Q4 hours and PR	Equipment	Procedure
Mouth and lip moisturizer	• As above	• As above
Oral secretion removal	• As above	• As above

Dale et al. [196]

9 Prevention and Treatment of Dysphagia

9.1 Prevention and Treatment of Dysphagia in Older Adults

Dysphagia management approaches can be combined with oral care regimens to reduce the risk of pneumonia in older adults. Treatment for dysphagia can include surgical, pharmacologic, and behavioral interventions. Surgical interventions

can be used to address a mechanical obstruction that is impeding bolus flow through the oral cavity or pharynx, such as tumor resection for patients with head and neck cancer or dilation for an esophageal stricture. Pharmacologic interventions may include medications to address the underlying medical condition that led to dysphagia (e.g., levodopa for Parkinson's disease) or a reduction or change in the dose of certain medications that can contribute to dysphagia (e.g., antipsychotics) in older patients, especially for those experiencing polypharmacy. Behavioral interventions for dysphagia are most commonly designed and implemented by speech-language pathologists (SLPs) who are typically the medical providers managing dysphagia. These SLP-led interventions can include compensatory approaches, eating and swallowing strategies, and rehabilitative interventions.

9.2 Compensatory Approaches to Dysphagia Management

These types of approaches to dysphagia management include dietary modifications, postural adjustments, and swallowing maneuvers that attempt to *bypass* or *compensate for* pathophysiologic changes in swallowing function. Dietary modifications may involve increasing the thickness of liquid or pureeing solid foods. The IDDSI framework has provided standardized definitions and clinically practical measurement approaches for the various dietary levels often prescribed to patients with dysphagia [140]. Thickened liquids are efficacious in reducing the incidence of airway invasion in certain groups of patients (post-stroke or with dementia) [197]; however, more research is needed in other patient populations, such as those with dysphagia following oncologic treatment for head and neck cancer [198]. However, studies have also suggested adverse outcomes of thickened liquid intake, including reduced fluid intake leading to dehydration [199]. Additionally, patients are often not adherent to this recommendation given the decreased palatability and thirst-quenching characteristics of thickened fluids. Modification to solid foods can assist with mastication, especially in older patients with missing dentition, and can also reduce the risk of asphyxiation.

Postural adjustments include a chin-down or chin-tuck posture, a head turn posture, or a head tilt posture. The chin-down posture has been shown to result in positioning of the base of the tongue closer to the posterior pharyngeal wall and to narrow the airway entrance [200]. The head turn posture is often recommended to patients with unilateral pharyngeal weakness in order to direct the flow of the bolus down the stronger side of the pharynx [201]. These two postures may be combined to improve clearance of the bolus through the pharynx [202].

Swallowing maneuvers also are often recommended as another way to compensate for impairments in swallowing physiology by altering the timing of select neuromuscular components of the pharyngeal phase [203]. These maneuvers include the effortful swallow, super supraglottic swallow, and Mendelsohn maneuver [203–206].

While these various compensatory approaches to dysphagia treatment can positively alter swallowing biomechanics, this must be evaluated and confirmed during an instrumental assessment for swallowing. The decision of which approach is most appropriate should be made by the SLP performing the assessment and will be based on the patient's specific swallowing impairments.

9.3 Rehabilitative Interventions for Dysphagia

In contrast to compensatory approaches to dysphagia treatment, rehabilitative interventions are intended to result in lasting change in swallowing physiology and result in improved function and outcomes. Beyond use of the maneuvers described above for immediate compensation of deficits during the swallow, these can also be used as an exercise protocol to improve strength and coordination. Other exercise protocols target various swallowing-related musculature, including the tongue, floor of the mouth, and pharyngeal muscles. The Shaker exercise consists of three 1-minute head lifts in the supine position with a 1-minute rest between lifts followed by 30 consecutive repetitions of head raisings in the same position [207, 208]. This exercise is performed twice per week for 6 weeks with the goal of increasing laryngeal elevation and upper esophageal opening [209]. Exercise regimens focused on increasing the strength of the oral tongue have been implemented. With a systematic, progressive protocol [210], these approaches have shown positive impact on swallowing biomechanics in older adults as well as patients with dysphagia [211–214]. These approaches may be facilitated by devices, like the Iowa Oral Performance Instrument® or the Tongueometer®. Expiratory muscle strength training (EMST) targets systematic exercise to increase maximum expiratory pressures and has been shown to improve respiratory function as well as swallowing function in patients with dysphagia [215–218].

9.4 Proactive Versus Reactive Approaches to Dysphagia Care

Despite evidence to support the use of rehabilitative approaches, dysphagia treatment frequently consists primarily of reactive approaches that include the compensatory techniques described previously. Reactive approaches also rely on clinical presence of dysphagia diagnosed through either bedside or instrumental assessment. For many patient populations including older adults with frailty or those with neurodegenerative disease or head and neck cancer, there is a shift to focusing on more proactive approaches to dysphagia management that are based on the concept of building functional physiologic reserve in swallowing-related muscles prior to onset of dysphagia [219]. Functional reserve refers to an organ's ability to fulfill its physiological activity when under stress which is the difference between its maximum capacity and the minimum activity necessary to function [220]. By shifting to

more proactive approaches, rehabilitative interventions like those described previously can be implemented to build functional reserve in patients at risk for developing dysphagia [219]. Additionally, through earlier involvement in the patient's care trajectory, interprofessional management can include both SLPs and dental providers, thereby reducing risks associated with combined dysphagia and poor oral health. Even in light of a known dysphagia diagnosis, interventions like oral care protocols can optimize health and quality of life for patients living with swallowing difficulty.

10 Conclusions

Oral health and swallowing function are highly interrelated, and both are affected by the aging process as well as a variety of disease conditions. The presence of poor oral health along with dysphagia puts patients at increased risk for adverse health outcomes, including aspiration pneumonia. Interprofessional approaches to early evaluation and identification as well as proactive approaches to treatment that target both oral health and swallowing function will be most effective in positively impacting quality of life and overall health across vulnerable patient populations.

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Xerostomia and Hyposalivation

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Saliva has a critical role in the maintenance of oral health. Although 99% of salivary content is water, saliva also contains immunoglobulins, glycoproteins, electrolytes, digestive enzymes (amylase and lipase), antifungal and antibacterial enzymes, mucins, and leukocytes, among other components. When salivary secretion decreases, the oral cavity becomes dry increasing the risk of oral diseases such as caries, periodontal disease, candidiasis, oral ulcerations, and bacterial sialadenitis. It may also impair individuals' ability to speak, chew, and swallow [1–4]. Salivary secretion is regulated by the autonomic nervous system, especially parasympathetic fibers [3, 5]. It is important to differentiate between xerostomia and hyposalivation. Xerostomia is the subjective feeling of dry mouth, whereas hyposalivation is the objective reduction of salivary flow. In some cases, patients with xerostomia may also suffer from hyposalivation. Similarly, there are patients who present with hyposalivation but may not report dry mouth sensation [6].

Dry mouth is a frequent problem in geriatric patients. There is controversy about whether salivary flow decreases with age [4]. The prevalence of dry mouth increases considerably in older patients, ranging from 17% to 40% in community-dwelling older adults and from 20% to 72% in institutionalized older persons [2, 6]. In this chapter, we will review the etiological factors associated with xerostomia in this age group, as well as its associated oral changes. We will discuss the diagnostic workup for xerostomia and hyposalivation and how to perform individualized treatments for these patients.

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1 Causes of Salivary Hypofunction in the Older Patients

There are different causes of xerostomia and hyposalivation. In the following paragraphs, we will review the different causes of dry mouth in geriatric patients.

1.1 Age

It is not clear whether aging itself is associated with salivary gland dysfunction [3]. Studies have shown that acinar cells in salivary glands decrease with aging and are replaced by fatty and connective tissues. Research reveals that acinar cells decrease by 30–40% between 34 and 75 years of age. Despite these age-related changes, epidemiological studies do not show an independent negative effect of aging on salivary flow. Other factors, namely, medication use and certain medical conditions, may be more likely to cause salivary gland dysfunction [2, 3].

The research evidence on the effects of aging on salivary function is mixed. Widely diverse inclusion criteria, different methodologies in the collection of saliva, the way xerostomia was defined, concurrent use of medications, coexisting medical and psychological conditions, and participants from diverse care settings (institutionalized or non-institutionalized) are some of the reasons explaining these divergent results. Longitudinal studies show that the degree of xerostomia increases in a linear pattern in individuals ranging in age between 50 and 65 years. Other studies show that the incidence of xerostomia increases with age. However, there are other studies that do not show significant age-related changes [2].

1.2 Gender

Xerostomia is more common among women. One explanation is that salivary glands in women are usually smaller and, therefore, have a reduced salivary flow reserve. Another factor is that women often take more medications than men. Studies in older individuals show that female sex is a risk factor for hyposalivation after adjustment for age, health status, and use of medications [2].

1.3 Diseases

Different systemic disorders have been associated with salivary gland hypofunction leading to xerostomia or hyposalivation [7]. Table 1 shows a listing of common medical and psychological conditions associated with salivary gland dysfunction.

Table 1 Common medical and psychological conditions associated with salivary gland dysfunction

Rheumatological chronic inflammatory diseases	Sjögren's syndrome Systemic lupus erythematosus Rheumatoid arthritis Scleroderma Primary biliary cirrhosis Mixed connective tissue disease Juvenile idiopathic arthritis
Endocrine disorders	Diabetes mellitus Thyroid disorders Cushing's disease Addison's disease
Neurologic disorders	Parkinson's disease Alzheimer's disease Bell's palsy Stroke
Psychological diseases	Eating disorders (anorexia, bulimia) Depression Anxiety Stress
Salivary gland diseases	Agenesis of salivary glands Ectodermal dysplasia Sialolithiasis Sialadenitis
Genetic disorders	Prader-Willi syndrome Down syndrome Papillon-Lefèvre syndrome Familial amyloidotic polyneuropathy Gaucher disease Hereditary hemochromatosis
Infectious diseases	HIV/AIDS Hepatitis C infection Tuberculosis Human T lymphotropic virus
Metabolic disorders	Dehydrated patients Alcoholism Anemia Patients with chronic renal failure
Others	Fibromyalgia Sarcoidosis Primary biliary cirrhosis Hypertension Fibromyalgia Chronic pancreatitis Graft-versus-host disease Cystic fibrosis Chronic fatigue syndrome Burning mouth syndrome Liver transplant candidates Atrophic gastritis

Rheumatological Diseases

Sjögren's syndrome (SS) is the most common systemic disorder causing hyposalivation [2, 8]. SS is an autoimmune rheumatic disease characterized by a chronic lymphocytic infiltration of salivary and lacrimal glands [3, 9]. It is classified as primary Sjögren's syndrome (pSS) when occurring as an isolated condition or as secondary SS (sSS) when it is associated with a coexisting autoimmune disease [10]. It usually appears in the fourth to fifth decade of life. Although it could manifest at any age, up to 20% of cases appear in older adults [7], and its prevalence is higher in women than men [9]. The most recent criteria were proposed in 2016 by the American College of Rheumatology and the European League Against Rheumatism [11]. The 2016 classification criteria consider, in addition to ocular and oral dryness, the presence of focal lymphocytic sialadenitis of minor salivary glands (focus score of ≥1 foci/4 mm^2, weight/score = 3), an anti-SSA/Ro-positive antibody (weight/score = 3), ocular staining score ≥5 (or van Bijsterveld score ≥4) in at least one eye (weight/score = 1), Schirmer's test ≤5 mm/5 min in at least one eye (weight/score = 1), and an unstimulated whole salivary flow rate ≤0.1 mL/min (weight/score = 1). A patient with a score ≥ 4 meets criteria for SS. Besides SS, there are other rheumatic diseases that may cause salivary hypofunction. In older patients, the most frequent conditions are rheumatoid arthritis, systemic lupus erythematosus, primary biliary cirrhosis, mixed connective tissue disease, and scleroderma [3, 7].

Endocrine Diseases

Diabetes mellitus (DM) is the most common endocrine disorder associated with xerostomia and low salivary flow rates [3, 12]. This disease is highly prevalent in older patients. DM has become a global epidemic with the overall prevalence among adults increasing considerably over the years [13]. The low levels of saliva could be attributed to alterations in the microcirculation of the salivary glands, damage to the gland parenchyma, degenerative processes of the nerve endings that innervate the glands, dehydration, polyuria, and disturbances in glycemic control [2, 3, 13]. As a consequence of hyposalivation, patients with DM are in a higher risk of developing tooth decay, taste disorders, oral infections (particularly candidiasis), burning mouth syndrome, or periodontal disease [13].

Apart from DM, thyroid dysfunction is one of the most frequent endocrine disorders affecting adults worldwide [14]. It could be classified as either hyperthyroidism or as hypothyroidism. Both diseases have been associated with reduced salivary gland function, more prominent in those patients with hypothyroidism [3, 14]. Alterations in the function of thyroid glands, especially in those patients with hypothyroidism, affect salivary gland function, which in turn could result in dental caries in atypical locations, halitosis, and difficulty in eating, potentially compromising patients' nutritional status and quality of life [14]. Patients with Cushing's or Addison's syndrome may also experience dry mouth and hyposalivation [7].

Neurologic Disorders

Several neurologic disorders are associated with xerostomia and hyposalivation. Parkinson's disease is one of the most common neurologic disorders in older adults.

It is a progressive, chronic, and neurodegenerative condition that affects 1% of adults over the sixth decade of life. Patients with Parkinson's disease may experience xerostomia, either as a side effect of medications or because of the decrease in salivary flow due to disease-related autonomic dysfunction. The resulting hyposalivation coupled with patients' difficulties in performing good oral hygiene increases the risk of developing tooth decay, periodontal disease, and dental loss [6]. Dysphagia is another common symptom of Parkinson's disease, affecting up to 75% of patients. Hyposalivation could contribute to dysphagia, which may further aggravate the feeling of dry mouth [3]. Other neurologic disorders that may cause salivary disorders are Bell's palsy and Alzheimer's disease. Hyposalivation may also appear in patients who have suffered a stroke and demonstrate associated neurological deficits [7].

Psychological Conditions

Depression and anxiety are common disorders in older patients and are frequently associated with xerostomia [7, 15]. These patients usually suffer from dry mouth related to the use of psychoactive drugs prescribed for these conditions, but sometimes, it could have a psychological origin [3, 12]. Other less common disorders that may cause dry mouth are stress and eating disorders such as bulimia and anorexia [7].

Genetic Diseases

Although rare in older adults, several genetic disorders are also associated with salivary gland dysfunction. Among the most common are Prader-Willi syndrome, Gaucher disease, Down syndrome, familial amyloidotic polyneuropathy, hereditary hemochromatosis, and Papillon-Lefèvre syndrome. Other possible genetic malformations associated with hyposalivation include agenesis of the salivary glands and ectodermal dysplasia [3].

Infectious Diseases

Patients with HIV may develop xerostomia and hyposalivation. The introduction of antiretroviral therapies has increased patients' life expectancy and quality of life. In these patients, xerostomia may result from salivary disorders associated with the viral infection or may be drug induced. HIV patients may also develop salivary gland dysfunction due to conditions common in this population including Kaposi sarcoma, intraglandular lymphadenopathy, or non-Hodgkin lymphoma. Hepatitis C is another infection that is associated with salivary disorders due to viral infiltration of the salivary glands. Tuberculosis and human T lymphotropic virus infection are also associated with salivary dysfunction [3, 7].

Other Disorders

Other disorders related to hyposalivation are alcoholism, anemia, dehydration, and chronic renal failure [3]. One of the main oral manifestations of patients undergoing hemodialysis is xerostomia. Moreover, most patients with chronic renal failure suffer from diabetes or hypertension requiring pharmacological therapies, which in turn increase the risk of reductions of salivary flow [16]. Older people are often dehydrated due to different causes. One of the most common is not drinking enough fluids due to physiological and functional decline. Dehydration is a complex

condition and in older adults is associated with a higher risk of morbidity and mortality [17, 18]. Graft-versus-host disease is a condition that may occur after bone marrow transplantation. This syndrome is characterized by a lymphocytic infiltration, mediated by autoreactive T cells, which affect several tissues and organs including the salivary glands. This disease could lead to salivary disorders [3, 7]. Sarcoidosis is a multisystemic disease of unknown etiology, probably due to a dysregulation of the autoimmune system, which leads to the formation of granulomas. In these patients, xerostomia, hyposalivation, and salivary gland swelling could appear [7]. Chronic pancreatitis could also affect the salivary glands. In addition, patients with fibromyalgia, cystic fibrosis, hypertension, chronic fatigue syndrome, burning mouth syndrome, primary biliary cirrhosis, atrophic gastritis and candidates for liver transplant may also experience xerostomia [7].

1.4 Head and Neck Radiotherapy and Chemotherapy

An important cause of xerostomia and hyposalivation in older persons with head and neck cancers is previous or current treatment with radiotherapy. The salivary glands are very radiosensitive to these treatments. Radiation induces a degenerative process leading to a reduction in salivary flow [2, 3]. In many cases, the treatment with radiotherapy induces a total loss of parotid gland salivary flow which may have serious consequences for the oral cavity. Doses greater than 60 grays (Gy) may produce irreversible hyposalivation, while doses of 30–50 Gy produce reversible damage [5]. These alterations in salivary flow may persist for years and in many of these patients may even become irreversible [3]. Chemotherapy can cause xerostomia in up to 50% of patients receiving these treatments. In these patients, normal salivary flow may take between 6 months to 1 year to recover after concluding the treatment [5].

1.5 Drugs

Xerostomia and hyposalivation have been commonly associated with the use of a wide variety of pharmacological agents. More than 400 drugs have been associated with xerostomia. In addition, the risk of xerostomia increases with the number of drugs (polypharmacy), higher doses, drug combinations, and duration of treatment. Some medications produce xerostomia, but do not always cause a reduction in salivary flow [2]. Older patients often take some type of drug on a regular basis to treat a range of chronic conditions. Studies show that 52% of men and 65% of women over 65 years take at least one medication. In addition, between 11% and 24% take more than four medications per day [19]. The concurrent use of multiple medications or polypharmacy has been associated with xerostomia and hyposalivation [1, 3, 7, 19–22]. According to studies, the prevalence of xerostomia in patients older than 65 years increases with the number of prescribed drugs. In fact, 37% of patients taking one

drug suffered from xerostomia as compared with 62% and 78% of those taking two or three drugs, respectively [7]. However, there are other studies that showed no association between the degree of xerostomia and the number of drugs received [23]. The duration of treatment may also influence the risk of salivary disorders [1, 19, 22]. According to some studies, patients who take drugs for a longer period of time have lower salivary flow rates [8, 24]. Below we will briefly describe medications often associated with salivary disorders. Table 2 shows all drugs associated with salivary disorders classified according to their mechanism of action following the guidelines of the Anatomical Therapeutic Chemical (ATC) Classification System [25].

Medications Acting on the Central Nervous System

Analgesics such as tramadol, morphine, and paracetamol (acetaminophen) are included in this group. These drugs can reduce salivary flow leading to xerostomia [3, 21, 22]. Among the antiepileptic and psychoactive groups of medications, benzodiazepines are the most often associated with salivary disorders [3]. Benzodiazepine-related drugs and antidepressants have also been associated with salivary disorders [21, 22].

Medications Acting on Muscarinic Receptors

This group includes drugs used for gastrointestinal disorders, urological problems (including urinary frequency, urgency, and incontinence), and chronic obstructive airway diseases. These drugs alter muscarinic receptors, thus increasing xerostomia [20, 22].

Medications Acting on Alpha and Beta Adrenergic Receptors

Alpha-1 drugs used for the treatment of hypertension such as central agents, some beta-blocker agents, and alpha blockers are frequently used in older patients to treat hypertension and benign prostatic hyperplasia. Within this group, there are also nasal preparations including pseudoephedrine. These medications reduce salivary flow increasing xerostomia [20–22]. Alpha-2 adrenergic receptor-blocking drugs such as dexmedetomidine, used to reduce anxiety and delirium in intensive care patients, and brimonidine used for glaucoma have been also associated with xerostomia [20]. Medications acting on beta adrenergic receptors are often used for the treatment of hypertension in older patients. These agents increase the risk of xerostomia [20, 22].

Medications Acting on More than One Receptor Type

There are other drugs acting on several receptors that have been associated with xerostomia: drugs for the treatment of functional gastrointestinal disorders such as prokinetics [22]; drugs to treat neuropathic pain such as antidepressants, sedatives, and hypnotics [22]; opioid drugs such as tapentadol [20–22]; antiepileptics such as carbamazepine [22]; psychoactive medications such as benzodiazepine derivatives and benzodiazepine-related agents [22]; antidepressant drugs such as selective serotonin reuptake inhibitors [21, 22]; and antihistamines for systemic use [22].

Medications that Produce Xerostomia with no Known Mechanism of Action

There are also multiple drugs associated with salivary disorders whose mechanism of action is not yet known such as drugs for acid-related disorders [21],

Table 2 Drugs associated with xerostomia/hyposalivation classified by their mechanism of action according to the Anatomical Therapeutic Chemical (ATC) Classification System

Drugs associated with salivary disorders according to ATC classification			
ATC first, second, and third level	ATC fourth and fifth level	Chemical substance	Site of saliva secretion control
A: Alimentary tract and metabolism			
A02 Drugs for acid-related disorders	A02AA04	Magnesium hydroxide	Not known but clinical effect reported
A03 Drugs for functional gastrointestinal disorders	A03AA07	Dicyclomine/ dicycloverine	Muscarinic receptors
	A03AB05	Propantheline	Muscarinic receptors
A04 Antiemetics and anti-nauseants	A04AD01	Scopolamine	Muscarinic receptors
B: Blood and blood-forming organs			
B01 Antithrombotic agents	B01AC06	Acetylsalicylic acid	Not known but clinical effect reported
C: Cardiovascular system			
C02 Antihypertensives	C02AB01	Methyldopa	Central nervous system
	C02AC01	Clonidine	Central nervous system
	C02AC05	Moxonidine	Central nervous system
	C02AC06	Rilmenidine	Central nervous system
C03 Diuretics	C03AA01	Bendroflumethiazide	Not known but clinical effect reported
	C03AA02	Hydroflumethiazide	Not known but clinical effect reported
	C03AA03	Hydrochlorothiazide	Not known but clinical effect reported
	C03AA04	Chlorothiazide	Not known but clinical effect reported
	C03AA05	Polythiazide	Not known but clinical effect reported
	C03AA06	Trichlormethiazide	Not known but clinical effect reported
	C03AA07	Cyclopenthiazide	Not known but clinical effect reported
	C03AA08	Methyclothiazide	Not known but clinical effect reported
	C03AA09	Cyclothiazide	Not known but clinical effect reported
	C03AA13	Mebutizide	Not known but clinical effect reported

Table 2 (continued)

Drugs associated with salivary disorders according to ATC classification			
ATC first, second, and third level	ATC fourth and fifth level	Chemical substance	Site of saliva secretion control
C07 Beta-blocking agents	C07AA06	Timolol	Beta-1 adrenergic receptors
	C07AB02	Metoprolol	Beta-1 adrenergic receptors
	C07AB03	Atenolol	Beta-1 adrenergic receptors
	C07AB07	Bisoprolol	Beta-1 adrenergic receptors
C08 Calcium channel blockers	C08DA01	Verapamil	Not known but clinical effect reported
C09 Agents acting on renin-angiotensin system	C09AA01	Captopril	Not known but clinical effect reported
	C09AA02	Enalapril	Not known but clinical effect reported
C10 Lipid-modifying agents	C10A	Lipid-modifying agents plain	Not known but clinical effect reported
G: Genitourinary system and sex hormones			
G04 Urological	G04BD04	Oxybutynin	Muscarinic receptors
	G04BD06	Propiverine	Muscarinic receptors
	G04BD08	Solifenacin	Muscarinic receptors
	G04BD09	Trospium	Muscarinic receptors
H: Systemic hormonal preparations excluded sex hormones and insulins			
H03 Thyroid therapy	H03AA	Thyroid hormones	Not known but clinical effect reported
M: Musculoskeletal system			
M01 Anti-inflammatory and antirheumatic products	M01AX05	Glucosamine	Not known but clinical effect reported
M03 Muscle relaxants	M03BX02	Tizanidine	Alpha-2 adrenergic receptors
M05 Drugs for treatment of bone diseases	M05BA	Bisphosphonates	Not known but clinical effect reported
N: Nervous system			
N01 Anesthetics	N01AH01	Fentanyl	Alpha-2 adrenergic receptors
N02 Analgesics			
N02A Opioids	N02AG02	Morphine	Central nervous system Precise mechanism of action is unknown
	N02AX02	Tramadol	Central nervous system
	N02AX06	Tapentadol	More than one receptor type
N02B Other analgesics and antipyretics	N02BE01	Paracetamol or acetaminophen	Not known but clinical effect reported
N03 Antiepileptics	N03AF01	Carbamazepine	More than one receptor type
N05 Psychoactive			

(continued)

Table 2 (continued)

Drugs associated with salivary disorders according to ATC classification			
ATC first, second, and third level	ATC fourth and fifth level	Chemical substance	Site of saliva secretion control
N05A Antipsychotics	N05AA0	Chlorpromazine	More than one receptor type
	N05AB03	Perphenazine	Muscarinic receptors
	N05AB04	Prochlorperazine	More than one receptor type
	N05AD01	Haloperidol	More than one receptor type
	N05AE03	Sertindole	More than one receptor type
	N05AH02	Clozapine	More than one receptor type
	N05AH03	Olanzapine	More than one receptor type
	N05AL05	Amisulpride	More than one receptor type
	N05AX08	Risperidone	More than one receptor type
	N05AX13	Paliperidone	More than one receptor type
N05B Anxiolytics	N05BA01	Diazepam	Central nervous system
	N05BA06	Lorazepam	Central nervous system
N05C Hypnotics and sedatives	N05CD01	Flurazepam	Central nervous system
	N05CD02	Nitrazepam	Central nervous system
	N05CD03	Flunitrazepam	Central nervous system
	N05CD04	Estazolam	Central nervous system
	N05CD05	Triazolam	Central nervous system
	N05CD06	Lormetazepam	Central nervous system
	N05CD07	Temazepam	Central nervous system
	N05CD08	Midazolam	Central nervous system
	N05CD09	Brotizolam	Central nervous system
	N05CD10	Quazepam	Central nervous system
	N05CD11	Loprazolam	Central nervous system
	N05CD12	Doxefazepam	Central nervous system
	N05CD13	Cinolazepam	Central nervous system
	N05CD14	Remimazolam	Central nervous system
	N05CF01	Zopiclone	Central nervous system
	N05CF04	Eszopiclone	Central nervous system
	N05CF03	Zaleplon	Central nervous system
	N05CF02	Zolpidem	Central nervous system
	N05CM18	Dexmedetomidine	Alpha-2 adrenergic receptors
N06 Antidepressants			

Table 2 (continued)

Drugs associated with salivary disorders according to ATC classification			
ATC first, second, and third level	ATC fourth and fifth level	Chemical substance	Site of saliva secretion control
N06A Antidepressants	N06AA10	Nortriptyline	More than one type of receptor
	N06AB03	Fluoxetine	Central nervous system
	N06AB04	Citalopram	Central nervous system
	N06AB05	Paroxetine	Central nervous system
	N06AB06	Sertraline	Central nervous system
	N06AB10	Escitalopram	Central nervous system
	N06AX12	Bupropion	Central nervous system
	N06AX16	Venlafaxine	Central nervous system
	N06AX21	Duloxetine	Central nervous system
	N06AX23	Desvenlafaxine	More than one type of receptor
	N06AX26	Vortioxetine	More than one type of receptor
N06B Psychostimulant agents used for ADHD and nootropics	N06BA04	Methylphenidate	Central nervous system
P: Antiparasitic products, insecticides, and repellents			
P01 Antiprotozoals	P01BC01	Quinine	Not known but clinical effect reported
R: Respiratory system			
R01 Nasal preparations	R01BA02	Pseudoephedrine	Alpha-1 adrenergic receptors
R03 Drugs for obstructive airway diseases	R03AC03	Terbutaline	Beta-2 adrenergic receptors
	R03AC12	Salmeterol	b2 adrenergic receptors
	R03AC13	Albuterol	b2 adrenergic receptors
	R03BA01	Beclomethasone	Not known but clinical effect reported
	R03BA02	Budesonide	Not known but clinical effect reported
	R03BA03	Flunisolide	Not known but clinical effect reported
	R03BA04	Betamethasone	Not known but clinical effect reported
	R03BA05	Fluticasone	Not known but clinical effect reported
	R03BA06	Triamcinolone	Not known but clinical effect reported
	R03BA07	Mometasone	Not known but clinical effect reported
	R03BA08	Ciclesonide	Not known but clinical effect reported
	R03BA09	Fluticasone furoate	Not known but clinical effect reported
	R03BB01	Glycopyrrolate/ glycopyrronium/ ipratropium	Muscarinic receptors
	R03BB04	Tiotropium	Muscarinic receptors

(continued)

Table 2 (continued)

Drugs associated with salivary disorders according to ATC classification			
ATC first, second, and third level	ATC fourth and fifth level	Chemical substance	Site of saliva secretion control
R06 Antihistamines for systemic use	R06AA02	Diphenhydramine	More than one type of receptors
	R06AE07	Cetirizine	More than one type of receptors
	R06AE09	Levocetirizine	More than one type of receptors
	R06AX13	Loratadine	More than one type of receptors
	R06AX19	Azelastine	More than one type of receptors
	R06AX22	Ebastine	More than one type of receptors
	R06AX26	Fexofenadine	More than one type of receptors
S: Sensory organs			
S01 Ophthalmological	S01EA05	Brimonidine	Alpha-2 adrenergic receptors

antithrombotic agents [21], calcium channel blockers [20–22, 26], agents acting on the renin-angiotensin system [21, 26], lipid-modifying agents [21, 26], anti-inflammatory and antirheumatic drugs [21], glucocorticoids used for chronic obstructive airway diseases, antiprotozoals (specifically quinine) [21], and bisphosphonates [21].

1.6 Lifestyle Factors

Modifiable risky behaviors may contribute to the appearance of dry mouth. Among them are excessive consumption of alcohol, tobacco, and caffeinated drinks and use of mouthwashes containing alcohol. Mouth breathing and snoring as seen in obstructive sleep apnea can also increase the risk of xerostomia [27].

2 Impact of Salivary Disorders in the Oral and General Health of Older Patients

Saliva has multiple functions that foster and maintain oral health. Reductions in salivary secretion may lead to alterations in the oral mucosa, caries, and discomfort, reducing patient's quality of life [3, 5, 9, 15, 28, 29]. Next, we will review common consequences of salivary disorders in older adults.

2.1 Changes in Taste

The taste of food stimulates the production of saliva. Saliva in turn dissolves the food to stimulate taste receptors. In addition, components of saliva such as bicarbonate ions can also affect the taste of food. Saliva also protects salivary receptors from atrophy, infection, mechanical damage, and drying out. As a result, when saliva decreases, the taste of food may be altered [28]. The sense of taste often decreases with aging. Several factors may contribute to these changes but among the most well-known are an increasing deterioration of the olfactory senses and side effects of drugs [6]. The research literature is mixed regarding the type, frequency, and severity of age-related losses in taste perception. Some investigators report that bitter taste is the most commonly affected, whereas sweet taste is less impacted by the aging process [30]. According to some authors, older people display a reduction in sensory-specific satiety as compared to younger subjects. This means that the triggers that normally would encourage the intake of different foods are reduced with aging, leading to acceptance of bland and monotonous diets. Others state that older adults compensate for losses in taste perception by increasing their intake of sweet and fatty foods [30]. Taste plays a major role in food perception, and taste disability influences intraoral food processing and perception [31].

2.2 Changes in Mastication, Alterations in the Formation of the Alimentary Bolus, and Swallowing

Saliva lubricates and softens food particles. It also exposes food to salivary enzymes and helps prepare the bolus for subsequent swallowing. Deterioration in the salivary flow rate has been associated with decreased masticatory function in older adults. The masticatory process is influenced by different factors such as the number of teeth, masticatory force, use of dentures, muscular alterations, and salivary flow [6, 28]. When the salivary flow decreases, the number of masticatory cycles increases. Studies show that diets requiring more chewing activity increase salivary flow. Many older patients tend to eat soft diets due to the lack of teeth and the presence of dentures [28, 29].

Saliva also helps in the bolus formation. Salivary enzymes in the mouth begin the digestion of triglycerides and carbohydrates. Saliva moistens the food, and salivary mucins help to bind the food particles and form the alimentary bolus. When there is a reduced salivary flow, the patient needs to drink more fluids to moisten the food which may reduce the cohesiveness of the alimentary bolus [28].

Swallowing is a necessary function for removing excess saliva from the mouth and ingesting solid and liquid food. The salivary flow, viscosity, and composition as well as food textures influence swallowing. When salivary flow decreases, swallowing intervals increase [28]. Oral lesions such as an atrophic, fissured, or dry tongue or the presence of certain infections can impair the patient's ability to swallow food.

Swallowing dysfunction can have an important impact on the nutritional status of older patients [15]. Many older adults who suffer from hyposalivation develop dysphagia [32]. Dysphagia may lead to decreased food and fluid intake leading to negative consequences such as malnutrition, risk of aspiration, and aspiration pneumonia that place the older patient's life at risk [6]. For a more in-depth discussion on the topic of dysphagia, please refer to chapter "Swallowing, Dysphagia, and Aspiration Pneumonia."

A decreased salivation rate is associated with other consequences. Impaired speech among older adults may have a great impact on patients' well-being and quality of life. Reductions in older adults' communication skills may lead to social isolation [6]. The research literature regarding the impact of dry mouth on subjective and objective halitosis is mixed. An utmost reduction in unstimulated saliva has been reported to influence the generation of volatile sulfur compounds that characterize halitosis. Needless to say, this condition in older adults might lead to stigmatization, social isolation, and poor quality of life [6]. As mentioned earlier, reduced salivary flow can alter the taste of food and impair chewing and swallowing processes. As a consequence of reduced salivary flow, patients may not be able to tolerate foods that are more difficult to eat such as raw carrots and meat, potentially decreasing their nutritional intake [29]. In addition, an impaired taste sensation can greatly affect appetite, which can further aggravate older adults' nutritional status [6].

Older patients with reduced salivary flow may also suffer traumatic oral lesions. Saliva plays a fundamental role in the lubrication of the oral mucosa, and certain dry foods such as toast or chips can damage an already dried and friable mucosa. It is also common that patients with dry mouth present with an atrophic, depapillated, fissured, and dry tongue. In addition, these patients may suffer from fissured lips and mucosal ulcers [33]. Patients with hyposalivation often show a poor tolerance to dentures. Saliva forms a protective film that aids in the retention of dentures. When salivary flow decreases, this retention capability is lost. This will considerably influence the nutritional status and quality of life of older patients wearing dentures [33].

2.3 Changes in Biofilm and Their Consequences

When saliva decreases, the oral microbial flora is altered. Concentration of certain microorganisms increases, such as *Lactobacillus acidophilus*, *Streptococcus mutans*, and *Candida albicans*, increasing the risk of caries and candidiasis [15, 28]. However, in certain patients such as patients with SS, it is not clear whether the periodontal flora is altered [34]. In addition, the buffer capacity and clearance effect of saliva decreases, lowering salivary pH which may in turn increase dental demineralization [15, 28]. Cavities appear in the cervical area of the teeth, near the root, and in other atypical locations such as the lingual surfaces, the incisal edges, and the cusps of the teeth [28]. In older adult patients, caries can lead to tooth loss and

subsequent edentulism which will further weaken chewing function, worsening nutrition and decreasing quality of life [6]. There is an inverse relationship between salivary flow rates and *Candida albicans* colony-forming units (CFU) among SS patients [35]. The increase of *Candida albicans* may favor the appearance of angular cheilitis, denture stomatitis, and oropharyngeal candidiasis among older adults [6, 35].

3 Diagnosis of Xerostomia and Hyposalivation

To properly diagnose xerostomia and hyposalivation, a complete clinical history, exam, and ancillary tests must be performed [3]. The tests to be performed will depend on the specific pathology and the possible causes of the xerostomia and/or hyposalivation, as we will see below.

3.1 Medical History

When a patient comes to the office complaining of dry mouth, it is critical to perform a complete and detailed medical history. The medical history should include the reason for the consultation, how long the patient has suffered from dry mouth, and associated symptoms. It is important to pay attention to underlying systemic pathologies and drugs associated with dry mouth. In patients with history of head and neck malignancies, it is important to ascertain whether the patient had received radiotherapy or chemotherapy in the past [5, 22, 36, 37]. Asking the patient about dryness in extraoral areas such as the skin and other mucous membranes (ocular, nasopharyngeal, or genital) may uncover underlying systemic pathologies such as SS. Cognitive problems are common in older adults. Therefore, clinicians should always keep in mind the possibility that the patient may have mild cognitive impairment or dementia which in some situations may require adaptations in the history and consideration of secondary sources of information such as caregivers and loved ones [30]. For more details, please refer to "The 3 Ds: Dementia, Delirium, and Depression in Oral Health" chapter in this book.

As mentioned earlier in this chapter, the discomfort associated with dry mouth is often the first and most common symptom reported by patients with xerostomia. It is common that patients reporting dry mouth notice that their saliva has become thicker and viscous or that they need to drink more fluids. They can also suffer functional problems such as difficulties in speaking, eating certain foods, and swallowing. Other frequent symptoms are halitosis and the sensation of burning and/or pain in the tongue. Edentulous patients may also suffer fissures in the corner of the lips or difficulties wearing dentures [30, 31, 38]. Sometimes it can be challenging to differentiate age-related physiological changes in the oral cavity from pathological conditions [30].

3.2 Intraoral and Facial Examination

A careful oral examination is essential to identify clinical signs that may suggest hyposalivation. When the protective function of saliva against different oral insults and infections is lost or diminished, patients may suffer from various xerostomia-associated pathologies such as caries and fungal infections.

Experts have reported several signs during the oral exam that may suggest the presence of dry mouth. The oral mucosa and a gingiva may appear bright, pale, and atrophic on exam [37]. Sometimes, during the oral exploration, the dental mirror will adhere to the oral mucosa or tongue, revealing an absence of saliva accumulation on the floor of the mouth or, when there is some saliva, that it is viscous and with a foamy appearance. In patients with hyposalivation, the tongue appears fissured, lobed, and with an atrophic appearance. The presence of caries is frequent, occurring mainly in the cervical or root areas [37]. Palpation of the salivary glands may detect certain degree of sialomegaly or swelling, which may be uni- or bilateral. The palpation must include extrabuccal and intrabuccal techniques (the bidigital form can be useful). The exit ostium of the glandular ducts should be examined to look for inflammation, and manipulation maneuvers including glandular expression may reveal little or viscous saliva coming out of the glandular orifices [5].

3.3 Sialometry

The degree of salivary glandular dysfunction should also be investigated. It is essential to differentiate whether the patient has xerostomia or hyposalivation. The most commonly used test to determine whether there is a decrease in the amount of saliva is sialometry [6]. There are different types of sialometry depending on whether the saliva from all glands is collected or whether the saliva is collected from individual glands. For clinical diagnosis, whole saliva collection is more useful. Sialometry will not be helpful in determining the cause of dry mouth [3].

The collection of salivary flow must be done first thing in the morning with the patient seated in an upright position. Ninety minutes before the procedure, the patient should not eat, rinse, drink, or smoke. Patients will collect their saliva in a graduated container. There are two types of saliva collection: at rest or unstimulated whole saliva (UWS) and under stimulation or stimulated whole saliva (SWS). When collecting saliva at rest, hyposalivation is defined as a salivary flow of <0.1 mL/min. Saliva should be collected for at least 10 min. The collection of stimulated saliva will require the patient to chew unflavored paraffin wax. Hyposalivation is diagnosed when the saliva flow is <0.5–0.7 mL/min. Stimulated saliva should be collected for at least 5 min [3, 5, 37, 38]. These two techniques are the most widely used. When the cause of dry mouth is medications, the unstimulated saliva is usually reduced, whereas the stimulated saliva values remain normal [5].

3.4 Biopsy of Minor Salivary Glands

Minor salivary gland biopsy may be useful in those older patients who are suspected of having SS (because they also suffer from dry eye) or other non-neoplastic diseases of systemic origin such as sarcoidosis, amyloidosis, or cystic fibrosis. In these conditions, the histological study will show the anatomopathological changes characteristic of each disorder. The biopsy is performed on the inner side of the lower lip [27].

3.5 Questionnaires

There are many available questionnaires for the evaluation of the severity of dry mouth [37]. One of the most widely used is the Xerostomia Inventory which contains 11 items. Each answer is scored using Likert-type options. This questionnaire is very useful to evaluate the degree of dry mouth caused by drugs, which is one of the most frequent causes of xerostomia in the older patient. This questionnaire is also recommended to assess the response to treatment [39]. The question "does your mouth usually feel dry?" has a high sensitivity but low specificity for the diagnosis of hyposalivation [37]. Other questions such as Does your mouth feel dry when eating a meal?; Do you have any difficulty swallowing?; Do you sip liquids to aid in swallowing dry food?; and Does the amount of saliva in your mouth seem to be too little or too much or you do not notice it? are also predictive of hyposalivation [5].

3.6 Other Diagnostic Methods

In some cases, other tests will be necessary to make a correct diagnosis, especially in those patients suffering from enlargement of one or more salivary glands. These tests include imaging techniques such as cone beam CT, magnetic resonance imaging (MRI), sialography, scintigraphy, and ultrasound. Another test used in cases of salivary gland tumors is fine-needle aspiration puncture [3].

In patients who also complain of dry eye, the determination of anti-SSA/SSB (anti-Ro/La) antibodies may be indicated. However, according to the 2016 classification criteria, only anti-SSA/Ro positivity is required. In rheumatic diseases, it is also useful to ask for serum levels of rheumatoid factor and antinuclear antibodies [11].

4 Treatment

The treatment of xerostomia and hyposalivation encompasses a series of interventions, which can range from preventive measures such as good oral hygiene and hydration, through the treatment of some systemic diseases, substitution of certain

drugs, and treatment with local measures or systemic drugs. The response to the same treatment can vary in each patient. It is therefore essential that patients receive personalized treatments depending on their needs. In addition, it is advisable to have a dentist follow these patients on a regular basis.

4.1 Preventive Measures

Increasing the daily water intake is probably the first lifestyle measure to implement when trying to reduce symptoms. Preventive measures should include good oral hygiene with fluoride toothpaste and regular visits to the dentist (every 3-4 months) for topical fluoride application and control of dental caries [6, 27]. During these dental appointments, it may be necessary to take radiographs to evaluate the caries risk of each patient, perform professional prophylaxis as needed, counsel the patient on oral hygienic self-care measures, advise patients on the correct use of dentures [6], provide nutritional information, and counsel patients to increase fluid intake in the evenings and avoid spicy, acidic, or hard foods and alcoholic and caffeinated drinks [6, 37].

4.2 Changes or Reduction of Drugs

If the cause of xerostomia is possibly due to drugs, reducing the number of prescribed drugs, reducing the doses, or replacing them with safer pharmacological and non-pharmacological alternatives may be appropriate [6, 27]. In these cases, the patient's primary care clinician should be consulted. Decisions about changing, eliminating, or reducing the dose of the offending drug(s) will always be a shared responsibility between the physician and patient [37].

4.3 Local Measures

Salivary stimulants such as chewing gum or candies and saliva substitutes are commonly used local agents. Chewing gum and candies should be sugar-free to prevent dental caries. These gums often contain xylitol, which reduces cariogenic bacteria. However, individual patient preferences must be considered before recommending specific products for older patients [37, 40]. Studies have shown the efficacy of 1% malic acid spray in the treatment of dry mouth in patients treated with antihypertensives and antidepressants. However, a potential drawback of this treatment is its potential erosive effect on enamel [37]. Saliva substitutes imitate saliva and may provide symptomatic relief. They are commercialized in the form of gel, spray, rinses, or toothpaste and include different tastes and ingredients [37, 41]. They commonly contain xanthan gum, hydroxyethyl cellulose, carboxymethylcellulose, mucins, polyethylene oxide, linseed oil, olive oil, xylitol, and betaine, among others

[27]. They may be the first therapeutic option when there is severe glandular dysfunction, and thus the salivary glands cannot be stimulated. The composition of these substitutes should resemble saliva as much as possible and therefore should have a neutral pH, fluoride, and electrolytes. Patients tend to report greater comfort when using them without significant side effects, although their superiority over placebo is controversial [42–44]. There are other alternative therapies such as electrostimulation [45], acupuncture [46], or hyperbaric oxygen [47], but they are not widely available to all patients.

4.4 Systemic Sialogogues

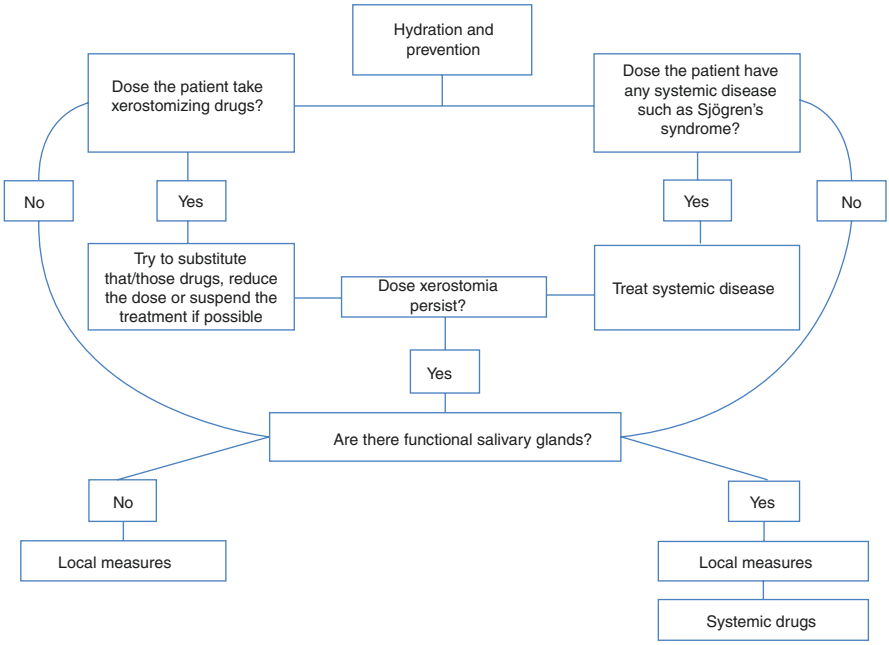
Pilocarpine and cevimeline are the most well-studied and commonly used drugs to treat xerostomia. These medications are effective only if functioning salivary parenchyma remains [3, 6, 10, 27]. Pilocarpine is a non-selective muscarinic agonist and parasympathetic agent. The recommended dose is 5–30 mg/day, and the usual dose is 5 mg every 8 h for at least 3 months. The use of this drug is associated with a reduction in dry mouth in patients who have received head and neck radiotherapy. The maximum effect occurs after 2–3 months of use [3, 37]. Cevimeline is a selective muscarinic agonist for M1 and M3 receptors. It is longer acting than pilocarpine, and its standard dosing is 30 mg up to three times/day for at least 3 months [37].

These drugs have side effects and interactions and should be used with caution in older patients. Common side effects are sweating, bitter taste, urinary frequency, sialorrhea, gastritis, nausea, vomiting, bradycardia, hypotension, bronchoconstriction, and dyspnea, among others. Before prescribing these drugs, it is appropriate to involve a primary care physician. Moreover, parasympathomimetic drugs may antagonize anticholinergic effects, and as a result, both pilocarpine and cevimeline are contraindicated in patients with cardiovascular disease, asthma, kidney failure, chronic pulmonary disease, and glaucoma, as those patients taking beta adrenergic antagonists [3, 6, 27, 37, 43]. Some of these pathologies are frequent in the older patient, so this type of drugs should be used with caution.

4.5 Treatment of Sjögren's Syndrome

Patients with SS are often treated by rheumatologists. Concurrent lifestyle modifications, local measures, and systemic sialogogues may improve clinical manifestations. Immunomodulatory/immunosuppressive drugs such as glucocorticoids, antimalarials, immunosuppressive agents, intravenous immunoglobulins, and biologics may be helpful in patients with active systemic disease. Treatment should focus on restoring organ function as soon as possible and then establishing a dose capable of maintaining the initial response [10]. Alpha interferon has been used with mixed results [3], while rituximab decreases the glandular lymphocytic

infiltrate present in this syndrome. Rituximab is useful in those cases where the patient has residual parenchyma [48]. However, there is no sufficient evidence to recommend one treatment over another nor the duration and dose to be used, so it is necessary to individualize the treatment [10].



Treatment of xerostomia in the older patient

5 Practical Considerations

We have made a practical guide for dentists (Table 3) including recommendations for the diagnosis and treatment of salivary disorders in the older patient discussed throughout this chapter.

6 Future Research

Salivary alterations in the older patient are frequent. Future studies should further clarify the mechanisms, clinical manifestations, and consequences of chronic systemic diseases and prescription drugs most frequently associated with xerostomia and hyposalivation. The treatment of xerostomia in the older patient is complicated by the concurrent use of drugs indicated for the treatment of a wide variety of chronic medical and psychological conditions. Future research may include

Table 3 Practical considerations for the diagnosis and treatment of the older patient with xerostomia

Diagnosis	
Medical history	Patient's symptoms Dryness of other mucous membranes and skin Previous and current diseases and whether they are under control Record the drugs taken by the patient. Check if these drugs are associated with dry mouth Risk factors associated with dry mouth: tobacco, alcohol, caffeinated drinks, toothpastes, and mouthwashes containing irritants
Intraoral examination	Bright and atrophic oral mucosa Dental mirror adheres to the oral mucosa or tongue Lack of saliva or low saliva viscous and foamy Several cavities and oral candidiasis Little or viscous saliva coming out of the exist ostium of the glandular ducts
Extraoral examination	Uni- or bilateral swelling of the parotid glands
Diagnostic methods	Sialometry: hyposalivation UWS <0.1 mL/min; SWS <0.5–0.7 mL/min. Advised in all patients Biopsy of minor salivary glands: if suspected of SS, sarcoidosis, amyloidosis, and cystic fibrosis Imaging techniques: when there is enlargement of the glands Blood test: anti-SSA/SSB, rheumatoid factor, antinuclear antibodies, glycemia, thyroid tests To assess possible improvement after treatment, use Xerostomia Inventory questionnaire previously to possible treatment
Treatment	
No reduced salivary flow	Preventive measures: drinking more water, no alcohol, no caffeinated drinks, no smoking, good oral hygiene, regular dental visits Local measures: topical stimulators and/or substitutes and use of toothpaste and mouthwashes for dry mouth (without lauryl sulfate)
Reduced salivary flow	Take into consideration the previous measures Assess with the patient's physician whether the number or dose of drugs associated with salivary disorders can be reduced In severe cases, without response to previous measures, with residual glandular function, and in which the patient's health permits, the use of systemic sialogogues should be considered

long-term cohort studies that investigate the use of topical salivary substitutes and stimulators in patients for whom the discontinuation of drugs associated with xerostomia and hyposalivation is not realistic.

7 Conclusions

Salivary dysfunction is common in older adults. These conditions can alter oral function reducing older patients' quality of life. Hyposalivation is associated with caries and fungal infections. The etiology of xerostomia is diverse but in the older

patient is usually associated with multiple chronic comorbidities and the prescription of multiple drugs. Dentists and physicians must be aware of the symptoms and signs associated with xerostomia and hyposalivation. The treatment of salivary dysfunction should be individualized according to the identified causes. In the older patient, it is essential to attempt to minimize or eliminate risk factors and to avoid the use of systemic salivary stimulants due to their potential for adverse drug effects. More research is needed to further examine the impact of safe and effective treatment strategies for older patients with salivary disorders.

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Management of Periodontal Disease in Older Adults

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The health and oral health needs of individuals change across the life course. In the oral cavity, the newborn does not have teeth present in the mouth, the first primary teeth begin to erupt between 6 and 9 months of age, and usually the last of the primary teeth exfoliates at 11 or 12 years of age. Beginning with the eruption of the permanent incisors at age 6 or 7, the teeth of the permanent dentition will need to function for 70, 80, or more years and are used multiple times each day, under the harsh conditions of the oral cavity. The maintenance of a functional dentition as a person ages is dependent on many factors, including personal oral hygiene practices and lifelong access to professional dental care. A functional and esthetic dentition, free from infection and pain, allows mastication of a healthy diet and is essential to the physical and emotional well-being of older adults.

This chapter will discuss the management of periodontal disease in the older adult from a holistic perspective. The focus will be on the concerns faced by patients and providers when caring for the oral healthcare needs of older adult patients, with the emphasis on the patient, and less so on specific techniques and procedures. The context will be management of periodontal disease in consideration of overall health, which assumes a larger role as a person ages.

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1 Introduction

Globally, the prevalence of periodontitis is high. The Global Burden of Disease study identified severe periodontitis as the sixth most prevalent disorder across the globe [1]. Further, both the number of older adults (defined as 65 years of age and older) and the percentage of the population in high income countries that are in this category have increased dramatically in the last decade and are projected to continue to increase in the next few decades [2]. Since the extent and severity of periodontitis are more severe with age, identification and management of older adults with periodontitis is recognized as a significant global public health concern, and the prevalence of oral disease has not improved in the 25-year interval from 1990 to 2015 [3].

The United Nations highlighted this global population shift in its report "World Population Aging 2019" [4]. Highlights from that report include:

1. Almost all countries are seeing an increase in the number and percent of the population who are 65 years of age and older. The current global estimate of the number of older adults is 703 million people.
2. Longevity is also increasing across the globe. A person who reaches 65 years of age can expect to live another 17 years, and that number will increase in the future. Women outlive men by almost 5 years, but that difference will shrink in the future.
3. As populations age, the demands on the public health systems will also increase.
4. Population aging should be managed on the national level by certain policies targeting older adults, including promotion of healthy living, educational programs, universal healthcare, and a gradual rise in the traditional age of retirement.

In the United States, the aging of the population is a public health concern (Fig. 1). The percent of Americans who are 65 years of age and older has increased

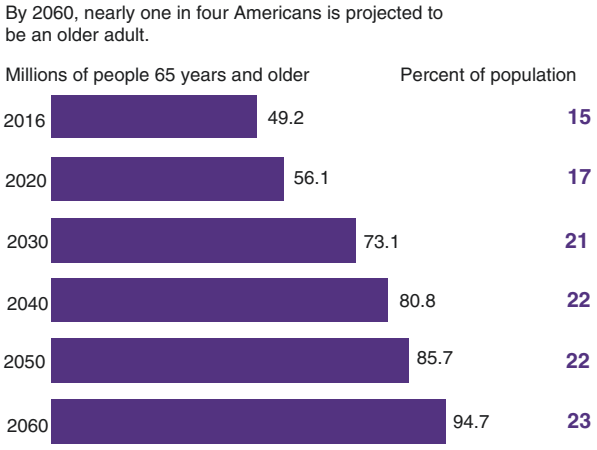

Fig. 1 Projections of the older adult population: 2020 to 2060. (Source: U.S. Census Bureau, 2017 National Population Projections; Vespa et al. [2])

dramatically. In 1960, only 9% of the population was 65 years of age and older. This percentage is projected to increase to 23% by 2060. By 2030, the percent of older adults in the population is projected to equal that of children and teenagers (21%). Further, the number of persons 85 years and older is projected to increase more than three times between 2014 and 2060, from 6 to 20 million [2]. For a more in-depth discussion on the topic, please refer to chapter "Epidemiology of Oral Health Conditions in the Older Population."

Regarding periodontitis, the prevalence in the United States is high and increases with age. The percentage of adults (30 years and older) with periodontitis has been estimated to be 42%, and almost 8% have severe periodontitis [5]. When examined by severity, the percent of individuals with any periodontitis, and the percent with moderate periodontitis, increases with increasing age, while the percentage with severe periodontitis increases until the early 50s and remains between 10 and 15% for older age groups. In addition to increasing age, other risk factors for severe periodontitis include race and ethnicity (Mexican American and non-Hispanic Black) and smoking [5].

Periodontitis is the major cause of tooth loss in older adults [6, 7] and loss of teeth can affect many aspects of a person's life. The ability to masticate normally is essential for consumption of a healthy diet. An intact and disease-free dentition allows for social interaction and avoidance of pain, resulting in better quality of life for older adults. Further, extensive oral disease, specifically periodontitis, has been associated with an increased risk of certain chronic diseases [8].

The importance of "Health in Aging" has been examined in a commentary that overviews the advances in our understanding of healthy aging [9]. Research in the past half century has led to a greater understanding of the biology of aging, how to differentiate aging from disease, as well as biological markers of the aging process. For many of the chronic health conditions that are more prevalent with aging, periodontitis has been documented as a risk factor, including cardiovascular disease [10], diabetes [11], respiratory disease [12], and Alzheimer's disease [13], or as a contributing factor in aging-associated disorders (i.e., frailty) [14]. These association studies have led to experimental studies that are identifying specific mechanisms that provide biologic plausibility for periodontitis as a risk factor for chronic diseases affecting older adults, for example, Alzheimer's disease [15]. For a more in-depth discussion on the topic of dementia, please refer to chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health."

A major emphasis is the need to reduce the period of disease so that the "health span" becomes as close as possible to the life span. This is an important concept for oral health. Further, Fried and Rowe [6] observed that health disparities will greatly influence this desired outcome. Disparities in access to oral healthcare and financial insecurity are major risk factors for oral diseases across the life course [16]. For a more in-depth discussion on the topic of health disparities, please refer to chapter "Health Disparities in Oral Health."

Periodontal disease, specifically periodontitis, is cumulative, and periodontal support for the dentition is reduced as a person ages, albeit at different rates for different individuals. Similar to many other chronic diseases that are common as a

person ages, periodontitis is a chronic disease with periods of exacerbation and remission, but with a trajectory that results in greater extent and severity of disease over time [17]. The result is loss of support for the teeth and ultimately abscess formation and discomfort, with eventual need for tooth extraction with the goal of eliminating infection. Once teeth are lost, replacement is generally required, and many options are available. However, the cost of the most satisfactory solution (dental implants and a prosthetic superstructure) is beyond the financial reach of most of the population even in high income countries and is limited to a very few individuals in low and middle income countries.

The management of periodontal disease/periodontitis in older adults involves consideration of many factors, including:

1. The status of the periodontium, and the dentition, as well as the general condition of the oral cavity including the mucosal surfaces and contiguous structures including the temporomandibular joints and muscles of mastication.
2. Health history/health status, with consideration of chronic diseases. Often consultation with other healthcare providers is necessary. Medication use, both prescription and over the counter, must be evaluated.
3. Dental history/dental status, including the frequency of visits to an oral healthcare provider, and the daily self-care (oral hygiene) regimen.
4. Social, economic, and individual considerations, including health literacy and financial security.

The goal of evaluation and planning is to create a personalized treatment approach that is both appropriate and achievable for each person.

2 Normal Oral Aging Versus True Oral Pathology

Aging is defined as the "process of growing old" but age and pathology are not synonymous. Specifically, it is important to distinguish between the concepts of "chronologic age" and "biologic age." In the former case, we are referring to the passage of time, typically in units of years, and it always increases at a set rate, i.e., an older person has more years lived than a younger person. In contrast, biologic age (also referred to as physiologic or functional age) considers factors besides date of birth such as genetics, lifestyle (exercise, weight, smoking), nutrition, and the presence of other diseases [18]. For a more in-depth discussion on the topic of age-related changes, please refer to chapter "Age-Related Changes in Oral Health."

We now understand that there are "young-old" people whose biological age belies their chronological age. This has spawned a new field of "geroscience" that seeks to understand the mechanisms that make aging a risk factor for chronic disease and that attempts to measure the rate of aging [19, 20]. Because there are often significant variations in the effects and rates of aging, chronologic age and biologic

age are often not aligned. This has significant consequences for the management of periodontal disease because treatment decisions should consider the individual variation in general health, host response, and disease expression [21].

Although with increased longevity there is an increased burden of oral disease (dental caries and periodontal disease), chronologic age alone does not have a negative influence on oral health [22]. It is therefore important to distinguish between normal effects of aging and oral disease [23]. In an older adult, normal signs of aging in the mouth would include up to 3 mm of buccal gingival recession, enamel wear and erosion, staining of any fracture lines, and darkening of teeth due to deposition of secondary dentin and enamel thinning [23]. However, in contrast to commonly held notions and beliefs, tooth loss is not a normal consequence of aging [24]. It is not age alone but the cumulative effect of other chronic systemic conditions (i.e., diabetes, osteoporosis), immunologic changes, pharmacologic interventions, functional limitations, and cognitive impairment which may have a negative effect on oral health. Personal situations, including health literacy and self-care, as well as access to professional oral healthcare, also play important roles. For a more in-depth discussion on these topics, please refer to chapters "Health Disparities in Oral Health", "The Role of Oral Health Literacy and Shared Decision Making", and "Barriers to Access Dental Care."

2.1 Salivary Function

Studies have shown that salivary function is well preserved in geriatric populations [25]. Xerostomia (dry mouth) is a condition that is often associated with old age, but it is not a consequence of aging in healthy older adults [26]. The most common cause of xerostomia in older adults are medications such as anticholinergics, tricyclic antidepressants, sedatives and tranquilizers, antihistamines, antihypertensives, and diuretics, which can dry out the oral mucosa and lead to problems with swallowing, mastication, communication, and denture retention [27, 28]. Other causes of xerostomia include several systemic conditions such as Sjogren's disease, HIV/AIDS, diabetes mellitus, and head and neck radiation therapy. A reduction in salivary production impacts the older adult with periodontitis since gingival recession accompanies loss of tooth support, exposing caries-prone root (cementum) surfaces. Overall, quality of life is greatly impacted, and individuals with dry mouth are at increased risk for dental caries, oral candidiasis, and other mucosal disorders. This becomes an even greater concern in older adults, who experience increased severity of periodontitis, accompanied by gingival recession and exposure of vulnerable root surfaces. It is therefore important for clinicians to recognize that dry mouth, although very common among older adults, is not a natural condition of aging and that the appropriate diagnosis must be ascertained to prescribe the appropriate therapy. For a more in-depth discussion on the topic of xerostomia, please refer to chapter "Xerostomia and Hyposalivation."

2.2 Periodontitis and Tooth Retention

Regarding the periodontium, recent surveillance from the National Health and Nutrition Examination Survey (NHANES) has shown that mild and moderate periodontal disease prevalence increases with age due to the cumulative nature of the disease, but interestingly, severe periodontal disease is not associated with increasing age. Periodontitis of moderate severity accounts for the majority of the age-related increase in the prevalence of periodontitis, whereas severe periodontitis prevalence is consistent at 15% or less, even among individuals 65 years and older [5]. This finding is likely attributable to the loss of the teeth at greater risk for periodontitis, and lost teeth are not generally included in periodontal indices.

Healthy aging is associated with good oral health [29]. A study of the oral health of centenarians and their offspring suggests that good oral health is a marker for systemic health and healthy aging [30]. In the Baltimore Longitudinal Study of Aging (BLSA) cohort, researchers found that there was substantial resiliency of the oral cavity during aging and that the oral cavity of healthy older people was comparable to that of healthy younger adults [31]. A study of the association between periodontal disease and mortality from all causes in the VA Dental Longitudinal Study concluded that periodontal status at baseline was a significant and independent predictor of mortality [32]. An interesting dichotomy is at play because aging alone does not contribute to oral pathology, but oral health does affects aging. It appears that it is not just that systemic disease influences oral health but that oral health influences certain chronic diseases [33, 34]. A pro-inflammatory phenotype is believed to be the mechanism underlying associations between periodontal disease and systemic diseases [35]. As noted, the severity of periodontitis is associated with an increased risk for diseases such as cardiovascular disease, diabetes, respiratory diseases, and Alzheimer's disease, as well as certain cancers, specifically lung and colorectal [36, 37].

2.3 Masticatory Function and Cognition

It is not only physical health but also mental health that plays a major role in healthy aging. Cognitive decline is a major concern among older adults, and its impact on oral health has been examined in several studies, although findings are not consistent. The interpretation of these studies is limited due to the bidirectional nature of poor oral health and impaired cognition, i.e., periodontal disease and tooth loss may be both risk factors for cognitive decline and consequences of cognitive decline. A recent systematic review assessing the relationship between oral health and cognitive function in older adults found that there was an association with specific domains of function such as learning and memory, complex attention, and executive function [38]. In the Atherosclerosis Risk in Communities (ARIC) study, a national prospective study of vascular disease among community-dwelling middle-aged

adults (45–64 years old), they assessed a 6-year change in cognitive function and multiple oral health measures and behaviors [39]. All measures of cognitive decline were associated with increased odds of tooth loss, but they cautioned that because this was a cross-sectional analysis, the association between cognitive decline and oral health could represent associations in either, or both, directions [39]. A later study of the ARIC cohort, with a final sample of 911 individuals, concluded that although complete tooth loss was significantly associated with lower cognitive performance, the number of teeth and periodontal disease did not predict subsequent cognitive decline over an 8-year period. This contrasts with other studies that have suggested that tooth loss was associated with an increased risk of both dementia and cognitive decline [40]. A mechanism to account for periodontal disease as a direct contributing factor in dementia has been described. Using both murine models and human postmortem tissue samples, the major periodontal pathogen *Porphyromonas gingivalis* and specifically proteases known a gingipains have been identified as etiologic factors in Alzheimer's disease [15].

Increasingly the importance and contribution of masticatory function to oral health and overall health has been examined (Fig. 2). Among older adults, periodontal disease is the greatest cause of masticatory dysfunction [41]. Some recent studies suggest that masticatory dysfunction due to tooth loss and/or muscle weakness may in fact be a risk factor for dementia [41, 42]. Without adequate mastication, there is a lack of stimulation of the central nervous system which leads to atrophy of the hippocampus, the area of the brain which controls learning and memory [43].

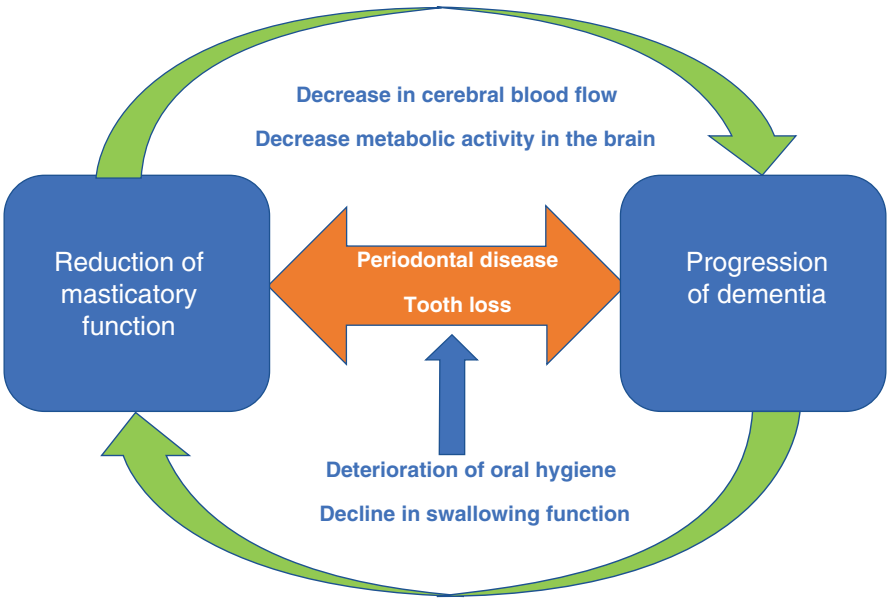

Fig. 2 Relationship between dementia and masticatory function. (Modified from Watanabe et al. (2015). Source: Watanabe et al. [41])

Animal studies support a reciprocal relationship between cognition and mastication such that a decrease in masticatory function due to tooth loss or soft diet may have negative consequences on aspects of cognitive health including spatial memory and learning ability [44]. There are some studies in humans; however, longitudinal studies are necessary to confirm a causal relationship as an explanation for the relationship between masticatory dysfunction and cognitive decline as many factors, including other comorbidities, nutrition, and reverse causation, may be at play.

3 Management of the Older Patient with Periodontal Disease

Periodontal disease is chronic, and the loss of soft and hard tissues is cumulative over the patients' lifetime [45, 46]. Older adults, thus, might present with more advanced cases of attachment and bone loss. The prevalence of periodontitis across the globe is high [1]. Severe periodontitis is most prevalent among adults 65 years or older, Mexican Americans, non-Hispanic Blacks, and smokers [5]. Dental practitioners should be aware of the high prevalence of periodontitis in US older adults and provide preventive care and counseling for this disease. In some cases, general dentists who encounter patients with periodontitis may refer these patients to see a periodontist for specialty care [5]. It is important, as for any patient and at any age, to properly diagnose and treat active periodontal disease as well as to correctly diagnose and maintain periodontal health on a reduced periodontium [47] (Fig. 3). The overarching goal should be to stabilize the periodontal condition by encouraging highly effective home self-care by the patients (or their caregivers when appropriate), eliminating areas of tissue inflammation and more involved periodontal defects, as well as ensuring frequent follow-up and professional maintenance visits. The treatment protocols for reducing inflammation and controlling periodontal disease are very similar in older adults to younger patients and should follow the same rationale [46, 47] (Fig. 4). Special attention should be paid to the manual dexterity of the patients to perform and maintain plaque control at home. Special aids should be provided and practiced individually to make sure proper home self-care is feasible and highly effective [47–50].

In recent years, there has been significant debate over the timing of recall intervals for dental appointments. Maintenance and recall visits should be individually tailored with consideration of the periodontal status, previous attachment loss, home self-care effectiveness, and adherence of the individual [50, 51]. Any deficiencies or concerns in the above parameters should prompt shorter intervals between recall and maintenance visits. The National Institute for Health and Care Excellence (NICE) in the United Kingdom issued guidelines for establishing individualized dental recall intervals [52]. For adults (18 years of age and older), the frequency was suggested to range between 3 and 24 months, dependent upon disease activity and risk factors. For older adults, however, those guidelines may not be appropriate, considering the multitude of factors that must be considered. Rather, consideration should be given to a frequency ranging from 1–2 months, when oral disease is advanced or when proper plaque control is difficult to achieve, to 6–12 months in very

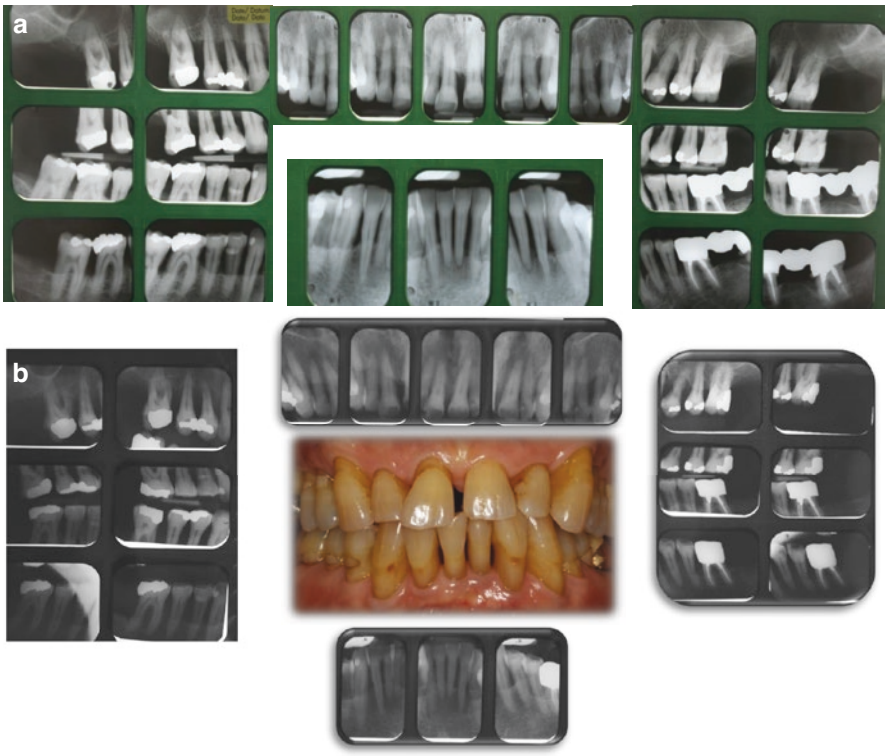

Fig. 3 A 76-year-old patient diagnosed with severe periodontal disease (**a**). Ten years following periodontal treatment (**b**), the dentition is stable, and the patient is well-maintained with no deep pockets or bleeding on probing

well-maintained and periodontally healthy individuals (Fig. 5). Factors that should be accounted for when recommending the frequency of maintenance visits include, among others, (1) oral hygiene and tobacco and alcohol consumption, (2) systemic risk and complicating factors that may influence the patient's periodontal health and their implications, (3) the outcome of previous care episodes and the suitability of previously recommended intervals, (4) the patient's ability to visit the dentist at the recommended interval, and (5) the financial costs to the patient [51]. It is important to realize that older individuals, with increasing complexity of oral and systemic conditions as well as, sometimes, decreasing ability to perform proper home self-care, will require more frequent maintenance visits.

Increasing patient knowledge of risk factors, their ability to modify risk, and providing a way for patients to quantify their risk empower patients to control their periodontal status and might help raise awareness and increase adherence. Some of the risk factors are modifiable, but others are non-modifiable, yet all need to be considered and explained to the patient. For example, plaque control by oral hygiene adherence and effectiveness is a major risk factor for periodontal disease that can be modified with proper education and training. Other risk factors are modifiable but with input from other healthcare providers. Uncontrolled or poorly controlled

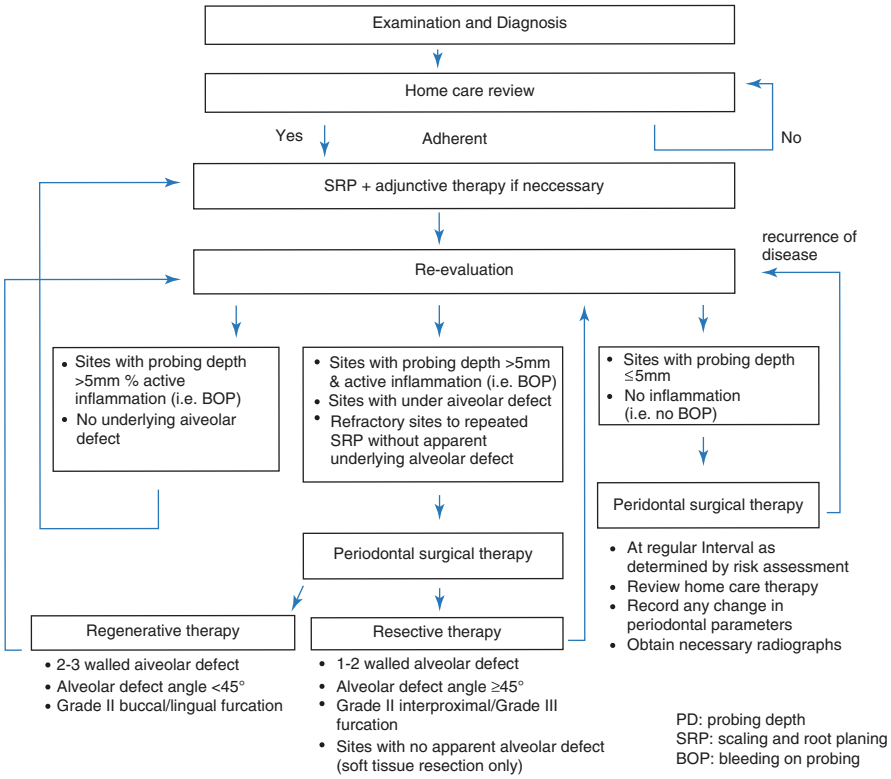

Fig. 4 A decision tree for treating a patient with periodontitis. (Reproduced with permission from Kwon et al. [46])

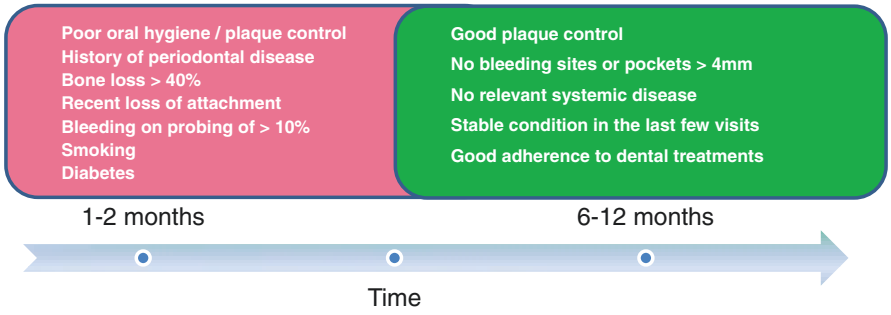

Fig. 5 Factors to be considered when determining frequency of periodontal maintenance visits. The frequency should range from 1–2 months in severe cases or in cases where proper plaque control is difficult to achieve (red box) to 6–12 months in very well-maintained and periodontally healthy individuals (green box)

diabetes is a risk factor for periodontitis, and improved glycemic control will both lessen the risk for systemic complications of diabetes and the risk of further progression of periodontitis [53]. In contrast, there is certainly a genetic component to periodontitis, which is non-modifiable [54]. Consequently, it becomes even more critical to emphasize modifiable risk factors. Goal setting has been recognized as a useful technique for improving oral health, and motivational interviewing is a broader technique that is also valuable in periodontal treatment [55].

4 Social Support and the Periodontium in Older Adults

There is ample evidence in the literature to suggest that social networks and connectedness are important determinants of good health and successful aging [56]. Social support is a modifiable risk factor for disease and thus can and should be addressed in the plan for an older individual's general as well as periodontal health. For older adults who may have limited social networks, this is an area where teledentistry may provide a crucial role and link to healthcare.

Although social support has long been recognized as an important determinant of general health (cardiovascular disease, pulmonary disease, mental health), research has increasingly recognized the impact of social support on clinical measures of oral disease, including periodontitis. Broadly defined, social support systems, also known as social networks, refer to the quality and quantity of social relationships that an individual has in their lives [57].The mechanism by which these networks affect health has been attributed to social norms, the diffusion of health-related knowledge, as well as stress resilience [58].

A few studies, including one of the English Longitudinal Study of Aging (ELSA) cohort, have found an association between structural social support and the number of remaining teeth among older adults [58, 59]. A recent study of individuals of Hispanic/Latino heritage found that US-born individuals with larger social networks had 17% lower odds of moderate-severe periodontal disease than those individuals born outside of the United States [60]. This protective effect of social capital on periodontal disease among the US Hispanic population is supported by other research and suggests that immigrant groups may be at higher risk of periodontal disease due to lack of social connectedness [61, 62].

5 Preserving Teeth or Placing Implant

In the past few decades, dental implants have assumed a fundamental role in periodontal therapy. Dental implants have consistently gained in popularity among providers and patients, sometimes at the expense of treating periodontal disease and retention of teeth. For the older adult population, it is very important to consider several important parameters before deciding to extract a tooth and replace it with a

dental implant. There are various considerations when suggesting that older adults proceed with dental implant treatment. These factors include the ability to perform and maintain proper plaque control, the actual need for the implant, some common risk factors for periodontal disease and dental implant failure, as well as the risk for peri-implant diseases. It is also of utmost importance to define and explain the planned maintenance protocol to limit future complications.

5.1 Plaque Control: Current and Future

Plaque control is the most important determinant of long-term success of dental implants [63–65]. Adequate plaque control should be achieved and maintained prior to as well as following dental implant placement. It is important to review and practice home self-care measures prior to placement of dental implants to all patients, but this is even more important when treating an older population that will present with comorbidities and reduced manual dexterity needed to maintain proper plaque control. Proper instruments should be provided and recommended to older individuals who have difficulty using traditional cleaning aids. These might include large-handle toothbrushes, special interdental cleaning aids, and electric toothbrushes. In other cases, the caregivers will play a crucial role in maintaining proper plaque control, and they should be instructed and guided on how to perform proper home self-care. It should be emphasized that the teeth being replaced were lost for a reason, and in most cases, the reason is plaque-related dental diseases. Since plaque control is a crucial component in implant success, proper home self-care practices need to be established prior to implant placement to avoid implant complications that result from the same poor self-care habits that led to the loss of teeth.

When extraction of all teeth is planned, and implant treatment will be provided in the future, the situation allows for observation of the level of self-care. The extractions can be delayed, and the existing detention can be used to educate the patient about plaque control. When there is need for total clearance, the patient probably lost their teeth due to oral disease linked to poor plaque control. If this habit is not corrected, the risk for implant complications or failure increases.

5.2 The Need for Tooth Replacement

The need to provide a dental implant in place of a missing tooth should be carefully assessed and explained to the patient. A single posterior tooth that was missing for years with no apparent consequences might be a good example of a case where an implant is not necessarily indicated. It is well established that, in some cases, bicuspid occlusion or shortened arches can provide proper support for dental and oral functions, and these options should be kept in mind when approaching

patients with missing teeth [66]. It was suggested that preserving 20 or more teeth (bicuspid occlusion) enables functions like biting, chewing, and enjoying almost all foods, regardless of the texture. This was established as a goal in some countries to encourage tooth preservation and proper dental care [67]. This concept has been shown to be well-accepted by dental providers and patients, and an analysis of nine systematic reviews concluded that this concept provided satisfactory function [68, 69]. This treatment approach was also determined to be cost-effective [70]. However, support is not universal [71], and there is a need for more long-term studies [68].

Many older patients will present with long-term partial edentulism, and their presenting condition should serve as evidence for the individual need for tooth replacement. The opposing dentition should also be examined carefully when determining the need for a dental implant. It is important to remember that a dental implant is a surgical procedure with possible short- and long-term complications [49, 63, 72], and therefore indications should be carefully weighed in consideration of possible adverse effects.

5.3 The Bone and General Healing Capacity of Older Adults

Overall, studies indicate that implants can be successfully placed in older adults. Since older adults might present with impaired healing capacity due to systemic diseases and altered metabolism, the osseointegration process as well as the soft tissue response around dental implants might be jeopardized. Further, all three stages of gingival/oral mucosal wound healing (inflammation, tissue formation, and remodeling) have been shown to be adversely affected by aging [73]. A variety of factors are involved in the long-term success of the implant, and special consideration should be taken prior to placing implants in older adults to limit the influence of those risk factors [74, 75]. Systemic conditions such as diabetes, osteoporosis, and other diseases that impair bone and soft tissue healing might delay or jeopardize implant success and survival. Specific treatments such as treatment with bisphosphonates might also lead to short- and long-term complications following surgical interventions, and thus, a thorough medical history is of utmost importance.

5.4 Other Diseases and Conditions that Might Influence Success (Diabetes, History of Periodontitis)

Common risk factors for periodontal disease and tooth loss as well as long-term implant survival were discussed previously. While aging itself is not considered a risk factor for implant loss [76], older individuals with a history of periodontal

disease are at greater risk for implant failure over time [77–79]. These factors should be all taken into consideration when developing a treatment plan.

5.5 Maintenance Protocol

As discussed above, a maintenance protocol should be tailored to each patient according to an individualized assessment of existing severity of disease, identifiable risk factors, and home self-care and personal characteristics. Patients, especially older adults with dental implants, should be seen more frequently for maintenance visits to maintain adequate health of the dentition as well as to detect and treat early complications as soon as possible [49, 77]. While it is recognized that dental implants and the natural dentition have some important differences in their biologic characteristics, this risk profile should be considered when developing the maintenance protocol for patients with dental implants [80].

5.6 Consideration of Future Implant Complications

While a clinician may observe that an implant is an excellent option when compared to a tooth demonstrating advanced periodontal involvement or extensive caries, the need to consider the possibility of future implant complications is part of the treatment planning process. Peri-implant diseases are becoming more prevalent, and management of these complications, including implant failure, should factor into the treatment approach. A history of periodontal disease is a risk factor for the development of peri-implant disease [81] and should be taken into consideration since many older adult candidates for implant placement have lost their teeth due to periodontitis.

Peri-implant diseases are inflammatory conditions affecting the soft and hard tissues around dental implants. The main clinical characteristic of *peri-implant mucositis* is bleeding on gentle probing where erythema, swelling, and/or suppuration may also be present. *Peri-implantitis* is a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone [82]. Peri-implant complications is a rather new concern, and its prevalence is increasing in recent years [82]. Older adults might be at increased risk for peri-implant diseases [80, 83]. Prevention is the most effective way to mitigate peri-implant disorders, and this begins with proper home self-care and regular professional care. Regular care will also allow for early detection of the disease [65, 84]. Since there is currently no “gold standard” of treatment for peri-implantitis lesions, prevention and early detection are of primary importance.

6 The Dental Office as a Point of Care in the Management and Screening for Systemic Disease

The dental office offers potential as a health location to promote general health and provide screening opportunities for conditions other than oral diseases [85]. Integration of dental professionals into the larger medical care system could advance efforts to identify and control prevalent conditions such as cardiovascular disease, diabetes mellitus, and respiratory disorders, each of which is associated with significant morbidity and healthcare costs [86]. Studies have suggested that a dental office is a suitable setting for the purpose of screening and referrals for these conditions and may result in medical expenditure savings [86–88]. The identified relationship between periodontal diseases and certain chronic systemic conditions should be emphasized and taken into consideration when treating the older adult with periodontitis.

Dental professionals can identify patients who are at risk for chronic systemic diseases and may otherwise not have the opportunity for screening [89, 90]. As an example, assessment of hyperglycemia in clinical dental settings has been widely studied and been found to be effective in identifying patients with previously unidentified hyperglycemia (glycated hemoglobin in the pre-diabetes and diabetes range) [91]. Referral to a medical provider for follow-up evaluation is an essential part of this new professional responsibility.

Promoting oral health might have a significant influence on general health as well, especially regarding cardiovascular diseases and diabetes. In a recent study which assessed the impact of periodontal treatment on diabetes-related healthcare costs in patients with diabetes, it was recommended that periodontitis, a possible complication of diabetes, should receive appropriate attention in diabetes management. The fixed-effect models showed −€12.03 (95% CI − €15.77 to −€8.29) lower diabetes-related healthcare costs per quarter of a year following periodontal treatment compared with no periodontal treatment. The findings of this study provide corroborative evidence for reduced general healthcare costs associated with conservative periodontal treatment in patients [92]. The staff at the dental office can also provide advice and help with other general preventive measures such as dietary consults and lifestyle changes to promote general health. Delivering a global message of overall health promotion may also make it easier to highlight the importance of oral health maintenance [88].

7 Conclusions

In the past, there was a common belief that tooth loss was part of aging, like hair loss, facial wrinkles, and other obvious signs of aging. Furthermore, patients sometimes would easily accept treatment plans that included tooth extraction. That is now changing, as many members of the generation born after the Second World War have enjoyed regular dental care and a complete or near-complete dentition as they age. As a profession, dentists and dental hygienists must constantly emphasize the

importance of prevention of dental caries and periodontal diseases and dispel the notion that tooth loss is expected as a person ages.

This is an illogical situation. If a patient is told that a toe needed to be lost, they would demand an explanation and understand how they can prevent similar outcomes in the future. The emphasis on prevention of tooth loss did not exist in the past, but that is changing, and must be consistently reinforced. Patients lose teeth due to caries or periodontal diseases, both of which are plaque-induced and generally preventable. By truly emphasizing prevention, perhaps in the context of a general healthy lifestyle, oral healthcare professionals can change patients' perception and behavior [93]. In that sense, all dental practitioners must be aware of the unique challenges that present when caring for the oral health of older patients. This will require additional emphasis in both pre-doctoral and post-doctoral education.

One critically important consideration is the ability of older adults to afford dental care services. In the United States, dental insurance is often a benefit of employment and is lost when a person retires. The definition of "older adult" has tended to focus on 65 years of age, which is the age when US citizens often consider retirement and become eligible for Medicare insurance. Medicare provides medical benefits but very limited dental benefits and then only for "medically necessary services." Routine preventive dental care is not covered (https://www.medicare.gov/coverage/dental-services). In the United State, less than 30% of older adults have dental insurance [94]. Therefore, retention of teeth, with a focus on teeth at increased risk of being lost due to periodontitis (maxillary and mandibular molars), should begin early in life and be re-assessed as a person enters their adult years. Consequently, older adults are faced with significant out-of-pocket expenses when accessing dental services. This occurs at a time when financial resources are fixed, and the additive effects of dental disease may require more care than earlier in life.

The need for inclusion of oral health benefits for older adults in national health plans must be a part of the solution to the high prevalence of dental disease in older adults [95]. The emphasis on improving the oral health of children in the United States has not been realized by middle-aged and older adults [95, 96]. In the United States, the effort to add basic oral health benefits into the Medicare program is gaining traction [97] with the compelling arguments of improved oral health and quality of life for older adults, as well as the potential for substantial savings in healthcare expenditures [92, 98]. These benefits are primarily associated with the provision of preventive periodontal services. Oral healthcare professionals and dental professional organizations must lead the effort to enact this change.

In conclusion, research and clinical developments over the past 20 years have led to a re-evaluation of the approach to the management of the older patient with periodontitis. The identification of periodontitis as a risk factor for many chronic diseases, as well as the impact of certain chronic diseases and environmental factors (i.e., smoking) on the progression and management of periodontitis, requires a thorough understanding of these conditions, often in close consultation with other healthcare providers. Paradoxically, this situation is complicated by the success realized in reducing tooth loss, resulting in older adults with a greater number of

teeth at risk for progression of periodontitis. Further, a reduced or disease-affected detention will negatively impact the quality of life of older adults.

The concern over the available resources to pay for periodontal care further complicates clinical management. The result is the need to develop individualized treatment approaches for each patient. Therefore, these considerations require a comprehensive, multidisciplinary, and interprofessional approach that can redefine the practice of dentistry in a context of health.

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Management of Caries in Older Adults

Gerry McKenna, Martina Hayes, and Cristiane DaMata

1 Global Epidemiology

Globally we are seeing the effects of an aging population. In many high income countries, as birth rates fall and life expectancy increases, the proportion of older adults within the general population has increased significantly. As fertility rates move towards lower levels, mortality decline, especially at older ages, assumes an increasingly important role in population aging. In low and middle income countries, where low fertility has prevailed for a significant period of time, relative increases in the older population are now primarily determined by improved chances of surviving to old age [1]. Over the next 50 years, life expectancy at birth is projected to increase globally by 10 years, to reach 76 years in 2045–2050. By the end of the next quarter century, life expectancy at birth is expected to reach, on average, 80 years in the more economically developed regions and 71 years in the less economically developed regions. As a result of the generalized shift in the age distribution of mortality towards older groups, more people will survive into their seventh, eighth and ninth decades around the world [2].

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2 The Oral Health of Older Adults

Epidemiological dental surveys from around the world clearly indicate that tooth retention has increased significantly amongst older adults as they retain their natural teeth into old age [3]. Unfortunately, the cumulative nature of the two main destructive dental diseases: caries and periodontitis, dictate that aging is always likely to be a factor associated with total tooth loss particularly amongst patients in lower socio-economic groups [4]. Clear socio-economic gradients in complete tooth loss have been identified in many countries, including the United Kingdom, Japan, Korea and in Scandinavia [3, 5–7].

Although the overall prevalence of total tooth loss has fallen sharply over recent decades, many patients now become edentate at an older age when they are generally less able to adapt to the limitations of complete dentures. The attitudes of older patients to oral health also appear to have changed as many take advantage of widely available sources of information and demand more from the dental profession. As a result, increasing numbers expect conservative treatment approaches rather than those previously centered around extractions and subsequent replacement of natural teeth [8].

While increasing tooth retention is seen as a leap forward in the oral health of the older population, it also brings with it the challenges of managing chronic dental diseases, including caries and periodontal disease. Due to factors, such as diet, reduced manual dexterity and xerostomia, these chronic diseases can cause considerable pain and suffering amongst older patients and impair oral function [9]. Dental caries remains a problem for this age group with a high prevalence of coronal and root surface caries found amongst old-age populations [10, 11]. In the 1998 UK Adult Dental Health Survey, the proportion of adults with 18 or more sound and unrestored teeth was only 5% amongst those aged 55 years and over [12]. The 2009 UK Adult Dental Health Survey indicated that this figure had improved but still remained at only 13% [12, 13]. The 2009 UK Adult Dental Health Survey reported that 27% of adults aged 65–74 years had evidence of dental caries whilst this figure increased to 40% for those aged 75–84 years [13].

The 1998 UK Dental Health Survey showed that almost 25% of the older adults had 12 or more teeth with a root surface that was either exposed, worn, filled or decayed [12]. The 2009 Survey reported that 73% of all adults had exposed root surfaces, and this increased to 90% for those aged over 55 years. The same survey reported that 11% of 55–64 years old had active root caries compared with 20% of those aged 75–84 years [13].

3 Oral Health in Long-Term Care Facilities (LTCFS)

It is widely reported that the oral health status of older adults within LTCFs is significantly worse than their community living peers [14]. With increasing age, the ability to care for their mouth deteriorates: polypharmacy leads to xerostomia, and

diets can become rich in sugars, while good daily oral hygiene is essential for the maintenance of complex dental restorations. All these factors increase the risk of oral disease and directly impact comorbidities.

Unfortunately, a growing proportion of residents in LTCFs are unable to self-care, and with increasing dependency, oral hygiene practices present a significant challenge. Current prevention practices and service provision in LTCFs is often poor. Challenges include inadequate resources and training, and these are compounded by high staff turnover. There is a significant difficulty in obtaining routine dental care due to the very complex needs of institutionalized older people, with a significant proportion suffering from cognitive impairment and dementia. Access to domiciliary dental services is often limited with subsequent admission to hospitals for dental problems which can be distressing for individuals and their families and very costly to the healthcare provider [2].

Within the United Kingdom, the National Institute for Health and Care Excellence (NICE) publishes evidence-based guidelines on all aspects of healthcare. In 2016, NICE published 'Oral health for adults in care homes (NG48)' which included a series of recommendations for LTCFs, including improving access to dental services for LTCF residents, improving the oral health knowledge and skills of care home staff and the implementation of oral health assessments, mouth care plans and daily oral care for all residents [15]. However, adoption of these recommendations has been challenging in many LTCFs as demonstrated by follow-up surveys in the United Kingdom [16]. For a more in-depth discussion on the topic of long-term care, please refer to chapter "Oral Care in Long-Term Care Settings".

4 Dental Caries

Dental caries is a multifactorial, bacterially mediated process that results in the destruction of mineralized tooth tissues. In light of the emergence of the partially dentate older population, there is a need for clinicians to understand the caries disease process in order to establish effective preventive and management regimes. However, older patients can present with some unique etiological considerations which increase their risk of developing dental caries particularly on the root surface [17]. Root caries as 'a cavitation below the cement-enamel junction (CEJ), not usually including the adjacent enamel, usually discoloured, softened, ill-defined and involving both cementum and underlying dentine' [18]. The root surface may be particularly vulnerable to mechanical destruction compared to enamel due to differences in the structure and chemical composition of cementum and dentine. In a population who are frequently exposed to scaling by dental health professionals, the cementum layer is frequently abraded away, exposing the dentine (Fig. 1). Root cementum and dentine are structurally different from enamel and react differently to cariogenic challenges – of note the critical pH of dentine and cementum is approximately 6.4 while that of enamel is 5.5.

Fig. 1 Exposed root surfaces in a partially dentate older patient

Fig. 2 Root caries in a partially dentate older patient

Fig. 3 Root caries in the abutment teeth for a removable partial denture

5 Diagnosing Root Surface Caries

The most common clinical descriptors of root caries are visual-tactile changes in the root surface (Figs. 2 and 3). Colour can range from tan to brown to black, and while color change is indicative of root caries, no correlation has been shown between color and lesion activity. Texture appears to be a better indicator of lesion activity, with active lesions being less resistant to gently probing than quiescent or

arrested lesions [19]. Many root caries lesions develop on the proximal surfaces and up to 20% can occur subgingivally [20]. These areas are challenging for the clinician to visualize and to access with a probe. As a result, lesions are often not detected at an early stage. The lesions tend to spread in a wide, circumferential pattern and pain is not a feature until an advanced stage. Frustrating for the dentist and the patient, the first sign of root caries may be a catastrophic fracture of the tooth at the gingival level. The difficulties of detecting this disease in its early stages is a considerable challenge.

6 Risk Assessment

A caries risk assessment should be a part of information gathered in treatment planning for all patients. Given the challenges in detecting root carious lesions early, particular efforts should focus on identifying those older adults at high risk of developing root caries and implement appropriate risk reduction measures. Root caries is a preventable disease; however, access to care, adherence issues, and cost may preclude the use of a preventive intervention on the entire older adult population. This means that one-third of the older adult population bears much of the root caries burden [21]. Therefore, if these individuals could be identified prior to developing the disease, targeted prevention measures could be delivered. A systematic review of root caries risk indicators found that the best predictor of future root caries development was a history of past root caries disease [22]. The clinician should treat any individual with a filled or decayed root surface as a high-risk individual for future disease. Other risk factors which have been identified include older age, number of teeth present, poor plaque control, and wearing removable partial dentures [23].

7 Caries Prevention Strategies for Older Adults

7.1 Oral Hygiene Advice for Older Adults

Beyond the oral cavity, many older people also carry the burden of systemic medical conditions [24]. These can diminish the priority for optimal oral hygiene in the daily routine of some older patients, while others will be dependent on caregivers for mechanical cleaning of the teeth. Many older adults are prescribed a large number of daily medications (polypharmacy), and xerostomia is a side effect of many commonly prescribed drugs [25]. Dry mouth is a major risk factor for dental caries as the protective lubrication of saliva has been removed. For a more in-depth discussion on the topic, please refer to chapter “Xerostomia and Hyposalivation”. Loss of manual dexterity, secondary to arthritis or neuromuscular degeneration, presents many older patients with an additional obstacle in maintaining adequate plaque

control. Something as simple as holding a toothbrush can be difficult, and manipulation of dental floss or other intricate interdental cleaning aids becomes impossible. Diminishing eyesight can also hinder proper oral hygiene technique. Some patients may be embarrassed to admit to any decline in physical capabilities, and oral health can suffer significantly before appropriate assistance is provided by a caregiver. Dentists and dental hygienists should consider this possibility if they observe a decline in oral hygiene in an older patient and highlight aids such as toothbrush grips, electric toothbrushes and holders for interdental floss and mouthwashes [26].

The simplest home-based measure to reduce caries risk is to incorporate a high-fluoride mouthwash into the daily routine. These are easy to use and do not require a high level of manual dexterity. Alcohol-free mouthwashes are more suitable for patients with dry mouth, and there are a number of mouthwashes specifically formulated to ease the symptoms of xerostomia. Patients should be advised to avoid using carbonated drinks or acidic sweets to alleviate their dry mouth; instead, providers should direct them to an alternative such as sugar-free chewing gum. While many older patients will be aware of the role of sugar in dental disease, the dangers of acid erosion may be less well known amongst this group.

7.2 Fluoride Interventions

High-fluoride mouthwashes can provide an additional source of fluoride, and daily use of 0.2% sodium fluoride mouthwash is frequently recommended for patients judged to be at high risk of developing caries. It may be preferable to ask patients to use the mouthwash at a different time to tooth brushing. This will allow spacing of fluoride exposure throughout the day to maximize its benefit; after lunch or dinner may be suggested as a suitable time to flush out any food debris. High-fluoride toothpaste may also be a useful preventive tool for older patients at high risk of developing caries. A meta-analysis of six randomized controlled trials demonstrated that 2800 ppm fluoride toothpaste resulted in significantly lower caries incidence compared to a 1100 ppm fluoride control [27]. As patients are well used to using toothpaste, a change to a high-fluoride toothpaste should be easily tolerated and 5000 ppm formulations are also available. High-strength-fluoride toothpastes should be kept out of reach of young children, and patients should be encouraged to expectorate after brushing, particularly where assisted toothbrushing is facilitated by a caregiver [28].

7.3 Chlorhexidine Interventions

Older adults often experience more rapid plaque accumulation than younger adults due to the dual effects of gingival recession and reduced salivary function. A number of studies have demonstrated the effectiveness of chlorhexidine 0.12% mouthwash in LTCFs Term Care Facilities to aid oral hygiene and, despite the potential for

staining, is a very useful adjunct in older adults who have difficulty in maintaining adequate plaque control through brushing alone. Chlorhexidine works best on a plaque-free surfaces to prevent plaque reforming, but it can also be effective in the presence of plaque [29]. Chlorhexidine mouthwash should be used at a different time to toothbrushing as many brands of toothpaste contain sodium laurel sulphate – a detergent which inactivates chlorhexidine.

7.4 CPP-ACP Intervention

A topical paste containing bioavailable calcium and phosphate has been commercially developed as Recaldent™, which is sold as Tooth Mousse® or as MI Paste Plus® (in combination with 900 ppm fluoride) (GC Corporation, Japan). As it is derived from milk casein, all potential users of Recaldent™ products should be questioned about any possible IgE-mediated casein allergies. These products can be applied at night-time after toothbrushing, and the manufacturers advise application of a pea-sized amount to each arch using a clean dry finger. The paste must be held in the mouth at least 3 minutes, as the longer it is maintained in the mouth with saliva, the more effective it is. After spitting out, patients are advised not to eat or drink for 30 minutes, and rinsing is to be avoided.

7.5 Professionally Administered Interventions

For older patients with a high caries rate or poor adherence with oral hygiene instruction, there are a number of surgery-based interventions available to reduce caries risk. The incorporation of chlorhexidine, fluoride and silver diamine fluoride (SDF) varnishes in the control of dental caries in older patients is a relatively recent development. A protective non-invasive medicament for preventing root caries lesions is of particular interest due to the nature of this destructive dental disease. A recently published systematic review and meta-analysis concluded that SDF provided a protective impact on root caries lesions after 24 months [30]. The application of varnishes is simple, quick and non-invasive and can be used in a domiciliary setting to reduce the development of new caries lesions [31]. Furthermore, it reduces dependence on patient adherence for success, and treatment can be provided by dental care professionals.

8 Challenges in the Operative Management of Root Caries

Root caries lesions may exhibit mixed cavity margins positioned in enamel as well as dentine [32]. Restoration of this cavity type is challenging with respect to the lack of restorative materials, which bond equally well to both dental tissues. The evidence

base for the selection of restorative material for the restoration of a root surface lesion is neither plentiful nor convincing. Most of the scientific literature examines lesions restored with amalgam, glass ionomer cement (GIC), resin-modified glass ionomer cement (RMGIC), modified polyacid resins ("compomers") or composite resins. A systematic review published in 2016 concluded that there was insufficient evidence to recommend any specific material [33]. However, failure rates of root caries restorations across all materials were extremely high; 82% of GIC restorations were considered a "failure" after just 24 months. A total of 25% of all composite restorations had developed recurrent caries after 2 years. Despite the poor survival rates of GIC restorations, many authors still conclude that GIC is the material of choice for root caries as conventionally setting glass ionomer cements were associated with protection against secondary caries – even after the filling itself had been lost [34]. Clinical judgement is essential in each individual case, and the choice of restorative material to restore a carious lesion on a root surface is influenced by the location of the lesion, aesthetic requirements of the patient, moisture control and future caries risk.

9 Utilizing Atraumatic Restorative Treatment (ART) for Caries Management in Older Adults

Providing operative dental care to older patients can be challenging, and traditional restorative approaches may not be accessible or even acceptable to some groups. Several authors have pointed out that most economically prosperous countries still prioritize traditional treatment of disease over prevention measures. This is, arguably, excessively costly and does not consider long-term maintenance requirements [35, 36].

In order to avoid further tooth tissue loss and enhance prevention amongst older individuals, minimally invasive dentistry (MID) should always be the first line of treatment for caries. It prioritizes prevention and provides guidance for patients to empower them to be responsible for their own oral health and intervene as conservatively as possible when a surgical approach is judged necessary, thus avoiding unnecessary tooth tissue removal. It was born from the evolvement in the understanding of the caries process and the mechanisms involved in its beginning, progression and control, together with improved dental materials. According to the MID concept, early caries detection and caries risk assessment, remineralization of demineralized enamel and dentine and optimal caries-preventive measures should always be used throughout an individual's life, and operative interventions should only be employed when all of these have failed [37]. In order to decide for a preventive or operative intervention, it is important to differentiate between active and arrested, cavitated and non-cavitated and cleansable and plaque trapping lesions. The type of lesion will influence not only the treatment to be carried out but also the type of material to be used. Cavitated lesions on the root surface that are shallow might become self-cleansable and arrested, and therefore, restoration might not be necessarily recommended. When there is a need for a filling to be placed, cavity preparation should be as minimal as possible to conserve natural tooth tissue.

Atraumatic restorative treatment (ART) is a very effective yet minimally invasive surgical approach for restoration of carious teeth (Fig. 4). It uses hand instruments for

Fig. 4 Root caries restored using ART on 15, occlusal caries on 47 also restored using ART

accessing carious lesions and removing decomposed dentine and a high-viscosity glass-ionomer to restore the cavity. Many studies worldwide have demonstrated that ART can achieve high survival rates in single-surface permanent teeth [10, 38, 39]. ART can be used successfully in non-clinical settings, including LTCFs and hospitals, and has been shown to be both cost-effective and acceptable to older adults [40, 41]. Furthermore, ART can be carried out by dental care professionals (DCPs), including therapists and hygienists. The use of DCPs to provide oral care for older people may help to improve access to dental services particularly for patients who are resident in LTCFs [42, 43]. The use of the ART approach could thus result in preventive and restorative care being delivered to a larger number of people compared to traditional restorative approaches. Studies carried out in older adults have demonstrated comparable survival rates for both ART and conventional restorations with glass ionomers [44, 45]. One of the largest studies which compared ART with a conventional restorative technique to treat carious lesions on older patients found that only 8.6% of the ART restorations placed on the root surface failed after 5 years. Overall, failure rates were similar between the ART and the conventional group [10]. Furthermore, the same study found that older adults accept ART well and are happy not to receive anaesthesia or drilling for restoration provision. Dental anxiety is a known barrier for dental attendance, and fearful older adults are less likely to visit a dentist and more likely to avoid or delay dental treatment. The use of ART could change this negative perception of dental treatment and make dental attendance more regular for some patients.

10 Consideration of Caries Development When Replacing Missing Teeth

Previously in this chapter, we have discussed preventive interventions to prevent older adults developing caries including effective mechanical cleaning and the use of fluoride. However, in addition to effective preventative regimes, operative dental treatment can also become an etiological driver for the development of caries. The most common example of this is in the replacement of missing teeth particularly when using a removable partial denture (RPD) [23, 46]. RPDs, which are

constructed from acrylic resin, typically cover substantial amounts of the soft tissues and create plaque traps and dead spaces where caries can develop (Fig. 5). Acrylic resin RPDs should be used as transitional prostheses where the remaining teeth are of poor prognosis and additions to the RPD are anticipated in the short to medium term. [47] Where the remaining natural dentition is of a good prognosis and a removable prosthesis is planned, then this should be constructed using a cobalt-chromium framework. This RPD design will provide a prosthesis which is tooth-borne but also minimizes the amount of coverage of the remaining hard and soft

Fig. 5 Lower acrylic resin RPD with extensive coverage of the gingival margins around the remaining natural teeth

Fig. 6 Upper and lower cobalt-chromium RPDs which have been designed to minimize coverage of the remaining hard and soft tissues

Fig. 7 A shortened dental arch in a partially dentate older patient

tissues (Fig. 6). Whilst a good preventive regime will still be required, the remaining dentition should be less prone to developing caries.

Where replacement of natural teeth is less extensive, then fixed prosthodontics can be considered, either as tooth supported or implant supported restorations. Where systemic medical comorbidities are well controlled, then dental implants can have excellent success rates in older adults [24]. Consideration should also be given to the use of the shortened dental arch concept, where a functional dentition is achieved through retention of natural teeth or using fixed prosthodontics to restore 10 occluding pairs of contacts (Fig. 7). This treatment planning philosophy does not necessitate the use of a RPD and is therefore easier for the patient to maintain and more cost-effective to deliver [48].

11 Conclusions

This chapter has discussed the changing oral health profile of older adults within the population. The emergence of a partially dentate older population is not only a significant advance in terms of oral health but also provides significant challenges for clinicians and patients in managing chronic dental diseases, including caries. Despite root caries being a preventable dental disease, prevalence is very high amongst older adults. Whilst some operative strategies have been discussed, including the application of ART, the most important element is prevention. Interventions using high-fluoride toothpaste and varnish are effective in preventing root caries, and the use of SDF is increasingly promising. Within the context of prevention, clinicians must ensure that they are not adding to the maintenance burden for older patients by providing RPDs, which are plaque retentive and encourage caries development. Alternative approaches should be considered including utilizing the shortened dental arch concept, which provides a functional yet maintainable dentition for older adults.

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Systemic Disease That Influences Oral Health

Jaisri R. Thoppay and Akhilanand Chaurasia

General health and oral health may interface at many levels [1]. "The oral cavity is the mirror image of systemic health" as highlighted in the US Surgeon General's Report on Oral Health in America 2000 [2]. Many systemic medical conditions may first manifest in the oral cavity [3]. Since the oral cavity is easily accessible, any alterations in systemic health reflected in the mouth can be of diagnostic value. Some interfaces between systemic and oral health are direct [1]. Such clinical oral presentations prompt the clinician to perform a focused evaluation and diagnostic workup [4]. Systemic conditions, for example, may present with symptoms of dry mouth, oral lesions, temporomandibular disorders, or orofacial conditions well before a definitive diagnosis can be made, allowing for an early diagnosis, and management which may in turn improve the patient's prognosis [5, 6]. This chapter offers an overview on the role of systemic diseases in oral health with a focus on common conditions in the geriatric population.

1 Background

Whereas clinical manifestations may be the result of the direct effects of systemic conditions on the oral cavity, indirect effects may be the result of the actions of the non-pharmacological and pharmacological treatments recommended for such conditions [7]. For example, osteoporosis may not have a direct effect on the structures

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of the jaw. However, the antiresorptive medications for the management of osteoporosis may cause osteonecrosis of the jaw in patients with underlying poor oral health. Adverse drug reactions to the administration of certain medications may manifested as erythema multiforme, Steven-Johnson syndrome, anaphylactic stomatitis, intraoral fixed drug eruptions, lichenoid drug reactions, and pemphigoid-like drug reactions [8, 9].

A bidirectional relationship may also occur. There are instances where adverse oral health may lead to complex health conditions and occasionally critical illness. Poor oral health may affect preexisting cardiac conditions, leading to infective endocarditis caused by existing oral microbiota. Both systemic health and quality of life are compromised when edentulism, xerostomia, soft tissue lesions, or poorly fitting dentures influence eating and food choices [10]. Oral and facial pain from dentures, temporomandibular joint disorders, and oral infections may affect social interactions and daily behaviors [11].

Common oral conditions, such as periodontal disease and dental caries, are chronic and associated with multifactorial determinants or risk factors. A causal relationship may be difficult to establish [4, 7]. Furthermore, a cause-and-effect relationship between systemic health and oral disease is not necessarily symmetrical. A well-documented example is the relationship between periodontal disease and diabetes mellitus type II [12, 13]. Patients are more likely to develop periodontal disease as compared to people without diabetes [14]. Poor diabetic control may significantly affect periodontal disease management and prognosis. Treating periodontal disease may reduce oral discomfort, which may assist patients in making better nutritional choices, thereby achieving better glycemic control [15]. A similar bidirectional relationship exists between diabetes, sugar consumption, and dental caries. Another example of an indirect causal relationship in older adults is the combination of periodontal disease and caries causing tooth loss, which subsequently may lead to poor dietary choices resulting in nutritional deficiencies or poor diabetic control.

2 Geriatric Assessment

Geriatric assessment is the multidimensional and multidisciplinary assessment of functional ability, physical health, cognition and mood, and socioeconomic status [16]. In addition to a complete history of presenting oral complaints, geriatric assessment includes a thorough medical and surgical history, medication review, and a geriatric review of systems [11, 17, 18].

A thorough medical history may help:

- Identify patients with undetected systemic diseases that may represent a severe threat to the patient's life or may further complicate dental treatments;
- Identify patients taking drugs that could interact with other prescribed drugs potentially complicating the care plan or provide clues as to whether the patient failed to report an underlying systemic illness;
- Allow the dentist to modify his treatment plan for the patient considering systemic disease or prescribed drugs;

- Provide safe dental care and prevent complications from dental procedures;
- Enable the dentist to communicate with medical consultants regarding the patient's systemic condition; and
- Establish an excellent patient-doctor relationship by showing the patient that we are genuinely interested in their overall well-being.

Oral manifestations of various systemic diseases may look alike, often manifesting as red and white lesions or erythematous oral ulcerations. Such manifestations may be difficult to diagnose solely based on signs and symptoms. Therefore, it is critical to assess the oral as part of the medical history and overall evaluation of systemic health. The figure illustrates a suggested workflow for addressing orofacial complaints. The first visit should start with a detailed history of present illness, past medical, dental, and medication history combined with a comprehensive oral examination complemented with additional diagnostic work-up (Fig. 1).

3 Systemic Health Affecting Oral Health Management

In an outpatient dental setting, managing a medically complex older patient may need modifications to routine dental care. A thorough history is necessary to establish the existence, and nature of any medical problems, assess risk, anticipate any complications, and minimize the chances of any medical emergency while providing appropriate dental treatment. Medical risk assessment requires the following [17]:

- Recognize significant deviations from normal health status that might affect dental management;
- Make an informed judgment on the risk of dental procedures to both outpatients and inpatients; and
- Identify the need for medical consultation.

Several guides have been developed to facilitate the efficient and accurate preoperative assessment of medical risk. The most commonly used are the American Society of Anesthesiologists (ASA) Physical Scoring System (Table 1) and the Goldman's Cardiac Risk Index.

The systemic medical complexity level may correspond to three areas: procedure-related, anesthesia-related, and provider-related. In general, oral health management often requires modifications based on the presence of systemic health conditions. Such modifications depend on the following factors: risk of infection, risk of bleeding, risk of medical complications, and risk of adverse outcomes and any potential drug interactions.

3.1 Risk of Infection

The risk of infection may occur in two clinical situations. First, poorly controlled systemic health can potentially increase the risk of dental infections (e.g., dental decay or periodontal disease). Second, patients with preexisting cardiac conditions

Fig. 1 Geriatric patient evaluation and workup flowchart

may develop infective endocarditis after a dental procedure or from untreated dental conditions that increase the risk of infection. The American Heart Association (AHA) has released guidelines recommending the use of antibiotic prophylaxis for patients with any of the following cardiac conditions or implanted devices [19].

- Prosthetic cardiac valves, including transcatheter-implanted prostheses and homografts
- Prosthetic material used for cardiac valve repairs, such as annuloplasty rings and chords
- History of infective endocarditis
- Cardiac transplant with valve regurgitation due to a structurally abnormal valve

Table 1 American Society of Anesthesiologists' (ASA) physical scoring system for dental treatment and anesthesia

ASA classification	Dental and anesthesia considerations
ASA 1 – Physical status: A patient without systemic disease; a normal patient	Routine dental therapy without modification. Suitable for treatment with anesthetic modality
ASA II – Physical status: A patient with mild systemic disease	Routine dental therapy with possible treatment limitations of special consideration (e.g., duration of therapy, stress of therapy, prophylactic considerations, possible sedation, and medical consultation)
ASA III – Physical status: A patient with severe systemic disease limits activity but is not incapacitating	Dental therapy with possible strict limitations or special consideration Anesthetic modalities generally contraindicated on an outpatient basis
ASA VI – Physical status: A patient with incapacitating systemic disease is a constant threat to life	Emergency dental therapy only with severe limitations or special considerations. Anesthetic modalities in the dental office are contraindicated

- Congenital (present from birth) heart disease (e.g., unrepaired cyanotic congenital heart disease, including palliative shunts and conduits, any repaired congenital heart defect with residual shunts or valvular regurgitation at the site of or adjacent to the site of a prosthetic patch or a prosthetic device)

Patients on immunosuppressant medications or those immunocompromised due to various systemic diseases (e.g., renal failure, transplant recipients, oncology patients receiving chemotherapy) may be at a higher risk of developing postoperative orofacial infections. A complete blood count and differential may also reveal lower absolute neutrophil counts (ANC) of <1500 cells/μL, moderate if 500–1000 cells/mm3, or severe if <500 cells/mm3 [20]. Any neutropenia may indicate the need for proper antibiotic coverage to prevent the risk of acute dental infections or postoperative orofacial infections. Patients with critically low ANC levels may pose a higher risk of infection. Patients with uncontrolled diabetes may also be at a higher risk of infection and poor healing. Hemoglobin A1c and blood glucose levels may provide valuable information to clinicians. Abnormal values should prompt dentists to be careful when performing emergency or essential dental care and only after a thorough discussion with medical consultants. Any elective dental procedures should be deferred until patients are clinically stable. Essential dental care may instead focus on acute pain management and the prevention and management of acute infections.

3.2 Risk of Bleeding

Increased bleeding risk may be due to spontaneous bleeding from periodontal or oral tissues or as a result of peri- and postoperative bleeding associated with certain medications or medical conditions. Spontaneous hemorrhage emanating from the

gingival sulcus or bleeding from oral tissues may occur in patients with an underlying systemic disease such as acute leukemia, pancytopenia, thrombocytopenia, hemophilia A and B, liver disease, or hereditary hemorrhagic telangiectasias [21]. Peri- or postoperative bleeding risk may also occur due to prescribed prophylactic aspirin or blood thinners for stroke or cardiovascular prevention. Table 2 shows the suggested dental management for patients receiving anticoagulants [21]. Blood tests related to hemostasis may include prothrombin time, international normalized ratio (INR), partial thromboplastin time, platelet count, clotting time, and bleeding time [22].

3.3 Risk of Medical Complications Before, During, and After a Dental Procedure

Medical complications may occur before, during, or after performing a dental procedure. Potential risks can be prevented by obtaining a thorough history, making appropriate modifications to routine dental procedures, and judiciously requesting consultations. Medical complications should be anticipated, and life-threatening events should be prevented. Although life-threatening emergencies in dental offices are uncommon, many factors may increase the likelihood of emergencies [23]: (1) a larger number of older persons seeking dental care; (2) therapeutic advances in medical and pharmaceutical fields; (3) longer dental appointments; and (4) increasing use of medications in dental practice [24]. Medical events occurring during dental treatments may include syncope, anxiety attacks, postural hypotension, reactions to topical epinephrine, or overdosing with a local anesthetic. In the older adult, syncope may be due to the interaction of coexisting medical problems that may impair cardiovascular and neurogenic compensatory mechanisms. Elevation of the legs and lowering of the head may help reestablish cerebral perfusion and end the syncopal episode. Often, no further treatment is necessary, and the patients rapidly recover. Repeated syncopal episodes in older adults warrant further cardiac evaluation. Other medical events in patients with preexisting conditions are seizures, asthma exacerbations, cardiovascular events [25] (e.g., angina pectoris, myocardial infarction), hyper- or hypoglycemic events, adrenal insufficiency, thyroid storm, or

Table 2 Treatment protocol for patients receiving anticoagulant therapy

Dental treatment risk	Dental treatment protocol
Low	Not necessary to stop anticoagulants
Moderate	Check prothrombin level possible change in anticoagulant medication after the medical consult
High	Defer any dental treatment if possible. For emergency or management to prevent sepsis, the patient may be seen as an inpatient in a hospital set up with a good team

a cerebrovascular event. Falls in older adults are not uncommon and can be prevented in dental settings.

Specific procedures such as nitrous oxide N_2O analgesia are contraindicated in older patients with chronic obstructive pulmonary disease [COPD]. The reason is that these patients may have preexisting alveolar bullae and, as a result, may be at higher risk for bullae rupture. N_2O administration, particularly during prolonged use, may lead to atelectasis and bullae rupture in patients with moderate to severe COPD [26].

3.4 Risk of Adverse Drug Events and Drug Interactions

Anaphylaxis is a severe and potentially life-threatening allergic reaction that may occur in dental practice. Several dental treatment-related medications are associated with anaphylaxis, including mouthwashes, local anesthetics, latex, and antibiotics. Drug-related mucocutaneous eruptions may also manifest in the oral and perioral regions. Table 3 highlights potentially dangerous drug interactions that may be encountered in general dental practices [3, 27, 28].

Furthermore, some drugs used to treat systemic medical conditions may have unintended effects in the oral cavity. A relatively common adverse reaction in the oral cavity is dry mouth or drug-induced xerostomia. Many medications

Table 3 Common prescription drugs in dentistry and their interactions

Drugs	Interacting drugs	Clinical manifestation
Epinephrine in local anesthetics	Beta-blockers	Hypertensive response, palpitations, elevation in blood pressure
	Tricyclic antidepressants	Increased sympathomimetic reaction
	An anesthetic agent such as propofol	Severe hypotension
NSAIDs	Warfarin, aspirin, SSRI	Increased bleeding risk
	ACE inhibitors, beta-blockers, diuretics	NSAIDs decrease the hypotensive effect of drugs
Macrolide antibiotics	Clopidogrel, warfarin,	Increased risk of bleeding
	Calcium channel blockers (CCBs)	Increased and prolonged hypotensive effect
Metronidazole	Warfarin, NSAIDs	Increased risk of bleeding
Azoles	Warfarin	Increased risk of bleeding
	Simvastatin	Muscle toxicity
Penicillin-based antibiotics	Warfarin	Increased risk of bleeding
Opioids	Antihypertensives	Increased and prolonged hypotensive effect

including but not limited to antihistamines, antipsychotics, antiparkinsonian medications, and antihypertensive medications may cause xerostomia by affecting resting salivary flow, while some medications suppress salivary gland acini causing salivary gland hypofunction. For a more in-depth discussion on the topic of xerostomia, please refer to Chapter "Xerostomia and Hyposalivation". Dysgeusia is often reported in patients taking lithium, antidiabetic agents, antibiotics, or chemotherapeutic regimens. Common medications such as nonsteroidal anti-inflammatory drugs [NSAIDS] can interact and cause lichenoid reactions in the oral cavity. Vesiculobullous or ulcerative lesions that mimic other immunologic diseases and reactions may include lichenoid drug reactions (Fig. 2), erythema multiforme (EM), which may present like oral erosive lichen planus, pemphigoid-like, pemphigus-like, and lupus erythematosus (LE)-like reactions [29]. There are case reports of oral adverse drug events caused by drugs such as cyanamide, anticonvulsants, antidiabetics, and antihypertensives [30]. Some medications, such as angiotensin-converting enzyme inhibitors (ACE) inhibitors, may cause oral burning. Antihypertensive medications side effects may include dysgeusia, gingival hyperplasia (nifedipine), lichenoid reactions, salivary hypofunction, and xerostomia [31, 32].

4 Systemic Health Manifesting in Orofacial Areas

Systemic conditions manifesting with oral signs and symptoms are common. Sometimes they may be the first sign or symptom of a specific systemic condition, and hence the dentist may be the first clinician to recognize it. Autoimmune disorders like Sjogren's syndrome may present with salivary gland hypofunction as the single presentation well before other clinical signs and symptoms manifest. Immunological and infectious conditions, hematologic disorders, vitamin deficiencies, endocrinopathies, and psychological disorders can present with oral signs and symptoms [11, 15]. Oral signs such as mucosal inflammation or infection, oral discoloration, decreased salivary flow, dental caries, and bleeding may indicate the presence of a systemic condition. The fact is that many different systemic conditions may present similarly, that is, with oral lesions (red, white), or erosive changes affecting the oral mucosa or periodontal areas, thus increasing the likelihood of a delayed diagnosis or misdiagnosis. Oral lesions commonly present as red, and/or white lesions but with distinguishing clinical characteristics. Coupled with a thorough medical history, oral examination, and judicious use of diagnostic tests that may lead to an early and accurate diagnosis [33]. Clinical competence in detecting abnormalities within the oral cavity, familiarity with typical manifestations of systemic disorders, and knowledge of the pathophysiology of those conditions are essential elements of the comprehensive orofacial exam [17]. A thorough history, review of systems, and a meticulous extraoral and intraoral exam will play a critical role in ensuring an early diagnosis. In the following sections, we will review oral manifestations in different organ systems.

Fig. 2 Lichenoid drug reaction secondary to NSAIDS

4.1 Gastrointestinal Disorders

Oral presentations such as granulomas or ulcerations in orofacial areas are easily visualized and aid in the recognition of inflammatory conditions such as Crohn's disease. The oral microbiome is a unique feature of the gastrointestinal tract. The oral cavity is a suitable environment for microbial agents due to its stable medium with optimal temperature, neutral pH, and salivary flow. The interaction between oral diseases and systemic conditions, such as in cardiovascular disease, head and neck cancers, and diabetes mellitus, may alter the oral microbiome either due to the disease process itself or due to disease management. Systemic medical conditions themselves may contribute to an altered oral microbiome. Table 4 lists oral manifestations of common gastrointestinal conditions [3, 33–36].

4.2 Renal Disorders

Renal failure can be due to end-organ damage secondary to many systemic disorders. Patients with renal failure often present with oral complications that may significantly impact older individuals receiving dental care. Orofacial manifestations

Table 4 Oral manifestations of gastrointestinal diseases

Gastrointestinal disease	Oral structure	Presenting signs and symptoms
Inflammatory bowel disease – Crohn's disease, ulcerative colitis	Vestibule and buccal mucosa	Oral ulcers, linear ulcerations, cobblestoning of buccal mucosa, mucosal tags, pyostomatitis vegetans
	Gingiva	Orofacial granulomas, granulomatous gingivitis
	Lips	perioral edema, cheilitis granulomatosis, angular cheilitis
	Tongue	Fissuring of the dorsum, mucosal tags
Celiac disease [spruce]	Oral mucosa	Aphthous ulcers
	Tongue	Atrophic, painful tongue with glossodynia – often related to secondary effect due to malabsorption of hematinics
Hepatitis, jaundice	Oral mucosa	Icterus of oral mucosa, which is readily seen on the palate and the sublingual mucosa, mucosal discoloration (yellow) caused by jaundice, petechiae, and ecchymoses caused by liver dysfunction, lichen planus associated with hepatitis C (in certain geographical regions), enlarged major salivary glands
Cirrhosis	Oral mucosa, tongue	Glossitis, angular cheilitis, mucosal discoloration, increased provenance of oral cancer, sialadenosis, increased periodontal disease
GERD (gastroesophageal reflux disease)	Oral mucosa, teeth	Oral burning, dysgeusia, halitosis, eroded teeth on the lingual surfaces

of renal disease and its treatments (e.g., dialysis and renal transplantation) include enlarged salivary glands, which are often asymptomatic, salivary gland hypofunction, parotitis, xerostomia, halitosis, dysgeusia, macroglossia, periodontal disease, pale mucosa (related to malabsorption of hematinics and low erythropoietin production), petechiae and ecchymosis, opportunistic candidiasis, glossitis, dysesthesia, glossodynia, and drug-induced gingival hyperplasia (Fig. 3). Patients on corticosteroids or immunosuppressive agents used to treat rejection in renal transplants or autoimmune renal conditions, may develop opportunistic dental infections or changes in jaw bone trabeculations. Steroid-related melanosis of the oral mucosa may be seen in patients on chronic steroid use [37–39].

4.3 Cardiovascular Disorders

Pain during angina and/or myocardial infarction may refer to the left mandible and occasionally presents as jaw or dental pain. A thorough temporomandibular evaluation along with an oral exam may serve to clarify the etiology of jaw-related pain or odontogenic pain and facilitate a prompt referral to medical care when a cardiovascular event is suspected. Cerebrovascular disease may also present with oral

Fig. 3 Oral candidiasis and glossitis

manifestations, including weak palate, flaccid tongue, paralysis of orofacial muscles, slurred speech, dysphagia, and poor oral hygiene on the affected side.

4.4 Endocrine Disorders

Oral manifestations of diabetes include a higher incidence of dental caries, glossodynia, oral burning, xerostomia with salivary gland hypofunction, poor wound healing, higher prevalence of periodontal disease, opportunistic oral candidiasis, and acute exacerbation of oral infections [14, 15, 40, 41]. Extraoral and intraoral findings of hypothyroidism may include a puffy face, enlarged lips, gingival edema and macroglossia [42]; in hyperthyroidism, tardive dyskinesia and oral tremor may also occur [42].

4.5 Hematologic Diseases

Anemia is the most common hematological condition in older people and often presents with angular cheilitis, atrophic glossitis, oral burning, and pale mucosal pallor [43]. Patients with neutropenia or leucopenia may display oral ulcerations,

exacerbation of dental infections, severe periodontal disease, and periodontal infections. These patients may also show a higher incidence of oral candidiasis and herpetic infections [20]. Individuals suffering from leukemia may present with an oral mucosa with ulcerations, opportunistic infections, mucosal bleeding, tongue bleeding, ecchymoses, petechiae, gingival and periodontal disease, gingival enlargements due to leukemic infiltrates, and gingival bleeding [44]. Dentists treating older patients with multiple myeloma, a condition that is more common with aging, may observe single or multiple "punched-out" or mottled radiolucent lesions on dental/facial radiographs, soft tissue plasma cell tumors, non-odontogenic pain mimicking dental pain, or trigeminal neuralgia. Patients with myeloma receiving antiresorptive medications may also develop medication-induced osteonecrosis of the jaw [45].

4.6 Neurocognitive Disorders

Patients with severe cognitive impairment are at increased risk for caries, periodontal disease, and oral infection because of decreased ability to engage in home oral care. In addition to poor oral hygiene, patients with Alzheimer's disease and related dementias have an increased prevalence of dental caries, periodontal disease, oral candidiasis, and salivary gland hypofunction [46, 47]. Those with Parkinson's disease may suffer from alterations of oral motor functions leading to drooling secondary to difficulties in swallowing. These patients often drool due to impaired swallowing secondary to muscle weakness and pooling of saliva, which may further increase the prevalence of dental caries and periodontal disease [48, 49]. Patients with Parkinson's may also suffer from oral burning; dysphagia; slow speech; tardive dyskinesia (involuntary oral-facial movements including lip-smacking, grimacing, tongue flittering), caused by long-term therapy with levodopa; tremors of the head, lips, and tongue; angular cheilitis; xerostomia; and salivary gland hypofunction secondary to the use of anticholinergic medications.

4.7 Respiratory Disorders

Patients with COPD on inhalation corticosteroids may develop candidiasis, periodontitis, and smoking-related intraoral findings (i.e., xerostomia, lesions including nicotine stomatitis, halitosis, tooth stain) [7]. Patients with tuberculosis may develop oral lesions (i.e., solitary ulcerations), enlarged cervical or submandibular lymph nodes, or scrofula [7]. Patients with asthma may develop fungal infections secondary to extended antibiotic use and hyperpigmentation of the mucosa from chronic steroid inhaler use (Fig. 4) [50].

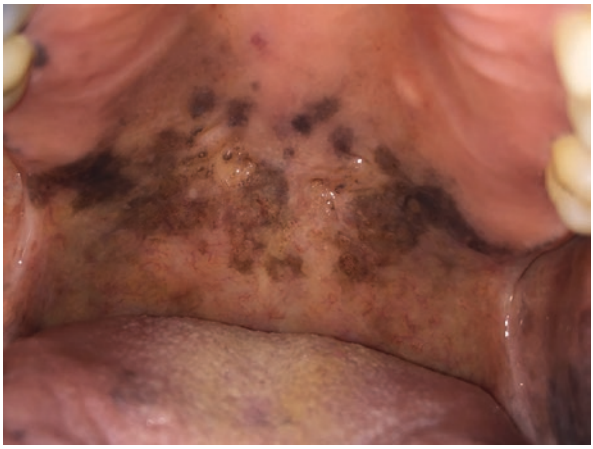

Fig. 4 Hyperpigmentation of hard and soft palate after chronic inhaler use

4.8 Autoimmune Disease

Lupus erythematosus may show a characteristic butterfly, malar rash on the cheeks and bridge of the nose, oral lichenoid lesions, xerostomia with salivary gland hypofunction, periodontal disease, caries, and oral candidiasis [5, 51, 52]. Individuals with Sjogren's syndrome may suffer from xerostomia with salivary gland hypofunction, dysphagia, dysphasia, lobulated tongue oral lesions, oral candidiasis, oral burning due to dry lips and mucosa, minor salivary glands with lymphocytic foci, and acinar destruction (Fig. 5), [5, 53]. Patients with fibromyalgia may present with orofacial pain and temporomandibular disorders with trigger zones [54].

5 Conclusions

In this chapter, we have reviewed how many systemic medical conditions may first manifest in the oral cavity. Since the oral cavity is easily accessible, any alterations in systemic health reflected in the mouth can be of diagnostic value. According to the US Census, by 2060 the number of US adults aged 65 years or older is expected to reach 98 million, or 24% of the population. This older population have a high prevalence of chronic medical conditions with systemic manifestations including the oral cavity. The design and implementation of comprehensive community oral healthcare programs for this growing number of older adults will certainly present numerous challenges. It will be critical to develop and implement feasible and comprehensive oral health status assessments and treatments for older patients with oral manifestations of systemic disease. Eliciting pertinent and relevant information about a patient's current medical and physical status and taking an accurate,

Fig. 5 Lobulated tongue

relevant, and concise medical history will ensure the prompt and accurate diagnosis of older patients with systemic conditions compromising the oral cavity. This process may require a close working relationships with medical providers and other healthcare professionals as part of an interprofessional approach for managing older adults with oral manifestations of systemic disease.

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The 3 Ds: Dementia, Delirium and Depression in Oral Health

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1 Epidemiology, Assessment, and Management

1.1 Dementia

Dementia is a disorder characterized by a decline in cognition involving one or more cognitive domains (learning and memory, language, executive function, complex attention, perceptual-motor, social cognition) [3]. Mild cognitive impairment (MCI) is a precursor condition, as shown in Table 1.

The person with dementia may show a gradual decline in cognitive function. Individuals may become forgetful especially for recent events. They must be reminded to perform healthy oral self-management behaviors. They may misplace their toothbrush or flossing aids. Individuals may have problems understanding oral health professionals' instructions or having difficulties expressing themselves or finding the right word. They may at times appear confused. Even if they remember to perform their daily activities, they may have trouble conducting self-care

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Table 1 Comparing mild cognitive impairment and dementia

Mild cognitive impairment	Mild dementia
Objective evidence of low performance in *one or more* cognitive domains that is greater than expected for the patient's age and educational background	Objective evidence of low performance in *more than one* cognitive domain that is greater than expected for the patient's age and educational background
Does not substantially interfere with daily activities, although complex functional previously tasks, such as paying bills, preparing a meal, or shopping, may take more time or be performed less efficiently. Independence in daily life is preserved, with minimal aids or assistance	Significant interference with the ability to function at work or at usual activities but still able to carry out basic activities of daily living (bathing, dressing, personal hygiene) and participate in some pastimes, chores, and social functions
Not explained by delirium or major psychiatric disorder	

activities requiring assistance or at least caregiver supervision. These cognitive symptoms may be accompanied by changes in behavior, which may further impair oral self-care and disrupt patient and caregiver routines. Depression and apathy are among the most common behaviors which may lead to disinterest or inconsistency in performing oral hygiene. Particularly challenging is the issue of shared decision-making. Although patients with mild to moderate dementia may be able to retain the ability to make decisions, as the disease progresses, the caregiver or surrogate may have to be increasingly involved in the decision-making progresses regarding oral healthcare interventions. For a more in-depth discussion on these topics, please refer to chapters "Ethical Considerations", and "The Role of Oral Health Literacy and Shared Decision Making".

The available evidence suggests that the etiology of dementia in older adults is complex and likely multifactorial, probably encompassing genetic, environmental, and lifestyle factors [4]. As the population ages, the overall burden of dementia is increasing worldwide. More than 5.2 million Americans are living with Alzheimer's disease or 1 in 8 Americans over the age of 65 have AD [4]. Prospective studies employing mild cognitive impairment (MCI) criteria at the outset have tended to report results of the incidence of MCI in the 10%–20% range [5]. It is estimated that by 2050, the number of people with Alzheimer's disease may nearly triple, from 5 million to as many as 16 million [6]. Therefore, we could extrapolate that at least 1 in 8 patients over the age of 65 seen in dental offices has cognitive impairment. The numbers may be lower since these patients tend to seek oral care less often than the general population. The most common types of dementia [7–9] and their clinical and pathological features are described in Table 2.

Other neurodegenerative disorders can also cause dementia, including Parkinson's disease, progressive supranuclear palsy, corticobasal degeneration, multisystem atrophy, and Huntington disease. Mixed dementia refers to the coexistence of more than one dementia-producing pathology, most commonly Alzheimer's disease and vascular dementia. Less common etiologies include alcohol-related dementia, chronic traumatic encephalopathy, normal pressure hydrocephalus (NPH), chronic subdural hematoma, and other central nervous system (CNS) illnesses (e.g., prion diseases, HIV infection) [7–9]. The assessment and diagnosis of dementia is multi-faceted, and its component are listed elsewhere in Table 3.

Table 2 Types of distinct dementia

Dementia type	Early characteristics	Pathology	Distribution
Alzheimer's disease	Slow, progressive decline in cognition (especially memory) and behaviors (apathy, depression)	Cortical amyloid plaque and neurofibrillary tangles	50–75%
Vascular dementia	Stepwise or gradual progression of cognition	Cerebrovascular disease, single infarcts in critical areas or more diffuse multi-infarct disease	20–30%
Dementia with Lewy bodies	Marked fluctuations in cognition, visual hallucinations, Parkinsonism	Cortical Lewy bodies	<5%
Frontotemporal dementia	Personality changes, mood changes, disinhibition, language difficulties	Damage limited to frontal and temporal lobes No single pathological changes	5–10%

Table 3 Components of assessment for dementia

Assessment	Notes
History and physical	History and physical including functional status, social and family history, and a complete neurological examination
Cognitive screening tools	Mini-Cog©, Folstein Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), Test Your Memory (pooled sensitivity of 75 to 92 percent and a specificity of 81 to 91 percent)
Neuropsychological testing	Determine etiology and severity
Depression screening	Depression can also worsen cognitive impairment in patients
Laboratory tests and imaging	TSH, vitamin B12, folate, RPR, HIV, brain imaging (CT or MRI) or amyloid PET scan of the brain

Management: The cornerstone of dementia management is non-pharmacological therapy and supportive care, including control of vascular risk factors [10], cognitive rehabilitation, nutrition counseling, and exercise and physical activity programs and caregiver support [11, 12]. The pharmacological treatment of AD consists of acetylcholinesterase inhibitors (donepezil, galantamine, rivastigmine) and memantine [11].

1.2 Delirium

Delirium is an acute disorder of attention and cognition in older adults that is common, serious, costly, under-recognized, and often fatal. A formal cognitive assessment and history of acute onset of symptoms are necessary for diagnosis [13]. Early recognition and treatment of the underlying cause of delirium is of great importance due to poor outcomes. Patients with delirium who present to the emergency

department have an approximately 70% increased risk of death during the first 6 months after the visit [14]. Delirium at admission to post-acute care is associated with a five-time increased risk of mortality at 6 months [15]. In older patients with dementia, delirium is associated with increased rates of cognitive decline [16–18], institutionalization, and mortality [19]. Delirium is mostly found in hospitalized patients, with the highest incidence rates noted in intensive care units and in postoperative and palliative care settings. The prevalence of delirium in the community is low (1–2%) [13], but since many studies involving delirium excluded patients with baseline dementia, the incidence and prevalence of delirium are likely underestimated. Since it is possible, albeit rare, for a delirious patient to be seen in a dental office for oral care, it becomes important to recognize delirium and refer the patient immediately to the emergency department for evaluation. Delirium should be suspected when the patient's confusion and/or agitation has had an acute onset according to the caregiver and the patient manifests inattention (core features of delirium), as well as either disorganized thinking or an altered level of consciousness [20].

Although a single factor can lead to delirium, the etiology of delirium in older adults is usually multifactorial [21]. In vulnerable patients, such as those with underlying dementia and multimorbidity, a seemingly benign insult (e.g., a dose of an opioid narcotic) might be enough to precipitate delirium. Conversely, in a young, healthy patient, delirium will develop only after exposure to a series of noxious insults, such as general anesthesia, major surgery, several psychoactive drugs, a stay in intensive care, or sleep deprivation. Screening for delirium in hospitalized patients should be done routinely on medical and surgical wards, but especially in ICU and postoperative patients, who have the highest incidence of delirium.

Management of delirium is focused on treating the underlying etiology and using non-pharmacological strategies, cognitive rehabilitation, drug reduction, drug-sparing approaches (i.e., substitution for less toxic alternatives), treatments targeted toward neuroprotection, improvement of sleep hygiene, and reduction of pain and stress (including complementary and alternative medicine) [21].

1.3 Depression

Depression is the most common psychiatric disorder in the general population [22] and the most common mental health condition in patients seen in primary care [23–26]. A systematic review and meta-analysis published in 2010, which included 24 studies based on the community-based older adults population aged 75 years and older, found that the prevalence of major depression ranged from 4.6% to 9.3% and that of depressive disorders from 4.5% to 37.4% [27]. The current view of the etiology of depression focuses on the alteration of three major monoamine neurotransmitters: serotonin (5-hydroxytryptamine, 5HT), norepinephrine (NE), and dopamine (DA). Other genetic and environmental factors, such as adverse life events including childhood trauma, impact the risk for developing major depression [28].

In the older adult population, depression mainly affects those with chronic medical illnesses and cognitive impairment. Depression causes suffering, family disruption and disability, worsens the outcomes of many medical illnesses, and increases mortality [29]. For a diagnosis of major depression to be made, the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) state that either depressed mood or loss of interest or pleasure must be present. Although not part of the diagnostic criteria, late-life major depression is often associated with bodily changes and cognitive impairment. Non-demented older people with major depression often have difficulties with concentration, speed of mental processing, and executive function [30, 31]. These deficits improve, but may not completely resolve, after remission of late-life depression [32–34].

In the absence of screening, it is estimated that only 50 percent of patients with major depression are identified [34]. This makes screening for depression very important. Short screening instruments include the Patient Health Questionnaire-9 (PHQ-9), the Patient Health Questionnaire-2 (PHQ-2), the Beck Depression Inventory for Primary Care (BDI-PC), and the 5-Item World Health Organization Well-Being Index (WHO-5). These can be self-administered by patients preceding their appointment or while in the waiting area.

The first-line treatment of depression consists of the combination of psychotherapy and antidepressant medication. Successful management of depression in late life is dependent upon several factors: addressing comorbid conditions, tailoring non-pharmacological and pharmacologic interventions to the individual patient, monitoring therapy for side effects and effectiveness, and close follow-up. Consultation with a psychiatrist should be considered for patients who have failed multiple trials of antidepressants or who prefer non-pharmacologic treatment [28].

2 The Importance of Cognition and Mood on Oral Health

2.1 Dementia

Oral health and cognitive health seem to have a bidirectional relationship. Some evidence suggests that patients with periodontal disease and normal cognition at baseline may be at higher risk for developing cognitive impairment. A single prospective cohort study showed that cognitively intact subjects at baseline who had elevated antibodies to periodontopathic microorganisms compared to cognitively intact patients without elevated antibodies were more likely to develop MCI and dementia on follow-up [35] (Level of Evidence 4). On the other hand, an expert review [36] suggests that cognitive decline frequently causes behavioral changes that may directly affect oral health. For example, patients with cognitive impairment may exhibit loss of interest and ability to complete oral self-care behaviors such as brushing and flossing. Failing to perform routine oral self-care may lead to a rapid development of hard and soft tissue diseases that result in further deterioration of

function and increased dental pain and suffering. While there is no evidence in the literature that oral pain leads to increased levels of depression or delirium in older adults, it is reasonable to assume from other evidence in chronic pain in other areas that it does. As the functional status of patients with dementia declines, a person's self-esteem and confidence may also decline [37], which may further impair oral health.

Two systematic reviews reveal the association between dementia and gum disease. A systematic review encompassing 10 cohort studies, 2 controlled trials, 14 cross-sectional, and 10 case control including 5687 participants in 38 settings [37] showed that older people with dementia had high scores for gingival bleeding, periodontitis, and plaque formation and needed assistance with oral care. This was corroborated by another systematic review of 56 cohort studies, including 8301 participants in 58 settings [38], that showed that individuals with dementia were more likely to present with gingival bleeding or inflammation and suffer from periodontal disease than people without dementia. This evidence confirms that adults with dementia are more vulnerable to gingivitis and periodontal diseases probably as a result of a decline in the patients' ability to perform oral self-care behaviors and other preventive measures (Level of Evidence 1).

The level of evidence linking dementia to dental caries and tooth loss compared to healthy controls is not as robust. A systematic review of 16 cohort studies including 803 participants in 10 settings found mixed results. Some studies showed that the number of teeth and periodontal disease were associated with risk of cognitive decline or incident dementia, whereas others did not find an association [39]. Another systematic review of 28 cohort studies including 4620 participants in 74 settings showed that those with dementia had a significantly fewer number of teeth, more carious teeth, significantly worse oral hygiene, and significantly poorer periodontal health [40] (Level of Evidence 2). The latest evidence from these systematic reviews suggests that patients with cognitive impairment may have fewer and more carious teeth.

The impact of poor oral health in patients with dementia may also have wider impacts on healthcare utilization and mortality. In a systematic review of 11 cross-sectional studies, the most common reasons for preventable dental hospital admissions in patients with dementia were dental caries, followed by embedded or impacted teeth [41]. A control trial in German nursing homes randomized 219 residents to either an intervention group that consisted of dental health education and ultrasonic baths for denture cleaning (n = 144) or a usual care, control group (n = 75). The study showed that those with higher plaque record had higher mortality, suggesting the benefits of the intervention [42] (Level of Evidence 4).

In summary, dementia and cognitive decline are risk factors for poor oral healthcare outcomes. Those in later stages of the disease tend to have more plaque accumulation, gingivitis, attachment loss, dental caries, and poor denture hygiene. Evidence-based interventions to address these deficits are addressed later in the chapter.

2.2 Delirium

There have not been studies on whether delirium is associated with an increased risk of poor oral healthcare outcomes. Based on evidence observed in patients with dementia, these patients will likely be uncooperative during their delirium, and we can speculate that they will have similar outcomes to those with dementia. However, there is no research literature that characterizes the oral health status of patients with delirium. As patients with delirium may be unable to perform oral self-care activities by themselves, it would be reasonable to assume that appropriate oral healthcare interventions may be effective.

2.3 Depression

Late-life depression has been consistently associated with disinterest in performing oral hygiene behaviors, leading to poor health outcomes. According to a systematic review of 26 studies, including 42,357 patients from diverse, mainly community-dwelling clinical settings [43], severity of depression, medication, and medical comorbidity were the most important medical barriers influencing the oral health of people diagnosed with depression. A systematic review [44] of 57 studies of oral health that included samples from 38–4769 mental health consumers found that the prevalence of suboptimal oral health was 61% among individuals with serious mental illnesses. The following outcomes were seen in most patients: xerostomia, gross caries, decayed teeth, and periodontal disease. In a systematic review of 26 cohort studies, including 334,503 adult patients from 32 settings [45], psychiatric diagnoses were associated with increased dental decay in dental surfaces and missing teeth. In a separate meta-analysis of 25 studies of 5076 psychiatric patients and 39,545 controls from hospitalized and community surveys, people with serious mental illness had greater odds of having lost all their teeth compared with those without mental illness [46]. This was corroborated by a systematic review of 16 studies [47], showing that depression in adults and older adults increased the odds of tooth loss and edentulism. However, the generalizability to older adults with depression is limited, because these systematic reviews only featured a small number of studies including older adults. More cohort studies of older adults with depression are needed to determine whether these associations persist.

3 Oral Health Assessment

Older adults with cognitive impairment (especially those in long-term care institutions) are not often evaluated and managed by dental health professionals. As an alternative, experts proposed that oral examinations should be supplemented with

oral health assessments and screenings conducted by trained nurses and other formal caregivers. These professionals can monitor institutionalized residents' oral health, evaluate oral hygiene care interventions, trigger calls for dentists when required, assist with individualized oral care plans, and assist with triaging and prioritizing residents' for a higher level of dental care [48]. A systematic review of 4 studies including 440 patients from 3 countries and 4 settings [49] looked at the use of instruments that nurses and other formal caregivers can use when evaluating residents' oral health. The results revealed that successful oral assessments by nursing staff required appropriate staff training and education by dental professionals.

The Brief Oral Health Status Examination (BOHSE) is a comprehensive, validated, and reliable screening tool that nurses and caregivers can use with cognitively impaired, institutionalized residents [50]. The BOHSE covers ten oral hygiene categories—lymph nodes, lips, tongue, cheek/roof of mouth, gums, saliva, natural teeth, artificial teeth, chewing position, and oral cleanliness. Using a penlight, tongue depressor, and gauze, trained staff can examine and grade the status of the oral cavity, surrounding tissues and natural or artificial teeth.

Other useful oral assessment tools that nurses and caregivers of institutionalized persons with dementia can use include the Index of Activities of Daily Oral Hygiene and the Mucosal Plaque Score [50]. Experts have proposed several strategies that staff can implement to facilitate patients and caregivers' cooperation with periodontal care in older adults with dementia (Table 4). These approaches centered on dispelling misconceptions, scheduled appointments at convenient times, strategic length of appointments, continuity of care among dental staff, and proper communication techniques such as the VERA framework outlined in Table 5 [51].

Table 4 Expert opinion strategies to engender cooperation for periodontal care

Dispel patients' and caregivers' attitudes and misconceptions regarding the ability of the dental team to cope with the symptoms of dementia by providing an environment where patients and caregivers feel comfortable
Appointments should be scheduled at the time of day that best suits the patient and caregiver
Long appointments are best avoided and, for patients with moderate dementia, are best kept to under one hour
Continuity of care is important for those with individuals with dementia, so try to have the same hygienist and dentist attend the patient
Use measures that ease the patient, interpret communication, and respond appropriately to patient's needs

Table 5 VERA framework

V = Validate, accepting that the behavior exhibited has a value to the person and isn't just another symptom of dementia
E = Emotion, paying attention to the emotional content of what the person's saying
R = Reassurance, can be as simple as saying "it'll be okay" and smiling, holding their hand
A = Activity, people with dementia need to feel occupied, active, see if you can engage them in some related activity

4 Interventions to Improve Oral Health in Persons with Cognitive Impairment

Most randomized controlled trials of oral health interventions for patients with dementia took place in long-term care settings. Dental expert opinion suggests that the management techniques that have worked in institutionalized patients may also work for persons with cognitive impairment living in the community.

In a systematic review of 8 cohort studies and 1 randomized control trial including 531 patients in LTC settings [52], the use of battery-powered devices improved the oral health status of nursing home residents with dementia. However, only one study was a randomized control trial, whereas all the others lacked appropriate controls. Of note, the randomized control trial did show an improvement in residents' oral health status. Multicomponent interventions may be especially effective for patients with cognitive impairment. The Managing Oral Hygiene Using Threat Reduction (MOUTh) intervention consists of 3 components: (1) an evidence-based mouth-care protocol for older adults with natural dentition and dentures, (2) recognition of care-resistant behaviors, and (3) strategies to reduce threat perception during the provision of mouth care. The MOUTh intervention employs strategies to prevent and reduce care-resistant behaviors including the following: establishing rapport by approaching the resident at or below eye level with a pleasant and calm demeanor; providing mouth care in front of a sink and in front of a mirror (to access procedural or implicit memories); avoiding elderspeak (a type of sing-song "baby talk"); chaining, which involves starting the mouth care and having the older adult finish the task; cueing by using gestures, pantomimes, and short, one-step commands; distraction; bridging, where the older adult is asked to hold a toothbrush during mouth care; rescue, where a second experimental staff provider may replace the first experimental mouth care provider if care-resistant behaviors escalate; and hand-over-hand, which involves either the older adult placing his or hand over that of the experimental mouth care provider or the experimental mouth care provider gently guiding the older adult's hands. In a randomized trial of 101 older nursing home residents with dementia and care-resistant behaviors, those patients receiving the MOUTh intervention had twice the odds of allowing mouth care and completing oral hygiene activities as compared with usual care controls with an established mouth care protocol [53]. The intervention also allowed staff to provide longer duration of mouth care to these residents. The investigators reported only small reductions in the intensity of care resistant behaviors and a small improvement in oral health.

In summary, this evidence suggests that the use of battery powered devices and multicomponent strategies aimed at reducing care-resistant behaviors will improve the oral health status of older adults with dementia in long-term care settings.

5 Interventions to Improve Oral Health in Persons with Depression

There is a paucity of evidence from randomized controlled trials on dental interventions in patients with depression. A study of a brief educational 10-minute video and educational brochure compared to the brochure alone significantly decreased the plaque record in patients with mental illness, both community-dwelling and institutionalized patients [54]. However, this trial in Korea did not include patients over 65 years old, so its generalizability to the population of older adults is limited. Expert opinion from dentists suggest that the appropriate dental management of geriatric patients with depression necessitates the use of anticaries agents containing fluoride, saliva substitutes, and special precautions when prescribing analgesics and local anesthetics [55].

6 Practical Considerations and Recommendations for Management of Patients with Cognitive Impairment and Mood Disorders

6.1 Simple Advice on Key Issues Based on Expert Opinion [56]

Prior to dental appointments, caregivers should be contacted 1 week to 2 weeks in advance of the appointment to update the patients' health, dental, and pharmacologic history.

6.2 During Dental Appointments

Due to the impact of dementia, delirium, and depression on oral health status, oral health professionals should consider assessing older adult patients for cognitive impairment and depression on the first visit and at least yearly thereafter with one of the screening tools listed in Table 6.

6.3 Communication

When communicating with older adults, use simple, short sentences and a soft tone of voice. Patients with dementia should be encouraged to express their ideas and feelings regarding their oral health. Asking a patient about her hobbies, favorite sports teams, or family may facilitate care and adherence, which helps foster rapport

Table 6 Practical screening for dementia, delirium, and depression disorders

Condition	Screening tool	Rationale	Validity
Dementia	Test Your Memory (TYM), Self-Administered Gerocognitive Exam (SAGE)	Self-administered	Better correlation than MMSE with neuropsychological testing [57]
Depression	PHQ-2	Short, quick to administer	Sensitivity comparable with the PHQ-9 in most populations [58]
Delirium	3D-CAM	Easy to administer	The sensitivity [95% CI] of 3D-CAM was 95% [84%, 99%] and the specificity was 94% [90%, 97%] [59]

and engagement with the shared decision-making process. Nonverbal communication, such as direct eye contact, empathetic facial expressions, and supportive body postures, may assist in communicating with patients with dementia. Patting the patient's shoulder and smiling can help decrease anxiety and increase cooperation. Demonstrating the procedures to be performed can alleviate fear and encourage cooperation. Even though caregivers should be involved in the decision-making process, the dentists should always address the patients during the interview.

6.4 Involvement of Caregivers

Based on expert opinion [56], the most beneficial advice for treating an older adult with dementia, delirium, and depression is the involvement of the older adults' caregivers. The older patient's caregiver is an essential asset to the dental office, because they are a source of familiarity in an unfamiliar environment, enable an accurate dental and medical history, assist in consolidating information that the older adult may not be able to articulate, provide continuity from appointment to appointment when the patient forgets details regarding their treatment plan, remind the patient about their future dental appointments, and provide support and reminders of oral daily, self-care behaviors such as when to brush or floss.

6.5 Managing Care-Resistant Behaviors at the Dental Office

With the aid of a caregiver, first use evidence-based behavioral approaches such as those described in the MOUTH intervention described earlier. If the behavior is not controlled with these interventions, based on expert opinion, sedation or general anesthesia may be necessary. Informed consent should be obtained if restraints are used [56]. Sedation may enable dental professionals to treat patients effectively and perform all required dental treatments during a single appointment, thereby saving time, cost, and inconvenience for patients and caregivers.

6.6 Oral Self-Care-Resistant Behaviors

Explain oral self-care in simple language: (1) Brush and floss your teeth every day; brushing and flossing help remove dental plaque, a sticky film of bacteria (germs). If plaque builds up on your teeth, it can cause tooth decay or gum disease. (2) Brush your teeth with fluoride toothpaste twice a day. Brush after breakfast and before bed. (3) Floss between your teeth every day. If you have trouble flossing, ask your dentist about using a special floss-aids instead. Techniques such as the teach-back and the use of written handouts may complement these interventions. Teach-back is a way to make sure the healthcare provider explained information clearly by asking a patient (or family member) to explain—in their own words—what they need to know or do and to check for understanding and, if needed, re-explain and check again. Research has shown that this technique may promote adherence, quality of care, and patient safety. For a more in-depth discussion on the teach-back technique, please refer to chapter "The Role of Oral Health Literacy and Shared Decision Making".

7 Future Research Agenda

There is a paucity of cohort studies characterizing the clinical presentation of patients with dementia in community-based dental clinics. Studies are needed on the validity of the Brief Oral Health Status Examination in community-dwelling older adults with dementia. Research into the efficacy of caregiver education programs, use of electronic toothbrushes, and replications of the MOUTH intervention in diverse community settings may provide valuable information to clinicians. Also given the paucity of data in older adults with depressive disorder, trials on the effect of educational programs on the plaque record of older adults specifically with depression are needed, and whether treatment of depression is associated with better oral healthcare outcomes. We need more studies in healthcare institutions on the effects of delirium on oral health status.

8 Conclusions

In this chapter, we presented a brief overview of cognitive and mood disorders in older adults including dementia, depression, and delirium, explored the relationship of oral health and these conditions, and offered advice on clinical interventions. One in 8 patients over the age of 65 seen in dental offices has cognitive impairment and over 35% have depressive disorders. Cognitive disorders such as dementia and depression lead to higher rates of caries, gum disease, tooth loss and edentulism. We discussed how the assessment and management of oral conditions may be adapted

to patients with cognitive and mood disorders (i.e., by involving caregivers) and gave oral health clinicians practical advice on how they should screen with validated screening tools (i.e., PHQ-2, 3DCAM, SAGE questionnaires) and manage these disorders in their dental practice by employing strategies to Engender Cooperation for Periodontal Care (i.e., such as the VERA Framework). We presented evidence that suggests that the use of battery powered devices and multicomponent strategies aimed at reducing care-resistant behaviors will improve the oral health status of older adults with dementia in long-term care settings. Finally, we formulated an agenda for future research to obtain a better understanding of how dementia, delirium, and depression impact oral health and the interventions that may be needed to address these conditions in the older population. We need more studies on the impact of delirium, depression, and dementia and their respective treatments on patients' oral health across the healthcare spectrum.

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Oral Care in Long-Term Care Settings

Ronald Ettinger and Leonardo Marchini

1 Introduction

The US population is aging, and the most recent data available suggest that in 2018 persons over 65 made up 16% of the total population [1, 2]. The older population has been projected to grow in number and percentage reaching 22% in 2050 [3]. As these people age, 34% of them will become frail and functionally dependent, that is, they will not be able to maintain their independence, and will require either home health services or long-term care services and other supports (LTSS) sometime during their life span [4]. In 2010, it was estimated that 10.9 million persons who lived in the community needed LTSS; half of them were over the age of 65. In addition, there were 1.8 million persons living in long-term care facilities (LTCF), the majority of which were older adults [5]. In 2019, it was noted that approximately 1.5 million persons were now living in nursing homes, and 65.6% were women, while 7.8% were over the age of 95 years, 33.8% were between 85 and 94 years, 26.4% were between 75 and 84 years, 16.5% were between 65 and 74 years, and 15.5% were under the age of 65 [6]. In general, nursing home residents need help with instrumental activities of daily living (IADLs) and at least one activity of daily living (ADLs). Consequently, many need help with daily oral hygiene and are more likely to have poorer oral health than persons of a similar age living independently [7–9].

The current cohort of older Americans is keeping their teeth for longer, as edentulism rates have declined to 17.6% for persons 65 years and older [10, 11].

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However, this rate varies by state, by income, and by education [11]. Currently, the majority of residents in long-term care facilities (LTCFs) are dentate [12], and it has been shown that poor oral health impacts a person's quality of life [13], by putting them at risk for pain and infection [14]. Also, it has been reported that lack of oral hygiene can precipitate aspiration pneumonia [15, 16]. Although this information has been known for some time, the provision of daily oral care and oral services for persons living in LTCFs is still poor [17], as communication between healthcare providers and dentists in LTCF is inadequate [18].

Most investigators who have attempted to introduce an adequate oral hygiene care program within LTCFs have failed once the supporting funding ceases. The main reasons for this failure are lack of an organizational culture within LTCFs to prioritize oral healthcare, which translates to the absence of enforcement of existing regulations/guidelines (OBRA 1987) [19]. Many LTCFs are understaffed and in addition the direct care workers (nurses' aides) are underpaid, overworked, and undereducated [17, 20]. Unfortunately, many of them have poor oral health themselves, so they are not motivated to care for the oral health of the residents. Therefore, the quality of any oral healthcare program in a LTCF will depend upon the importance the director of nursing and the administrator place on the oral health of the residents [19].

There have been many modes of delivery of dental care services in LTCFs. The method most acceptable for dentists has been transporting residents to a local dental practice, which will accept these patients. This method is inconvenient and costly for nursing homes, because they must designate a staff member to accompany the resident to the appointment. Therefore, nursing homes would prefer it if the residents' family members were willing to transport them [21]. To provide services in the nursing home, the simplest method has been emergency care only using a tackle box, which contains enough instruments and supplies for the extraction of teeth and the adjustment of dentures. The next level, which includes more comprehensive care, uses portable equipment that can perform preventive procedures and simple restorations. At the next level, the dental provider would use mobile equipment, which is set up in the nursing home for a period of time, and allows the dentist to do comprehensive care, including more complex procedures. Mobile vans have been equipped to visit nursing homes, but their use is limited by geography and the weather, because it requires taking the residents from the home to the van for care.

This chapter will expand on the details of the LTCFs population and their oral health problems. It will discuss dental care delivery systems, which have evolved, and define possible advantages and disadvantages of each of these systems and how these have been impacted by the COVID-19 pandemic.

2 Description of Long-Term Care Facilities and Their Population

Traditionally, nursing homes were used to provide services for frail and functionally dependent older adults, as well as younger adults with disabilities, who were unable to support themselves independently in their daily lives. With the advent of the Affordable Care Act (ACA), a new term for nursing homes was defined as

long-term care services and supports (LTSSs). This new term includes both institutionally and noninstitutionally based care, which includes adult day services, home health agencies, hospice, nursing homes, and assisted living facilities (ALF) and similar residential care communities [22].

Within the long-term care population, there are two major groups of residents. The first group are those who live in the facilities and receive long-term care, the second group are those who are admitted for post-acute care, usually following a stay in the hospital. The two groups have different clinical characteristics, as well as different sources of funding for their stay in the LTCFs [23]. The first group need permanent help with their activities of daily living, while the second group need help for a limited period of time to recover from their illnesses and should be able to return to their communities. The funding for the first group is either by out-of-pocket or by private nursing home insurance, or, if they become very poor, they may qualify for Medicaid, the US government healthcare insurance for the poor. The second group of older adults are usually funded by Medicare, the government healthcare insurance for Americans over 65 years of age, for up to 100 days, after a medically necessary hospital stay of at least 3 consecutive days. If the recovery time needs to be longer, then the cost will need to be financed either by out-of-pocket, by private insurance, or by Medicaid [24].

The traditional pool of family caregivers has changed due to decreasing family size and increasing employment rates among women, which has resulted in an increasing need for paid long-term care services for frail and functionally dependent family members. In the past, family members with early to middle stage dementia who were at risk, and living by themselves, were cared for by their families. However, this situation has changed as there is nobody at home during the day to care for these persons [22]. Consequently, these older adults with frailty would have three options. If the family can afford it, then they can employ a caretaker to come to the home or, if it is available, the older adults can go to an adult day care center. The third option is a long-term care facility, which can vary from residential care communities to a traditional nursing home [22].

Data from the National Longitudinal Caregiver Study [25] reported that the caregivers' reasons for placing dependents in LTCFs were related to the need for more skilled care (65%), the deterioration of caregiver's health (49%), the dependents' dementia-related behaviors (46%), and the need for more assistance (23%). For persons living at home, cognitive impairment and incontinence are common reasons for families to place their relatives in LTCFs, because dealing with these conditions severely impacts the life satisfaction of the family and caregivers. The majority of these frail and functionally dependent older adults have maintained some natural teeth. These natural dentitions need continuing daily oral hygiene care, which they may or may not get adequately when residing in a LTCF [17].

3 Oral Health Problems Among Residents of LTCFS

There is very little current data on the dental status of LTCFs residents, as there has not been a national study since 1997 [26, 27]. However, there are some regional studies in which the dentate status among LTCFs residents has been reported and

varies from 53% in Kentucky [9] to nearly 80% in Florida [12] (see Table 1). The increased retention of teeth has resulted in a need for maintenance of these heavily restored dentitions (Figs. 1 and 2), which sometimes results in a need for complex restorations [10].

Many of the LTCFs residents are taking multiple medications to treat their numerous medical problems. It has been reported that over 400 medications have some potential for causing hyposalivation and xerostomia [30, 31]. The effects of these conditions on the heavily restored dentitions are increased plaque levels, resulting in new coronal caries, recurrent caries, root caries, and an exacerbation of periodontal disease (Fig. 3). These oral diseases can cause a decrease in oral health-related quality of life [31]. Poor eyesight, decreased hand-eye coordination, reduced

Table 1 Dentate status of residents in long-term care facilities in the USA

Author	Year	State	Percentage dentate
Murray et al. [12]	2006	Florida	79.6
Bush et al. [9]	2010	Kentucky	53.3
Chen et al. [28]	2013	Minnesota	69.9
Caplan et al. [29]	2017	Iowa	67.0
Marchini et al. [17]	2018	Iowa	77.8

Fig. 1 Intraoral view of an 82-year-old female resident with a heavily restored dentition, who is still able to maintain oral hygiene at an acceptable level, although there is evidence of plaque accumulation and localized marginal gingivitis

Fig. 2 Ortho-pantomograph of the same 82-year-old resident pictured in Fig. 1, showing her heavily restored dentition

Fig. 3 Intraoral view of 68-year-old female resident, showing plaque accumulation resulting in coronal and root caries and periodontal disease, in an already heavily restored dentition with a history of taking multiple medications with xerostomic potential

manual dexterity, and cognitive impairment can cause increased plaque levels, which can lead to higher levels of oral disease unless appropriate daily oral hygiene routines are provided by LTCFs staff [32, 33]. For a more in-depth discussion on the topics of xerostomia, periodontal disease, and cognitive impairment, please refer to chapters "Xerostomia and Hyposalivation", "Management of Periodontal Disease in Older Adults", and "The 3 Ds: Dementia, Delirium and Depression in Oral Health".

However, there is data to show that the daily oral hygiene support by staff in LTCFs is often poor or inadequate [17, 34]. The reasons for this dilemma are that the primary caregivers are nurses' aides, who often have poor oral health themselves and are inadequately trained to carry out oral hygiene procedures for residents, especially those who resist care. In addition, the nurses' aides are underpaid and overworked, and many LTCFs are understaffed, which results in inadequate oral healthcare for the residents. There have been several attempts to improve oral hygiene routines in LTCFs [17, 20]. The most successful has been the hiring of a dental hygienist either part-time or full-time to help with daily oral healthcare [35]; however, most LTCFs are not prepared to pay for these services, as dental care is not reimbursable through the health insurance of Medicare, unlike physical therapy, speech therapy, or occupational therapy [36, 37]. Another successful approach has been to designate one of the nurses' aides as the "oral health specialist" and, after some training, to have them spend at least 50% of their time caring for the oral health of the residents [38]. Unfortunately, when the grant money runs out for such a program, so does the support of the LTCF. Another problem is the high rate of turnover of LTCFs staff. If a training program exists within the LTCF, unless it is repeated on a continuous basis, the resignation of the current staff will dilute the commitment of the nurses' aides to an oral hygiene program; and when the new staff are hired, they have not benefited from the training program nor from the cooperative environment previously achieved [39].

Consequently, many reports have found poor oral health among LTCFs residents [17, 40, 41]. The consequences of an inadequate dentition can be inability to chew food adequately that can result in poor nutrition [42], as well as difficulties with communication [43], and declining systemic health, such as poor glycemic control

[44], increased risk for cardiovascular disease [45], and aspiration pneumonia [46]. The microbial colonization of hard surfaces, such as teeth and/or dentures, allows for formation of biofilms. These biofilms if left undisturbed due to a lack of oral hygiene change from gram-positive and mostly aerobic to gram-negative and anaerobic, which if inhaled can cause aspiration pneumonia, which is the leading cause of death in LTCFs [47]. There are several studies that have shown that daily oral hygiene for residents decreases the incidence of aspiration pneumonia in LTCFs [46]. For a more in-depth discussion on this topic, please refer to chapter "Swallowing, Dysphagia, and Aspiration Pneumonia".

The COVID-19 pandemic has negatively influenced access to care for LTCFs residents, because currently many facilities will not allow healthcare practitioners into their premises, unless they are salaried staff. LTCFs are reluctant to send their residents to other healthcare facilities, unless the resident requires emergency care or hospitalization, which rarely includes oral healthcare. The consequences for the residents' oral health are an exacerbation of their caries and periodontal disease, especially because oral hygiene routines have been disrupted due to COVID-19 social distancing protocols [48, 49]. The emergency approval of COVID-19 vaccines and its currently availability for healthcare providers and LTCFs residents will change the negative impact of isolation on the residents and should allow them to regain access to regular oral healthcare.

4 Types of Oral Health Services for LTC Patients

Historically, there have always been a few dedicated dentists who have been prepared to care for residents in LTCFs, by either having them transported to their dental offices or by visiting them at their residences [50]. The reluctance of the majority of dentists to care for these persons has been studied over time, and a series of barriers have been identified [50, 51]. The barriers include lack of training in geriatric dental medicine, the cost in terms of time and efficiency caring for these patients, the complexity of the residents medical and pharmacological regimens, as well as the complexity of dealing with deteriorating, heavily restored dentitions [51, 52]. Additionally, some dentists may also be negatively influenced by the prevalent ageist culture in modern societies, predisposing them against caring for this age group who requires more time and also challenges the culture of efficient practice management [53].

Some families of residents in LTCFs are also reluctant for their relatives to receive dental care because it is expensive, and unless they have private dental insurance or are covered by Medicaid, all costs are out-of-pocket. Medicare does not cover routine dental care, only some oral surgical procedures [37]. Another reason for families' reluctance for providing dental care for their relatives is because they believe that such care will disrupt the life of their relatives [50]. Some older adults with frailty may have had bad childhood experiences with dental care and consequently may fear or distrust dentists [10]. Many residents may have low dental

health literacy [54], which impacts their understanding of the importance of dental care and daily oral hygiene routines, such as tooth brushing and the use of fluoridated toothpaste, which means they may not brush their own teeth regularly or they may resist help with oral hygiene.

Finding a nearby dentist who is prepared to treat LTCF residents may also be a barrier, as the accessibility of dentists' office may be a problem, even if he/she is willing to care for the residents. Some such office barriers include not having ramps, wheelchair accessible elevators, doors wide enough to accommodate wheelchairs, and operatories that are wheelchair accessible [55]. The staff of such an office needs to be sensitive to patients with vision and hearing disabilities, as well as knowing how to safely transfer patients.

The time of day to appropriately schedule residents may depend on their medical problems. For instance, patients with chronic heart failure are best seen in the morning, because they are strongest after a night's rest. Residents with arthritis need time to have their joints unstiffen; therefore, late morning to early afternoon are more appropriate appointment times for these patients. Mid- to late morning is appropriate for residents with dementia, as they may become more confused and sundown as the day progresses. Several residents may be underweight and may need appropriate support, such as pillows, egg crate foam, etc., to sit comfortably in the dental chair. These patients cannot tolerate long procedures, and their appointments should not exceed 2 hours, which must include travel time, as well as the time in the dental office [21].

Many practitioners may not want to treat LTCF residents, because they may become frustrated as these patients are unable to maintain their daily oral hygiene, and consequently their oral health may decline no matter what treatment is provided by the dentist. Their oral health may be further impacted by xerostomia caused by the medications they are using, their visual impairment, as well as their lack of manual dexterity [56].

Many residents do not have relatives living nearby and require the LTCF to transport them to the dentist's office, which incurs expenses for the facility. These expenses include providing an appropriate vehicle or a driver and/or a nurses' aide to accompany the resident, which means the aide is not available for duties within the facility. An alternative to transporting the resident is to provide care within the LTCF. One advantage is that many residents with frailty do not cope well with being transported out of their environment. Also, residents who are incontinent or catheterized are more easily treated within the LTCF [21].

The simplest mode of dental care for LTCFs residents is the use of a "tackle box" (Fig. 4). The tackle box contains equipment and supplies that allow the dentist to adjust dentures and do simple extractions [21]. A simple but necessary procedure would be to show the nurses' aides how to put the residents' name on their dentures. The simplest method is to abrade the surface of the denture and write the resident's name on the denture with a marking pencil and then to cover the area with two layers of clear nail varnish. This technique will allow the name to remain for 12–18 months. The "tackle box" can be used to treat caries using atraumatic restorative treatment (ART) technique, which includes silver diamine fluoride (SDF)

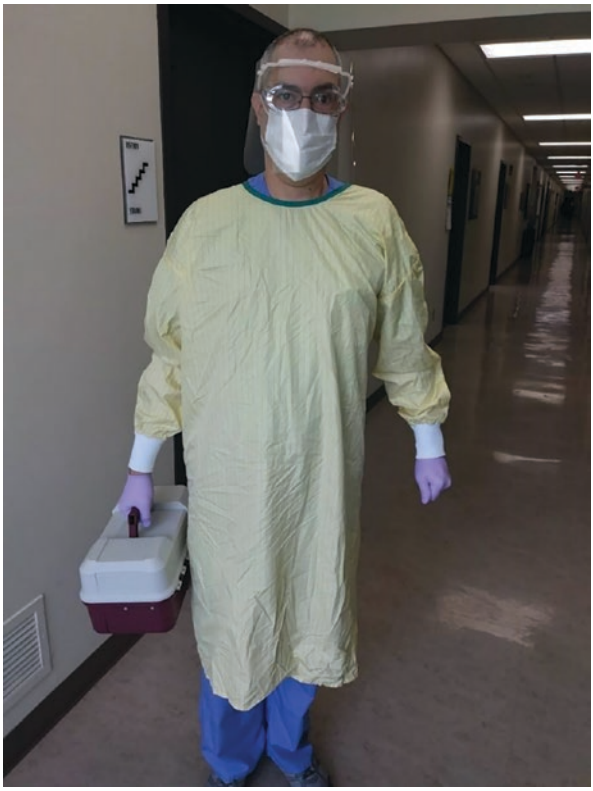

Fig. 4 Dentist visiting a long-term care facility, with the appropriate PPE, carrying a tackle box to provide a denture adjustment for a resident

applications and glass ionomer restorations [57]. These procedures require only hand instruments and do not generate aerosols, reducing the risk of COVID-19 infection [36]. For a more in-depth discussion on the topic of caries management, please refer to chapter "Management of Caries in Older Adults".

At the next level is commercial portable dental equipment, which allows the dentist to do the procedures described previously as well as direct restorations using rotary instruments, surgical extractions, and rest preparations for removable partial dentures (RPD). This equipment is not usually capable of sustained use but is efficient for intermittent procedures (Fig. 5). Some dental associations have bought this kind of equipment, which can be utilized at no cost by their members.

However, mobile equipment is now available, which is as effective as traditional dental office equipment (Fig. 6). This equipment allows the dentist to see multiple patients with comparable efficiency to a traditional dental office and provide comprehensive treatment. The advantage of this equipment is that it can be easily transported and timely installed in a facility, which allows providers to waste a minimum of their time prior to caring for residents, making it more cost-efficient for the dentist [57].

Especially equipped vans (Fig. 7) have been designed with dental chairs and other equipment. However, for a frail, functionally dependent or cognitively

Fig. 5 An Example of a portable dental unit (Aseptic Transport II, Aseptico, Inc Woodinville, WA 98072)

impaired persons, moving them from the LTCF to the mobile van can create serious risks or precipitate inappropriate behaviors. In hot weather, there is a risk of hyperthermia. In cold weather, there is a risk of falls, as well as hypothermia. Also, the van needs to be wheelchair accessible either with a ramp or a lift. Another disadvantage of the mobile van is related to their power source, which usually requires a 220-volt connection, and water lines that may freeze in the winter [57] If the van and the vehicle are directly connected, when the engine needs to be serviced, the equipment becomes unavailable, which further increases the cost of service.

Some large LTCFs that have a high proportion of private pay residents are able to provide in-house dental facilities for their residents, which allow the oral healthcare practitioners to have similar surroundings to a dental office and that is designed to care for at-risk and wheelchair-bound patients. To make such an on-site dental

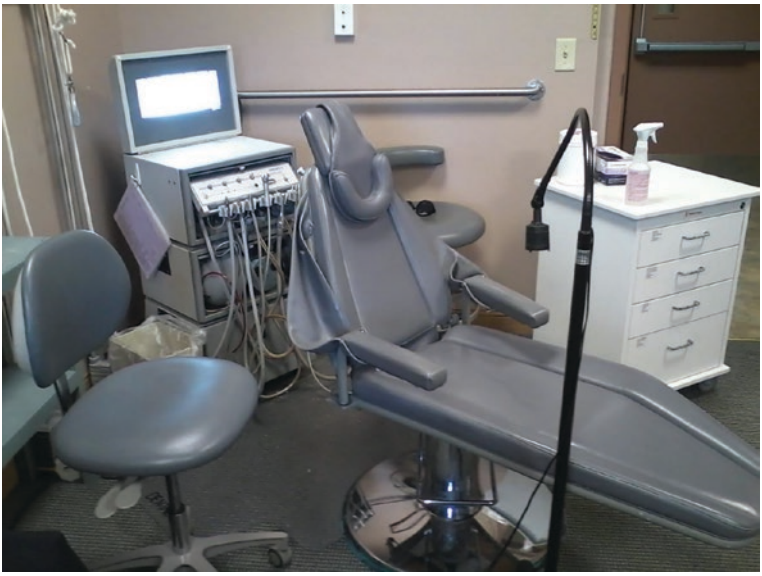

Fig. 6 An example of mobile equipment from DNTL (ProCart II) set up in a room in a nursing home with a portable chair and light, which is used by the University of Iowa's Geriatric Mobile Unit Program

Fig. 7 The van used by the Geriatric Mobile Unit Program parked outside of nursing home, in the Iowa winter, showing the problems that weather can pose to such a program

facility economically feasible, the LTCF should have at least 150 to 200 residents. To be flexible, these programs should also have some portable equipment to be able to treat residents in their rooms if they are bedridden [21]. In some cases, these operatories may be shared with podiatry and occasionally with hair dressing shops. These LTCFs may be able to employ a hygienist either full- or part-time to care for the residents, providing the state regulations allow indirect supervision by a dentist [57]. In Table 2, the advantages and disadvantages of different types of dental care delivery systems for LTCFs are summarized.

The most important service a consultant dentist needs to instigate in a LTCF is to develop a continuing and functioning oral hygiene program within the facility. Educating the director of nursing (DON) and the administrator to support such a program is not easy as previously discussed. This program should also include the help of the LTCF dietician to reduce the residents' intake of refined sugars and other carbohydrates, as well as discouraging the residents from snacking between meals or consuming sugary treats and carbonated beverages.

In-service programs for nurses' aides should begin by asking them what barriers they face when providing daily oral hygiene care for the residents. It helps to provide hands-on training with residents, especially showing the aides how to manage care-resistant behaviors, such as refusing oral care, kicking, hitting, biting, spitting, or inability to understand what is happening and/or to follow directions. The program should then describe basic communication techniques, as can be seen in Table 3.

Table 2 Advantages and disadvantages of different types of dental care delivery systems for LTCFs

Type of program	Advantages	Disadvantages
Transport to practice	Dentist has all equipment Cost-effective for dentists Cost-effective for LTCF if family transports the resident	Office needs architectural changes to accommodate wheelchairs Not cost-effective for LTCF if responsible for transportation Maybe stressful for residents
"Tackle box"	No additional equipment costs Ease of portability Cost-effective for LTCFs Less stressful for residents	Time-consuming for dentist Limited range of treatment options
Portable equipment	Ease of portability Ease of set-up Cost-effective for home Less stressful for residents	Time-consuming for dentist Limited range of treatment options Cost of equipment
Mobile equipment	Cost-effective for home Still portable Less stressful for residents	Time-consuming for dentist High cost of equipment Transportation and set up time
In-house facility	Cost-effective for dentist Less time consuming for dentist Less stressful for residents	High cost of equipment for LTCF

Table 3 Basic communication techniques to be used with care-resistant residents

Basic communication techniques
Be patient, respectful, and gentle when approaching the resident
Avoid removing the resident from his/her favorite activity
Address the resident by his/her name
Always smile
Keep eye contact, preferably at the resident's eye level
Approach the resident from the front; move slowly
Introduce yourself to the resident
Use plain language and short sentences
Provide only one instruction at a time
Briefly explain what you are doing and why you are doing it, and repeat it as necessary
Be sure to provide constant encouragement and abundant and immediate positive reinforcement for good behavior

If the resident does not voluntarily cooperate in toothbrushing, it may be helpful to simply touch the lips and teeth with a toothbrush, which may trigger a reflex related to toothbrushing. If there is further resistance, Jane Chalmers [58] has summarized in detail techniques that have been used to manage oral hygiene care for residents with dementia. One such technique for helping to clean a person's teeth who will not open his/her mouth is to take a toothbrush; bend it back at a 45° angle; slide the bent toothbrush into the angle of the mouth, holding it against the cheek, to break the perioral muscles spasm; and allow for the removal of plaque and debris. Some other techniques, which have been described to communicate with residents with challenging behaviors, are shown in Table 4.

When discussing with nurses' aides, the reasons why they were reluctant to brush residents' teeth was a fear of being bitten and punched. To protect themselves, nurses' aides can be shown how to approach the resident from the side, gain his/her attention, and then move behind him/her, cup the chin with one hand, and slowly bring the brush to the mouth with the other hand. This allows the nurses' aide to protect themselves from being kicked or punched as they can control the residents' hands. If the resident has a rocking chair in his/her room, it is very useful to place a foot on the rocker, tip it back, and bring the resident back toward the caregiver's abdomen, which gives easier access to the mouth, from a more protected position (Fig. 8).

If the resident is agitated, it is important for the caregiver to determine if the resident is at risk of self-injury or of hurting others, prior carrying out oral healthcare at this time. The caregiver may try distraction and/or rescuing techniques, but if the resident does not respond, then the procedure should be aborted for another more convenient time when the patient is less agitated.

If the resident has a permanent nasogastric tube and is bedridden, many caregivers do not believe that the resident needs oral hygiene care. However, even though the resident is not eating, he/she is still generating biofilm, which if undisturbed increases the risk of aspiration pneumonia. Many of these residents cannot follow instructions and will not open their mouths to allow their teeth to be brushed. To overcome this problem, it is possible to insert a tongue depressor between the teeth

Table 4 Techniques to communicate with residents with challenging behaviors

Name of the technique	Description of the technique	Example
Rescuing	A second caregiver comes to deliver care, as the first caregiver leaves or steps back	The resident resists having the teeth brushed by one caregiver. A second caregiver takes over the resident's care.
Distraction	The resident can be distracted by singing a favorite song, by holding an item (such as a blanket or a doll), by watching a TV show or other video on YouTube	A resident is agitated during dental care. The resident is offered a doll or soft blanket as a distraction and this usually calms him/her down.
Bridging	The resident's sensory connection to the activity can be improved by having he/she hold the same object that is being used by the caregiver	Have the resident hold a toothbrush while the caregiver brushes his/her teeth with another toothbrush
Hand over hand	The resident is guided in an activity by the caregiver placing his/her hand over the resident's hand, in order to complete the task	Have the resident hold a toothbrush and then the caregiver places his/her hand over resident's hand and guides the toothbrushing
Chaining	A caregiver starts an oral healthcare activity and then lets the patient finish it	The caregiver places the resident's denture in his/her hand and encourages him/her to return the denture into his/her mouth

Fig. 8 A resident sitting in a rocking chair; the caregiver is tipping the chair backward to improve access to the mouth while brushing the residents' teeth

and then slide another one underneath it and keep adding them until the mouth is opened wide enough to insert a toothbrush. If that toothbrush is attached to suction, the mouth can be cleaned, the tongue brushed, and chlorhexidine sprayed to prevent dental diseases.

The development of a preventive program may help to reduce the effects of xerostomia and plaque accumulation in the residents' dentitions. The use of prescription high concentration fluoride toothpastes, such as toothpastes with 5000 ppm fluoride content, and no alcohol, or 0.12% chlorhexidine rinses have been shown to help reduce caries and periodontal disease [3]. Residents who are in a semicomatose state need to have their teeth, tongue, and gums wiped 2–3 times/day with moist gauze or glycerin and/or 10% solution of bicarbonate of soda to remove the coating which forms on these tissues [21]. The residents' lips should also be lubricated with lanolin to prevent drying and cracking. For care-resistant residents, the use of chlorhexidine in atomizers, which can be squirted into the buccal mucosa, has been shown to be efficacious [59].

5 Influence of the COVID-19 Pandemic on Oral Health Services for LTCFS Residents

In addition to the abovementioned barriers, residents of LTCFs are now facing new barriers related to the COVID-19 pandemic, which is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2). The major risk factors for poorer COVID-19 outcomes have been identified as older age and comorbidities [60], for instance, the case fatality rate for individuals aged 80+ has been reported to be about 22% [61].

LTCFs have become high-risk sites for COVID-19 infection and transmission. Many LTCFs have had outbreaks of COVID-19 around the USA, which may be caused by asymptomatic shedding of the virus, a lack of adequate personal protective equipment (PPE) for the staff, limited tracing of COVID-19 positive staff, and the limited testing of residents and staff [6, 62]. Unfortunately, many direct care workers in LTCFs have received inadequate training on how to protect themselves and others from COVID-19 infection. Also, many live in homes with multiple generations of family members, which reduces social distancing, and many must rely on public transportation to reach the LTCFs. These social issues heighten the staffs' risk of being infected by SARS-Cov-2, which has resulted in widespread virus outbreaks in LTCFs [49, 63]. As cognitively impaired residents now constitute a large proportion of residents in American LTCFs, many will not observe precautions related to COVID-19, such as wearing masks and maintaining social distancing, and so are at higher risk of getting infected and infecting others [6].

Another unintended consequence of the pandemic is that nurses' aides are avoiding providing daily oral hygiene help for residents, because they are afraid of getting infected by the residents' saliva, which increases plaque levels in residents and results in more untreated dental disease [36].

LTCFs have improvised new infection control protocols as a result of COVID-19, such as forbidding group activities and reducing or barring visitors, which includes dentists and other non-salaried providers [6]. During these months of LTCFs lockdowns, elective dental treatment has been postponed, and the consequences will be increased severity of dental disease among residents [3].

The use of tele-dentistry has emerged as a method to triage residents either to monitor their dental problems, to prescribe analgesics or antibiotics, and, if necessary, to refer residents to a hospital with a dental department for extractions. There have been reports that neglected dental infections may result in a hospital admission requiring the administration of IV antibiotics for facial swelling due to a dental abscess [3]. However, some cognitively impaired residents are not easily transferred to a hospital. The policy of some LTCFs is that if a resident leaves the facility, the LTCF will require that the resident quarantines outside the facility for 14 days before he/she can return. Many families have become very stressed because they are unable to visit their family members who are residing in a LTCF and to safely provide healthcare for the resident outside of the facility.

6 The Integration of Oral Healthcare in LTC Services

In the 1980s, as a result of a federal class action lawsuit, due to decades of scandals caused by inappropriate care and lack of regulations, the Congress mandated a study of nursing home regulations, which was led by the Institute of Medicine. This resulted in the Omnibus Budget Reconciliation Act of 1987 (OBRA-87) [64]. These regulations required LTCFs to have a dentist affiliated with the facility and that each resident has a dentist of record and an annual dental in service [1]. Unfortunately, nursing home assessors did not routinely inspect each resident to determine their oral health problems; consequently, the nursing homes ignored these regulations. In 1990, Medicare and Medicaid introduced new regulations, including new standards of care, which were resident-focused and outcome-oriented. This process resulted in a range of new federal enforcement measures, which required Medicare and Medicaid to certify nursing facilities to use a standardized, reproducible, comprehensive functional assessment tool for all residents and to develop individualized care plans. As a consequence, the Resident Assessment Instrument (RAI) was developed under the supervision of the Health Care Financing Administration (HCFA), which included the Minimum Data Set (MDS) [64]. However, several studies have indicated that the MDS dental assessments identified very few oral health problems and that even when problems were identified, it did not result in dental care, as the nurse assessors still do not inspect the resident's oral health [6, 65].

It is clear that dentistry has been missing in geriatric interprofessional teams [66], in part because dental education has been separated from medical and allied healthcare training programs. The impact of oral health on the older patient's well-being is not fully understood by non-dental healthcare professionals. A possible

solution would be to develop geriatric interprofessional education (IPE) courses [67]. The World Health Organization (WHO) defines IPE as "when two or more professions learn with, about and from each other to enable effective collaboration and improve health outcomes." The WHO then defines interprofessional collaborative practice as "when multiple health workers from different professional backgrounds provide comprehensive services by working with patients, their families, caregivers, and communities to deliver the highest quality of care across settings" [68]. Interprofessional care for frail and functionally dependent older adults is critical due to the complexity of their healthcare needs and the small number of specialists available to consult and treat them [69, 70].

An example of a government sponsored program to improve the oral health of residents in LTCFs is Australia's "Better Oral Health in Residential Care Model." The basis of this program was to change the perception of healthcare workers that oral health was the responsibility of dental professionals and to make healthcare workers understand that it was the responsibility of the healthcare team. This model advocates for sharing roles among nurses, primary care providers, nurses' aides, and dental professionals to implement four key oral health-related processes, which "include oral health assessment, oral healthcare planning, daily oral hygiene support, and dental assessment and treatment" [71].

However, due to the existing limitations in geriatric clinical education in dental schools, many dentists are not familiar or comfortable using portable and mobile equipment to treat residents in LTCFs [72]. Many studies [50, 51] have shown that some dentists are prepared to care for these patients in their private practices but that can create problems for the patients and the LTCFs with regard to added stresses for the patients and transportation problems for the facilities. Another barrier for the dentist is that they are inadequately reimbursed for the additional time required to travel to and from the LTCFs and the extra time it takes to care for these older adults with frailty due to their limited ability to cooperate during treatment.

Possible strategies to mitigate these problems to train and allow allied oral healthcare professionals, such as expanded function dental hygienist and dental therapists, to provide care for the residents under indirect supervision of a consulting dentist [3]. The use of tele-dentistry to diagnose some oral lesions would reduce traveling time for the residents and dentists, allowing for more efficient and cost-effective care for this population [73].

7 Some Solutions to Problems Caused by COVID-19

Tele-dentistry (Fig. 9) has become an important tool to remotely assess frail and functionally dependent older adults who might not be able to come to the office due to COVID-19 and related isolation or quarantine [74]. This technology can be used to remotely assess a LTCF resident who has acute dental needs and is isolated. Such a resident may need a prescription for analgesics, or for antibiotics if there is any

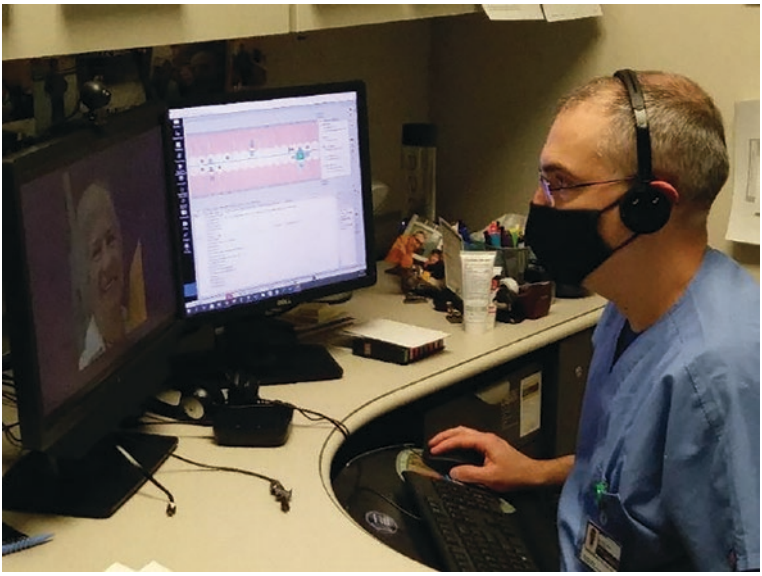

Fig. 9 A tele-dentistry consultation with a resident of a long-term care facility to determine her chief complaint, in order to decide if it is necessary for the dentist to visit the facility or if the resident needs to be referred to the dental practice. Please, note that she is a patient of record and that the dentist has access to her electronic dental records

sign of infection, such as facial swelling. If necessary, a referral may be required to transport the resident to a hospital emergency department that has a dental service.

Using this technology legally requires the dentist to appropriately identify the patient, e.g., by confirming their name and date of birth, which requires the dentist to have the patient's clinical records available. It may also require a staff member or the patient's legal advocate to be present in order to inform the patient/legal advocate about the limitations associated with tele-dentistry. At the end of the remote appointment using tele-dentistry, the dentist must keep detailed notes of the appointment. Dentists should avoid using tele-dentistry to consult with patients who are not patients of record, unless the patient has been referred to them.

Frail and functionally dependent older adult patients residing in LTCFs and their care providers should also be educated about the mitigation strategies that are being used in dental practices to improve infection control and aimed at minimizing COVID-19 transmission. These strategies include initial contact by telephone or tele-dentistry apps to identify the patient and their chief complaint, including asking about the existence of any COVID-19 symptoms. If the dentist refers the resident to his/her dental practice, the resident's temperature will be taken, and the accompanying person will be asked to maintain social distancing and to wear a mask. The dental provider will be wearing appropriate PPE, which will include a face mask and a shield, as well as a waterproof gown. Infection risks will be minimized by reducing aerosol generating procedures, such as the use of SDF and ART to manage caries, and hand scaling for periodontal maintenance. If aerosols need to be

generated, then the addition of extraoral high suction units can be employed to reduce the risk of aerosol-induced contamination.

Residents with dementia will have difficulties with tele-triage and the new protocols related to COVID-19. For instance, residents with dementia, who make up 48% of the LTCFs population [62], will react negatively to the use of face masks and shields by the clerical staff and dental providers (Fig. 10). This reaction can make providing dental treatment for these patients very disruptive. Many residents with hearing and vision problems will be unable to hear or lip read their dental provider if he/she is wearing a N95 respirator, a face mask, and a full-face shield [4].

Consequently, more older adults with dementia may need to be treated under general anesthesia (GA). The circumstances will depend on the patients' level of cognitive impairment, their disruptive behavior, and the type of dental care they need. Access to operating rooms for dental treatment under GA has been restricted in the past and has become extremely difficult due to COVID-19. A system for prioritization will need to be developed under these new conditions [75].

When dentists are allowed to reenter LTCFs to deliver elective dental care, they will need to use enhanced infection control precautions, such as inquiring if the

Fig. 10 Dentist wearing the appropriate PPE, which has evolved as a result of the COVID-19 pandemic

residents have had immunization for COVID-19 prior to the consultation. Additional measures should include improved decontamination of equipment and surfaces with 80% alcohol wipes. If aerosols need to be generated, the room being used should have the door closed, and the clinician will need to bring an extraoral high suction unit. Fogging protocols of the room should follow aerosol generating procedures, although this procedure has become controversial [3].

To support the required PPE and added equipment and supplies, reimbursement rates will need to be increased. Therefore, as a group the American Dental Association and other professional organizations will need to lobby third-party companies and government agencies to increase their reimbursement rates, if dental professionals are to safely care for these frail and functionally dependent older adults [3].

8 Conclusions

To be in compliance with OBRA-87, every LTCF should have a consultant dentist who has a contractual agreement with the facility to examine and treat all of the residents who consent to receive dental care. The consultant dentist should develop an oral health program for the institution together with the administrator, the director of nursing, and the medical director. Such a program should include:

1. Each resident should have a dentist of record included in their medical files.
2. An oral screening on or about the time of admission should be done by a dentist.
3. A yearly examination as required by the resident assessment instrument – minimum data set (RAI-MDS 2.0), either by a dentist or dental hygienist.
4. A yearly in-service for the nursing staff on an oral health topic, either by a dentist or dental hygienist.
5. All oral prosthesis should be marked with the resident's name or number.
6. There should be a customized written program of oral hygiene care for each resident, which includes:
   (a) The cleaning of teeth and/or dentures that should be performed daily, preferably by the resident, but if they are not competent, then by a staff member.
   (b) Modified or adapted toothbrushes for the resident's specific needs, if necessary.
   (c) An ultrasonic device for cleaning dentures.
   (d) The encouragement of residents to remove their dentures while sleeping, unless they are necessary to support a continuous positive airway pressure (CPAP) device.
7. If the resident requires treatment, then the treatment plan should follow the concepts of rational treatment planning, with the following priorities:
   (a) The highest priority is the relief of pain and the treatment of acute infection.

(b) Depending upon the life expectancy of the resident, dental treatment may be limited to emergency and maintenance procedures.
(c) Restoration of esthetics may be a valuable contribution to the emotional welfare of the family and the resident, even at the terminal phase of life.
(d) Restoration of function should be a priority taking into account what treatment is in the best interest of the residents after evaluating all their modifying factors.
(e) All other treatment is elective depending on the needs and expectations of the residents and their families.

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Oral Health of the Palliative and Hospice Patient

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The World Health Organization defines palliative medicine as specialized medical care for people living with a serious illness. It focuses on providing comfort and quality of life through the comprehensive assessment and treatment of physical, psychosocial, and spiritual needs [1]. Oral healthcare represents an essential aspect in the management of patients with serious and advanced life-threatening conditions. As a result, oral healthcare professionals become indispensable members of palliative care and hospice interprofessional teams [2]. The purpose of this chapter is to review the concepts of palliative care and hospice in the context of dental practice. We will review the definitions of palliative care and hospice, focus on specific oral healthcare issues arising during the care of patients with palliative care and hospice needs, review key ethical concepts at the end of life, and discuss the role of oral healthcare professionals as members of the palliative care team.

Research shows that older adults with serious illness and those with life-limiting conditions at the end of life have a high prevalence of oral problems that results from the direct effects of the underlying disorders and the adverse effects of the recommended therapies for these conditions [3, 4]. Oral diseases including mucositis, xerostomia, oral candidiasis, and oral pain, can have significant local and

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systemic consequences and substantially compromise the quality of life of individuals with serious illness. The early identification and treatment of oral conditions among older adults with palliative care and hospice needs could minimize pain and suffering [3]. However, there are important barriers to overcome when managing these patients. Evidence reveals that about 40% of palliative patients at one point during their illness may lose the ability to communicate their symptoms [5]. This may contribute to the underreporting and underestimation of oral conditions, which may result in the failure of healthcare professionals to properly address them [6]. Regular assessments may help identify oral conditions and facilitate the implementation of appropriate and timely interventions. As we will review during this chapter, caregivers play a critical role during clinical encounters when patients with palliative care and hospice needs are unable to communicate.

1 The Concepts of Palliative Care and Hospice

Palliative care and hospice are part of a continuum of healthcare for patients with serious illnesses. Palliative care can be provided at any time during the trajectory of any serious illness, while hospice care is offered for patients at the end of life. In the next sections, we address each of these concepts, highlighting the main commonalities and differences between both concepts (Fig. 1).

1.1 Palliative Care

Palliative care focuses on anticipating, preventing, diagnosing, and treating symptoms experienced by patients with serious illnesses. Moreover, palliative care professionals play an essential role in assisting patients and their families in making important healthcare decisions. Palliative care becomes a resource for anyone living with a serious illness, and it is appropriate at any stage of the illness. Palliative care can be provided along with the delivery of curative treatments [1, 3]. A centerpiece

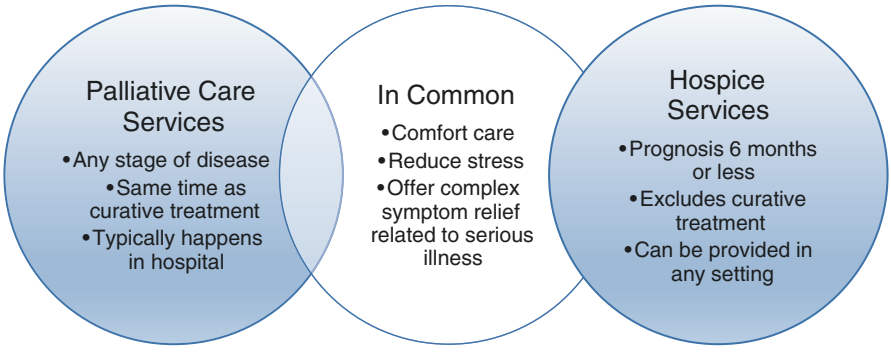

Fig. 1 Differences and similarities between palliative care and hospice

of the palliative care approach is the interprofessional team that provides comfort care while maintaining optimal function and well-being [7]. The team often consists of palliative care physicians, nurses, dietitians, social workers, and chaplains.

The delivery of palliative care early in the course of a life-limiting illness can improve the quality of life for patients; decrease overall healthcare utilization, including hospitalization [8]; shorten hospital stays; and reduce the need for non-beneficial therapies [9]. The palliative care approach does not aim to hasten or postpone death. Research shows that palliative care increases hospice care use and improves patients' quality of life and even survival [10]. In terms of healthcare utilization, palliative care interventions can significantly reduce total healthcare costs in patients with advanced cancers [8, 11]. Each year, an estimated 40 million people need palliative care. Unfortunately, despite the potential benefits of palliative care approaches for patients with serious illness, only about 14% of people, who need palliative care worldwide, currently receive it [1].

Worldwide, efforts are underway to expand palliative care services for patients in need. The 2014 World Health Assembly passed a resolution appealing to member countries to incorporate palliative care services into their respective healthcare systems [12]. Furthermore, two more important developments at the global policy level are worth mentioning. First, in 2000, palliative care was included in the United Nations' International Covenant on Economic, Social, and Cultural Rights, which states: "States are under the obligation to respect the right to health by, inter alia, refraining from denying or limiting equal access for all persons… to preventive, curative, and palliative health services." Second, essential medicines for palliative care were included into the 18th World Health Organization (WHO) essential medicines list in 2013 [13].

1.2 Hospice

As curative interventions no longer achieve the patient's care goals, patients may begin the transition to hospice care. Hospice care is defined as comfort care for patients facing a terminal illness [14]. Patients qualify for hospice care when their physicians estimate that the patient's prognosis for survival is 6 months or less if the disease runs its course. As with palliative care, hospice provides comprehensive comfort care as well as family support. Unlike palliative care, hospice no longer focuses on cure. Increasingly, people with serious illnesses that no longer respond to curative interventions are choosing hospice care as an alternative at the end of life. Hospice can be provided in any setting—home, nursing home, assisted living facility, or inpatient hospital. In the USA, hospice services are covered by government insurance such as Medicare or Medicaid, as well as most private healthcare insurance. Medicare and many private insurance plans cover the cost of palliative care. This coverage is different from the hospice care benefit [14]. In other high-income countries such as Australia, palliative and hospice services are funded by Medicare [15], whereas in Canada, palliative care is provided free of change to eligible patients [16]. An example of a middle-income country, Colombia, has a palliative care law requiring that palliative care be offered to all patients with cancer [17].

Table 1 Karnofsky Performance Scale Index [22]

Able to carry on normal activity and to work; no special care needed	*[100]* Normal no complains; no evidence of disease *[90]* Able to carry on normal activity; minor signs or symptons of disease *[80]* Normal activity with effort; some signs or symptons of disease
Unable to work; able to live at home and care for most personal needs; varying amount of assistance needed	*[70]* Cares for self; unable to carry a normal activity or to do active work *[60]* Requires occasional assistance but is able to care most of his personal needs *[50]* Requires considerable assistance and frequent medical care
Unable to care for self; requires equivalent of institutional or hospital care; disease may be progressing rapidly	*[40]* Disabled; requires special care and assistance *[30]* Severely disabled; hospital admission is indicated althought death not imminent *[20]* Very sick; hospital admission necessary; active supportive treatment necessary *[10]* Moribund; fatal processes progressing rapidly *[0]* Dead

Table 2 Palliative Performance Scale (PPS)

%	Ambulation	Activity level evidence of disease	Self-care	Intake	Level of consciousness
100	Full	Normal, no disease	Full	Normal	Full
90	Full	Normal, some disease		Normal	
80	Full	Normal with effort, some disease		Normal or reduced	
70	Reduced	Can't do normal job or work with effort, some disease		Normal or reduced	
60	Reduced	Can't do hobbies or housework significant disease	Occasional assistance needed	Normal or reduced	Full or confusion
50	Mainly sit/lie	Can't do any work, extensive disease	Considerable assistance needed	Normal or reduced	Full or confusion
40	Mainly in bed	Unable to do any work, extensive disease	Mainly assistance	Normal or reduced	Full or drowsy or confusion
30	Bed bound	Unable to do any work, extensive disease	Total care	Reduced	Full or drowsy or confusion
20		Unable to do any work, extensive disease		Minimal	
10		Unable to do any work, extensive disease		Mouth care only	Drowsy or coma
0	Death	–	–	–	–

In the USA, hospice eligibility requires that a physician certifies the patient has less than 6 months to live if the disease follows its usual course [18–20]. Accurate prognostic information is important for patients, families, and physicians, i.e., it can help physicians decide whether to initiate or continue anticancer therapies [21],

facilitate transitions to hospice care, enable appropriate advance care planning, and ensure end-of-life shared decision-making. Clinicians may use performance status measures defined as global assessments of the patient's level of function. The Eastern Cooperative Oncology Group (ECOG) scale and the Karnofsky performance status (KPS) [22, 23] are two widely used methods to assess the functional status of patients with serious illnesses [24]. The Palliative Performance Scale (PPS) (Table 2) [25] is another tool to assess functional performance. It also helps determine progression toward the end of life. PPS ratings directly correlates with short-term prognosis for terminally ill patients with or without cancer. The ECOG is a scale extensively used in oncology settings to assess disease progression, assess the disease impact on activities of daily living, and determine appropriate treatments and prognosis. It describes the patient's level of functioning in terms of their ability to care for themselves, activities of daily living, and physical function. Researchers worldwide use the ECOG performance status when planning trials to study new treatment strategies. The ECOG assists physicians in monitoring the patient's level of functioning during treatment and determine disease progression. Like the ECOG, KPS (Table 1) classifies a patient according to their levels of functional impairment, compares the effectiveness of therapies, and assesses patient prognosis. The lower the Karnofsky score, the worse the survival for most serious illnesses [26]. It is generally accepted that a KPS or PPS score of 50 or less indicate that the patient may have a prognosis of 6 months or less for survival [25].

2 The Role of the Dental Care Professional in Palliative Care and Hospice

The World Congress of 2015 adopted the Tokyo Declaration on Dental Care and Oral Health for Healthy Longevity, with the main goal of collecting scientific evidence on the contribution of oral healthcare and formulate policies based on such evidence [27]. Oral health is a key indicator of overall health, well-being, and quality of life. The Global Burden of Disease Study 2017 estimated that oral diseases affect 3.5 billion people worldwide [28]. Unfortunately, there is insufficient data to assess the extent of oral health problems in patients with severe and life-limiting illness. This is likely because of an underestimation of oral conditions in many patients with serious illness receiving palliative care or hospice services.

Although not often considered standing members of core palliative care or hospice teams, dentists and other healthcare professionals play important roles in the care of these patients [3]. Dental professionals provide needed expertise to assess and manage the oral healthcare needs of individuals with serious and life-limiting illness, improving symptom management and promoting oral self-care in close collaboration with members of the core interprofessional team. Palliative oral care focuses on strategies for maintaining patients' quality of life and comfort. In palliative care, oral healthcare goals include adequate pain control, avoidance of infection, and prevention of and prompt removal of dental plaque, calculus, or food debris. The interprofessional team works in close collaboration with dental

healthcare professionals, patients, and families to prevent and treat problems as they arise. The basic principle of oral palliative care is focused primarily on the principle that good oral hygiene is critical for oral integrity. Dentists may mitigate oral complications by performing regular oral prophylaxis and providing necessary preventive, corrective, and restorative dental treatments. These interventions may serve to alleviate oral symptoms, reduce their risk for mouth sores, denture sores, periodontal disease, and oral infections. Early and accurate clinical diagnosis of oral conditions in palliative patients must be instituted to minimize pain and suffering.

Although most palliative care patients may have compromised oral health, they seldom receive adequate and timely oral care services [29]. The reasons for these deficiencies are various [30]. Traditionally healthcare providers in palliative care have focused on general healthcare often overlooking oral needs. Other contributory factors are lack of dental insurance [31], high dental treatment costs, not understanding the importance of oral health [32], lack of access to dental care services, and lack of specialized dental training in palliative care and hospice [3]. Another common problem is that dental care professionals are not often included in core palliative care teams [33, 34]. Solutions to these problems may require a repertoire of strategies. Proposed solutions include promoting bedside oral healthcare for older adults with serious illness and symptom management through an enhanced collaboration between interprofessional team members, regular mouth care, and early identification of dental problems to minimize pain and complications. Finally, this interprofessional collaboration could also help dentists understand their patients' prognoses, better address when and how to implement palliative treatment, and how to minimize futile and potentially harmful dental treatments with the goal of improving quality of care [35].

3 The Oral Assessment of the Older Adult with Palliative Care and Hospice Needs

An adequate assessment is the first step to establish the patients' baseline oral health status. The assessment may determine the existence of any oral conditions requiring additional evaluation and treatment by a dental health professional. In institutionalized patients, examination of the mouth should be done daily for early detection and treatment of oral problems [36]. Multiple oral health assessment instruments have been developed. A meta-analysis compared several of these instruments and concluded that three instruments – the Brief Oral Health Status Examination Tool (BOHSE), the Oral Health Assessment Tool (OHAT), and the Dental Health Registration (DHR) – are valid and reliable assessment tools to assess the oral health of nursing home residents [36]. For community dwelling patients, if they are unable to perform self-care, much of their oral care is provided

by family members or home health aides who provide care at home. We were not able to find research describing training or screening tools recommended for the assessment of oral health in palliative care patients in community settings. Therefore, it would be advisable to adapt some of the previously described instruments for use in community-dwelling settings.

Trained nursing personnel can use the BOHSE and the OHAT to assess the oral health of nursing home residents. Both tools serve as screening instruments that would trigger appropriate and timely referrals to dentists for additional evaluation and treatment. The DHR evaluates plaque formation as a measure of dental hygiene without the need of special equipment, which may not be widely available in long-term care facilities. The BOHSE consists of 10 items that reflect the status of oral health and function, including lips, tongue, tissue inside the cheek, floor and roof of mouth, gums, saliva, condition of natural teeth, condition of artificial teeth, pairs of teeth in chewing position, and oral cleanliness. The final score is the sum of the scores from the 10 categories and can range from 0 (very healthy) to 20 (very unhealthy) [37]. The OHAT is a modified version of the BOHSE consisting of eight areas: lips, tongue, gums/tissues, saliva, natural teeth, dentures, oral cleanliness, and dental pain. The final score can range from 0 (very healthy) to 16 (very unhealthy) and is obtained from the sum of the scores of the abovementioned eight areas, which are rated on a 0–2 scale: 0, healthy; 1, oral changes; and 2, unhealthy [38]. The DHR is a quick and easy to use assessment tool that nursing personnel can implement with dentate patients. It registers the presence or absence of plaque on teeth and can serve to monitor changes over time. The scale is scored from 1 to 4: 0, continue as usual; 1, check for deterioration and pay attention to difficult areas; and 2–4, dental hygiene needs to improve [39]. These tools have been validated in cognitively intact and cognitively impaired nursing home residents. However, there are no studies that have specifically validated these instruments in patients receiving palliative care or hospice. There is a need for more research that validates the use of these instruments in patients with palliative care and hospice needs in noninstitutional settings.

4 Risk Factors of Poor Oral Health

4.1 Poor Oral Hygiene

Poor oral hygiene is associated with physical, psychological, and social consequences for patients with palliative care needs. Unfortunately, poor oral hygiene is common in this population [40–43]. Healthcare professionals should regularly encourage their patients to participate in daily oral self-care activities. When unable, because of cognitive or functional impairment, caregivers should assist patients

with these tasks. Risk factors for poor oral hygiene include patient and caregivers' educational level and lack of awareness of the importance of routine oral care to prevent complications [29]. Many patients may not have the means or ability to visit a dentist or dental hygienist in a timely manner due to limited transportation, lack of dental insurance, and/or economic constraints. For a more in-depth discussion on the topic of health disparities, please refer to chapter "Health Disparities in Oral Health".

4.2 Polypharmacy

Drugs are by far the most common cause of xerostomia, dysgeusia, and stomatitis [44]. Many medications can cause dry mouth including among the most frequent offending medications those with anticholinergic activity, including many antiemetics, antihistamines, antipsychotics, tricyclic antidepressants, antispasmodics, and bronchodilators. Other frequent culprits include several types of antihypertensives, diuretics, benzodiazepines, and opioids [44, 45]. Dysgeusia, the altered perception of taste, is associated with several medications use to treat serious illness, including antineoplastics (bleomycin, carboplatin, cisplatin, cyclophosphamide, doxorubicin, 5-fluorouracil, gemcitabine, levamisole, and methotrexate), psychotropics, opioids, antimicrobials, and antihypertensives [46]. A thorough medication review may identify responsible medications. If possible, deprescribing the suspected medications should be attempted as the initial approach to improve symptoms. For a more in-depth discussion on the topic of xerostomia, please refer to chapter "Xerostomia and Hyposalivation".

4.3 Functional Impairment and Frailty

Evidence suggests that functional impairment and frailty are associated with worse dental health [47]. In many patients with serious or terminally illness, traditional oral hygiene practices may not be feasible due to declining health and poor physical function [48, 49]. Many palliative patients are disabled, weak, cognitively impaired, and often institutionalized. Unfortunately, oral health procedures are frequently given low priority when compared to other care tasks performed by nursing staff and caregivers [50]. This can stem from inadequate training, limited time availability due to other competing needs, or the unpleasantness of the task [51]. Patients who need help with oral hygiene have twice as many cases of dental caries or retained roots than those who are independent [5]. Individualized oral hygiene care plans that incorporate caregivers, caregiver training programs, shorter intervals between dental evaluations, the use of fluoride, and management of xerostomia constitute adequate interventions [5].

4.4 Cognitive Impairment

Compared with patients with intact cognition, individuals with cognitive impairment have poorer oral hygiene, more gingivitis, more decayed root surfaces, a higher plaque index, higher number of decayed coronal surfaces, higher number of filled root surfaces, and more missing teeth [5, 52]. In community-dwelling patients with cognitive impairment, the risk of dental caries increases due to diminished oral hygiene, insufficient caregiver support, and lack of regular dental care [5]. Patients with severe cognitive impairment often require the assistance of a caregiver to perform oral care. These patients may also become uncooperative and even resist care with oral hygiene routines [53]. Strategies to improve patients' cooperation include allowing patients to determine the location of the examination, explaining the steps of the procedure, allowing rest periods during the examination, and including caregivers that the patient knows and trusts [37]. For a more in-depth discussion on the topic of dementia, please refer to chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health".

5 Common Oral Health Conditions in Palliative and Hospice

5.1 Swallowing Disorders and Aspiration

Dysphagia or difficulty swallowing is often present in patients with advanced physical and mental illness. Dysphagia frequently leads to aspiration, which can result in aspiration pneumonitis, pneumonia, and even death. Additionally, it can lead to dehydration, malnutrition, caregiver burden, and poor quality of life [54]. In many palliative patients with dysphagia, a joint decision between the palliative medicine team and patients or surrogates may be to allow patients to continue eating despite their risk of aspiration. In these cases, the goal is to provide pleasure, socialization, and nutrition. Different approaches are used to manage swallowing impairment and may include diet modifications, such as thickening liquids and pureeing solids, keeping an upright head position during meals, and exercise programs targeted to strengthening muscles involved in swallowing such as functional dysphagia therapy [55]. For a more in-depth discussion on the topic of swallowing disorders, please refer to chapter "Swallowing, Dysphagia, and Aspiration Pneumonia".

5.2 Cancer Treatment and Oral Mucositis/Stomatitis

Mucositis is the inflammation of the mucous membranes lining the digestive tract. It is caused by the loss of epithelial cells and release of proinflammatory substances frequently associated with radiotherapy of the head and neck, with or without

chemotherapy [56]. Stomatitis is the inflammation of the mucous lining of the mouth structures [57]. Clinical manifestations can vary from erythema to necrosis or deep ulceration of the mucosa [58]. Mucositis causes severe discomfort and pain which can be debilitating and lead to intolerance of normal diets, sometimes to the point where patients may need gastrostomy tubes to provide supplemental nutrition and hydration [56]. It is important that patients with planned radiation therapy to the head and neck undergo a comprehensive, baseline oral/dental exam including radiographs. Providers should educate patients on maintaining good oral hygiene and avoiding caustic and drying agents that could further exacerbate their symptoms [59]. Most treatments for mucositis are limited to palliation and treatment of pain (see Orofacial Pain section). Providers should have a low threshold to obtain cultures for suspected infections, including fungal and viral, as they may not present typically, go unrecognized, and lead to bacterial superinfections.

5.3 Problems with Saliva

Xerostomia or dry mouth is quite common in palliative and hospice patients with some studies reporting a prevalence as high as 70%. It can be objective or subjective, depending on the presence of signs of dry mouth such as frothing, stringing of saliva or glazing of the oral mucosa [45, 60, 61]. There are several causes of xerostomia, including drug induced, irradiation, salivary gland diseases, infections, and dehydration [44, 45]. Xerostomia can cause discomfort and pain, difficulty eating and swallowing, problems with dentures, altered taste of food, difficulty speaking, increased risk of infections and dental caries, halitosis, nutritional impairment, and decreased quality of life [45, 60]. The main pillars of the treatment of xerostomia are treating the underlying causes, symptomatic treatments, and treatment of associated complications [62]. Any causal agents should be eliminated, if possible. Other treatment modalities consist of saliva substitutes, stimulation of residual gland function with sugar-free candy or chewing gum, and cholinergic agonists (pilocarpine and cevimeline). Staff should educate and encourage patients to maintain good oral hygiene, including the use of alcohol-free antimicrobial mouthwashes [45]. For a more in-depth discussion on the topic of xerostomia, please refer to chapter "Xerostomia and Hyposalivation".

Sialorrhea or excess salivation is usually caused by overproduction or excessive secretion of saliva [63, 64]. Sialorrhea usually represents a side effect of medications, vitamin deficiencies, gastroesophageal reflux, or poor oral clearance of saliva secondary to dysphagia. The most common causes of dysphagia associated with sialorrhea are underlying neurologic and neuromuscular diseases such as Parkinson's disease, and amyotrophic lateral sclerosis (ALS), and malignancies such as head a neck cancers. The excess saliva can then spill over the bottom lip leading to drooling, which in turn can cause rashes, skin irritation and breakdown, and poor quality of life. Sialorrhea can also result in aspiration, choking, poor oxygenation, and the onset of pneumonias [65]. Management of sialorrhea can be

non-pharmacologic or pharmacologic. Non-pharmacologic modalities include orthodontic procedures, functional dysphagia therapy, use of cough assistance devices, and suction devices [63, 64]. Pharmacologic agents may include glycopyrrolate, scopolamine, atropine, and benztropine. These medications are anticholinergic and an expected adverse effect is xerostomia. Botulinum toxin injections into the salivary glands have also demonstrated positive effects [65].

5.4 Dysgeusia

Dysgeusia or distortion of the sense of taste is frequently seen in palliative patients [49, 66–68]. Dysgeusia can lead to the loss of eating pleasure, anorexia, nutritional deficiencies, and decreased quality of life [69]. Most affected are patients with head and neck cancers treated with chemotherapy and radiation. Dysgeusia can also be caused by infections, zinc deficiency, hypothyroidism, Cushing's syndrome, liver disease, sequelae from ENT operations, and some medications like psychotropics, opioids, and antihypertensives (Table 4). In cases of chemotherapy and radiation to the head and neck, taste disturbances are caused by damage to the taste buds or salivary dysfunction. Other causes may include an underlying infection which may require antimicrobial therapy. Providers should routinely ask about these symptoms as patients may not volunteer the information. Management of taste disturbances includes treatment of the underlying cause, dietary therapies focusing on foods that have pleasurable tastes and are culturally appropriate, avoiding unpalatable foods, and providing food enhancers. Zinc therapy is also recommended as its deficiency has been associated with dysgeusia [46].

5.5 Orofacial Pain

Causes or orofacial pain are various (Table 3). Orofacial pain is often encountered in palliative patients with a reported prevalence ranging from 4% to 67% (Table 3). Like in any other patient, individuals with serious and terminal illness may also complain of pain originating from common dental conditions, including dental caries, abscesses, pulpal pain, and periodontal disease. Lesions of the oral mucosa may also include aphthous stomatitis, herpes simplex, candidiasis, blistering conditions, traumatic lesions, and radiation- or chemotherapy-induced mucositis [70]. Pain is usually located around the tooth or lesion. This type of pain can lead to anorexia as chewing and temperature changes usually increase pain. Periodontal and pulpal pain disorders are managed by dental practitioners. Musculoskeletal pain disorders such as temporomandibular disorders (TMD) are usually secondary to pain of the muscles of mastication, the temporomandibular joints (TMJ), and/or associated ligaments and tendons. Pain is usually felt in the preauricular areas and can lead to restricted mouth opening and pain with eating or talking. Management usually includes

Table 3 Causes of oral pain

System	Sources of pain
Dentoalveolar/oral mucosal	Dental Periodontal Pulpal Salivary gland disease Oral mucosal disease Maxillary sinusitis Cancer
Musculoskeletal	Temporomandibular disorders
Neurovascular	*Primary headache* Migraine Tension-type headache Temporal arteritis Trigeminal autonomic cephalalgias
	Neuropathic pain Trigeminal neuralgia/trigeminal neuropathic pain Glossopharyngeal neuralgia Postherpetic neuralgia Burning mouth
	Other Central stroke pain Chronic idiopathic facial pain Atypical odontalgia

Modified from: Orofacial Pain (Book) Zakrzewska, Joanna [70]

Table 4 Prevalence of oral health problems in different studies

Study	Population type/size	Oral pain (%)	Xerostomia (%)	Dysgeusia (%)
Oneschuk et al. 2000 [43]	Patients with advanced cancer ($n = 99$)	16	88	
Davies et al., 2001 [62]	Inpatient or outpatient palliative advanced cancer patients ($n = 120$)	–	78	–
Alt-Epping et al. 2012 [66]	Palliative care inpatients ($n = 101$)	4	83	68
Wilberg et al. 2012 [67]	Palliative care cancer inpatients ($n = 99$)	67	78	68
Van Lancker et al. 2016 [68]	Older patients receiving palliative cancer care ($n = 400$)	17.3	77	35
Özalp et al. 2017 [99]	Palliative care clinic ($n = 170$)	–	87.6	–
Magnani et al. 2019 [49]	Hospice patients ($n = 75$)	14.7	74.9	49.3

exercise programs, pain medications, and intraoral splint therapy. It is important to include a psychosocial evaluation of these patients, since depression and anxiety can be associated to TMD. Cognitive behavioral strategies can lead to better outcomes in patients with TMD and depression or anxiety [70]. Neuropathic pain is felt in structures that follow a nerve distribution but may not show any clinical evidence of

pathology. The pain is usually described as tingling, burning, pins and needles, and electrical and may be associated with anesthesia, paresthesia, dysesthesia, hyperesthesia, or hypoesthesia. Trigeminal neuralgia, postherpetic neuralgia, and burning mouth syndrome are examples of this type of pain. Neurovascular pain includes migraines, temporal arteritis, and tension headaches. Neuropathic and neurovascular pain disorders are managed medically with therapies directed to the underlying pathophysiology [70]. In patients with cancer receiving palliative care, pain can be the consequence of a primary, systemic, or metastatic cancer affecting peripheral and/or central nervous systems [71]. Three of the most common pain presentations of patients with intracranial tumors who come to the dental office are symptoms of TMD, trigeminal neuralgia, and persistent idiopathic facial pain [72]. Pain can be secondary to metastatic lesions to the mandible, the TMJ, and other areas of the head and face. In systemic cancers like lymphoma, leukemia, and myeloma, pain can result from tumor infiltration of bone, gingiva, and tissues proximal to teeth [72].

Pharmacologic management of orofacial pain includes the use of NSAIDs. However, dentists should be aware of the significant risks associated with the use of these medications in older adults. When used chronically, NSAIDS can cause hypertension, worsening of kidney function, and gastric irritation. Topical analgesics can be used in different forms: injections of lidocaine for trigeminal neuralgia or lidocaine patches for neuropathic pain [70]. Liquid anesthetic administered intraorally may be beneficial in oral mucosal lesions. Corticosteroids can be applied topically or injected directly into the TMJ. However, these medications should be reserved for cases of acute trauma, severe limitations of mouth opening, or as a brief therapeutic trial [70]. Antidepressants, including tricyclic, selective serotonin reuptake inhibitors (SSRI), and serotonin noradrenaline reuptake inhibitors (SNRI), are an important part of the management of neuropathic pain. Opioids should be reserved for patients with malignant pain and those with nonmalignant pain for whom more conservative measures have failed or who are at high risks of adverse effects from the use of other medications, including NSAIDs.

5.6 Oral Infections

The oral cavity is colonized by a stable microbiota (“microbial homeostasis”). Biofilm is a layer of microorganisms that covers the teeth, the gingival crevice, and the dorsum of the tongue. Multiple mechanisms help to maintain the normal commensal flora and prevent infections. The *oral mucosa* serves as a physical barrier to invading organisms, and in many areas, a biofilm cannot establish due to the rapid turnover of the surface cells. Oral infections occur in patients with damage to the oral mucosa. *Commensal flora* prevents the colonization of pathogenic organisms by competing for space and nutrients. Commensal organisms can be affected by the use of antibiotics, salivary disfunction, and a high carbohydrate diet, which leads to a decrease in the pH of the oral cavity favoring the growth of pathogenic microorganisms that cause dental caries. *Saliva* has many different actions and salivary gland dysfunction can lead to an increased prevalence of oral and systemic

infections. The *immune system* in the mouth includes innate immunity, consisting of phagocytes and complement, and acquired immunity consisting of humoral (immunoglobulins including secretory IgA, and serum IgG, IgM, and IgA) and cellular immunity that includes T cells. The components of the immune system reach the mouth through the gingival crevicular fluid, which is a serum transudate that passes into the gingival crevice from the systemic circulation. Immunodeficiency causes changes of the oral microflora that may lead to an increased prevalence of oral infections [36]. Infections affecting the mouth can be bacterial, viral, and fungal.

5.7 Halitosis

Halitosis is defined as offensive odors emanating from the mouth, nose, sinuses, or pharynx. Pathologic halitosis can be a symptom of regional pathology such as periodontal disease or systemic pathologies such as esophagitis, pyloric stenosis, uremia, diabetes ketosis, or neoplasms. Xerostomia (discussed above) can also contribute to halitosis [73]. Halitosis can have psychological and social effects in patients with serious and terminal illness [46].

6 Oral Health at the End of Life: Dying with Dignity

The Institute of Medicine defines as a good death "one that is free from avoidable distress and suffering for patients, families, and caregivers; in general, in accord with patients' and families' wishes and reasonably consistent with clinical, cultural, and ethical standards" [74]. Oral healthcare professionals have a responsibility to address oral symptoms at the end of life with the goal of improving or maintaining patients' comfort and quality of life.

Hospice patients have a high prevalence of oral problems associated with their serious and terminal illnesses [3, 4, 75]. Evidence shows that 40% of palliative patients suffer from oral conditions for a prolonged period. The loss of the patients' ability to communicate their oral health needs may further contribute to the underreporting of oral conditions among terminally ill patients. The early identification and treatment of these oral conditions by dentists will minimize patients' pain and suffering. Table 5 shows an example of strategies aimed at maintaining and treating oral health for patients at the end of life.

7 Ethical Considerations at the End of Life

Clinicians play a pivotal role both in defining and executing the medical care plan and in providing continuity of care as goals evolve and change over time [76]. Practitioners often initiate discussions about life-sustaining treatments, educate

Table 5 The Scottish palliative care guidelines for the management of oral care of patients nearing the end of life [100]

Include mouth care in the patient's care plan
Encourage family members to participate in mouth care activities with guidance and support from the team
If possible, change or stop medications that are causing dry mouth
Conduct mouth care as often as necessary to maintain a clean mouth
In patients who are conscious, the mouth can be moistened every 30 minutes with water from a water spray or dropper or ice chips can be placed in the mouth
In unconscious patients, moisten the mouth frequently, when possible, with water from a water spray, dropper, or sponge stick or ice chips placed in the mouth
Water-soluble lubricant should be applied to prevent cracking of the lips
Use a room humidifier or air-conditioning when the weather is dry and hot
Ensure help is offered to clean teeth or dentures
Manage oral pain symptomatically, using analgesics via a suitable route
Most importantly, stop treatment of the underlying cause of oral pain when the burden of treatment outweighs the benefits

patients and families, help families deliberate care options, and make recommendations about treatment plans. As part of this role, the hospice team is responsible for guaranteeing that the patient's wishes are documented and supported by the appropriate medical orders [76, 77]. Oral health professionals may contribute to this conversation by sharing their expert opinion on best practices for adequate oral health maintenance and treatment. The focus of the following sections is on ethical issues at the end of life. For a more in-depth discussion on the topic of ethics, please refer to the chapter "Ethical Considerations".

7.1 Withholding and Withdrawal of Life Support

The withholding and withdrawal of life-sustaining therapies are considered by most experts ethical, moral, and medically appropriate decisions when the treatment no longer fulfills the patient's goals. Although withdrawal and withholding of life support are considered ethically equivalent, the reality is that most clinicians and patients may not feel so. The experience of withholding as compared to withdrawal therapy has been examined in two large questionnaire-based surveys, one from North America and the other from Europe [78, 79]. In the North American study, 61% of physicians reported being more distressed at the prospect of the withdrawal of therapy than they were about withholding treatments. Similarly, a European survey [78], showed that physicians were more willing to withhold treatment than they were about the withdrawal of the same therapies. Healthcare professionals are under no obligation to offer ineffective treatments, i.e., treatments that no longer offer benefits to the patient. Acceptable clinical practices on withdrawal or withholding of treatments depend on an understanding of medical, ethical, cultural, and religious issues. There is a need to individualize goals of care discussions

considering the preferences, beliefs, values, and cultural background of both the patient and their families [76]. A strong consensus is that the withdrawal or withholding of life supporting treatments is seen as a decision that allows the disease to run its natural course, rather than a decision to hasten death.

7.2 Shared Decision-Making (SDM)

Shared decision-making is a structured method that incorporates clinical evidence as well as patient values and preferences into medical decision-making. Clinicians should periodically revisit treatment preferences as goals evolve and change over time in patients with serious and life-limiting illnesses. Shared decision-making is supported by evidence from 86 randomized trials showing that participation in SDM fosters patients and family's knowledge of their conditions, increases patients' confidence in their decisions, makes patients more active participants in their care, and, in many situations, leads patients to select more conservative treatment options [80]. Achieving shared decision-making depends on building a good relationship between clinicians and patients so that information is shared, and patients are supported in the deliberation and expression of their preferences and views. To accomplish these tasks, there is a proposed model based on choice, option, and decision talk. The model has three steps: (a) introducing choice; (b) describing options, often by integrating the use of patient decision support; and (c) helping patients explore preferences and make decisions. This model rests on supporting a process of deliberation and understanding that clinicians must respect the patients' preferences [80, 81].

7.3 Informed Consent

Informed consent has become the mainstay for protecting patients' legal rights and guiding the ethical practice of medicine [82]. The higher standard of informed consent further protects patients' rights to autonomy, self-determination, and inviolability. The ethical principle of informed consent seeks to respect patient autonomy by ensuring that treatments are directed toward the ends desired by the patient. Informed consent involves providing patients with accurate and adequate information about the risks, benefits, and alternatives of a treatment in a manner that is free from coercion. Unfortunately, research evidence shows that patients remember little of the information disclosed during the informed consent process [83–86] and that their level of comprehension is often overestimated [87, 88]. Comprehension is related to factors such as patient age, education, intelligence [86], cognitive function, locus of control, and anxiety [82, 83, 89]. These problems are exacerbated in older adults at the end of life when the prevalence of terminal delirium is high, impairing the patient's ability to actively participate in the decision-making process. In this

context, clinicians will need to engage surrogate decision-makers including family members and loved ones.

7.4 Decision-Making Capacity

As we have seen in the previous section, active participation in the medical decision-making process requires that patients retain the ability to understand the benefits and risks of, and the alternatives to, a proposed treatment or intervention (including the option of no treatment). Patients have medical decision-making capacity if they can demonstrate an understanding of the situation, appreciation of the consequences of their decision, reasoning in their thought process for the decision, and the ability to communicate their wishes. Physicians will often be called to determine the patient capacity to give consent for treatment. During the process, the physician making these determinations will consider four elements: Patients must be able to (1) demonstrate understanding of the benefits and risks of, and the alternatives to, a proposed treatment or intervention (including no treatment); (2) demonstrate appreciation of those benefits, risks, and alternatives; (3) show reasoning, or the ability to compare benefits and risks in making a decision; and (4) communicate their choice [90, 91]. If the patient is unable to meet the capacity criteria, the healthcare team will have to rely on appointed or designated surrogate decision-makers.

7.5 Advance Care Planning (ACP) and Advance Directives (AD)

Advance care planning is the communication process that supports adults at any age or stage of health in understanding and sharing their personal values, life goals, and preferences regarding future medical care [92]. The objective of ACP is to ensure that patients make treatment decisions in anticipation of the onset of serious illness so that clinicians can provide care that is consistent with such goals [93]. Advance directives, on the other hand, are documentation of the patients' goals and values reflecting the results of advance care planning discussions [94–97]. ACP may or may not include completion of an advance directive (AD). Advance directives may state how treatment decisions should be made on their behalf in the event they lose the capacity to make such decisions in the future. There are various kinds of ADs, but the most recognized in the United States are the Living Will (LW) and the Durable Power of Attorney for Health Care (DPAHC). LWs document patient preferences for life-sustaining treatments and resuscitation. DPAHCs (also known as "Health Care Proxy Designations") document their choice of a surrogate decision-maker. It is a signed legal document authorizing another person to make medical decisions on the patient's behalf in the event the patient loses decisional capacity [98]. Most recently, the Physician Orders for Life-Sustaining Treatment (POLST)

have become a valuable addition to the arsenal of available advance directives [89]. A key advantage of POLST advance directives is that these documents serve as a set of actionable and transferable medical orders that direct medical care consistent with patients' goals of care at the end of life. Dental professionals will need to be aware of their patients' preferences as they may be caring for patients with serious and life-limiting illness who may have lost their ability to participate in shared decision-making.

8 Conclusions

Oral health professionals have an opportunity to make significant contributions to palliative care by addressing oral symptoms of patients with serious and terminal illness and thereby contribute to improving and maintaining their comfort and quality of life. Palliative dentistry is necessary in the management of patients with advanced life-threatening diseases or conditions. Dentists and other oral health care professionals may be able to alleviate some of the common oral problems faced by these individuals. Oral health care professionals may offer these patients preventive, corrective, and restorative dental treatments. Educating healthcare team members on the important role of dental care providers in palliative care teams is essential for achieving patients' comfort and well-being. Advance care planning and completion of advance directives may serve to foster a process of shared decision-making that aims to preserve patients' autonomy.

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Ethical Considerations in Geriatric Dentistry

Carlos S. Smith

1 What Is Ethics?

Ethics has long been defined as a branch of philosophy and theology that involves systematizing, defending, and recommending concepts of right and wrong behavior. The American College of Dentists defines ethics as studying systematically what is right and good with respect to character and conduct [1]. In short, ethics is about choices. The choosing to act or to not act. Ethical issues faced by dentists and members of the dental team (dental hygienists, dental therapists, dental assistants, and dental office administrative staff) are ever-evolving, both increasing in number and in the complexity of factors needing to be reviewed, considered, and addressed [2]. Ethics affect every decision made in the dental office and are inextricably linked to the daily decisions of overall dental practice. The pursuit of embodying the best of dental ethics and ethical decision-making is both an individual and collective matter.

What one dentist chooses to do or not do has implications and consequences not only for that individual but also for the profession as a whole. What dentist hasn't heard the inevitable phrase, "I hate dentists," upon entering an operatory and greeting a new patient. Often regarded as simple patient anxiety, it is worth noting that a previous dental provider, although not expressly causing the dental anxiety/trauma, certainly could have had a role in shaping or exacerbating such patient anxiety in a prior encounter. A previous dentist's choosing to act or not to act could have heavily influenced the patient's view of both that dentist specifically, but also the patient's view of dentists generally and the profession as a whole. Research has shown that the skills, attitudes, and philosophies of various dentists that persons may have encountered in their life spans can affect their oral health status [3].

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2 Providing Care for the Geriatric Patient

The US Census Bureau projects that by 2030, more than 20% of the population will be 65 years or older compared with 13% in 2010 [4]. While the geriatric population is ever-growing, the typical older patient is no longer simply a denture wearer. Particularly, as the geriatric population booms, this generation of seniors is often more educated, is more financially well-off, and has a history of routine dental care utilization [5]. Yet typical socioeconomic barriers to access to care remain. Along with continued advancement in dental treatments and more complex treatment planning options, today's geriatric patient has increasingly retained their natural teeth; thus, a larger number of older people will be seeking dental care in the upcoming years [6]. The retention of teeth also presents a challenge for both patient self-care and oral professional care to maintain the dentition for a whole lifetime [7]. Oral health status in older adults also reflects the cumulative outcomes of oral health behaviors, diseases, and their treatments during a life span [7].

The dental needs of older adults are also changing and growing. "The management of older patients requires not only an understanding of the medical and dental aspects of aging, but also many other factors such as ambulation, independent living, socialization, and sensory function. Many barriers may interfere with providing older patients with dental care, including heightened dental complexity, multiple medical conditions, diminished functional status, loss of independence, uninformed attitudes about dental care in old age, and limited finances."[7] Dental practice specific to geriatric patient care raises specific ethical issues due to the evolving dental needs of older adults. While ethical dilemmas have been vastly studied, taught, and applied, all dentist-patient interactions do not necessarily give rise to an ethical dilemma. However, every dentist-patient, or even dentist-team member, interaction does have within it an ethical dimension.

3 Informed Consent and the Geriatric Patient

One of the most well-known ethical aspects of dental practice is obtaining informed consent. However, despite its common practice, it is also one of the most leniently applied and understood concepts with significant ethical underpinnings. While widely minimized to a signature of understanding and approval, informed consent is of particular interest and concern among an aging patient population. Obtaining informed consent is in all reality more than a simple conversation. It is a communication between patients and their healthcare providers with a goal to ensure full understanding of the clinical procedures that will be performed [6]. The informed consent process should include a discussion of the expected risks, benefits, and alternatives that are available to them and an opportunity to ask questions, discuss their choices, and have time to reflect and provide a clear indication of their eventual decision [6]. The literature suggests that informed consent should include five basic

elements or domains: capacity, information, comprehension, voluntariness, and a final decision or choice [6].

Capacity to consent refers to the patient's ability to understand the purpose, implication, and consequences of treatment [2]. Capacity is an issue of the patient's physical and cognitive ability to fully participate in the informed consent process [6]. Within the geriatric patient population, there are those who suffer limited capacity to make decisions for themselves, including cognitive impairments as a result of mental illness, stroke, dementia, delirium, or other related issues [8]. It has long been established that Alzheimer's patients present "unique caregiving problems because of troublesome symptoms including impaired memory, disorientation, poor judgment, inappropriate, unpredictable, or dangerous behaviors, incontinence, and the need for constant surveillance" [8]. For a more in-depth discussion on the topic of cognitive impairment, please refer to Chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health".

One of the most significant ethical challenges within the issue of informed consent and geriatric dentistry is the fact that capacity to participate in the informed consent process may fluctuate over time. There is also very little standardization of how capacity is accessed and if it is appropriate in the dental clinical setting for that to be a chairside assessment and/or decision. It is also possible that ageism, the holding of negative stereotypes and beliefs regarding older adults, may influence dentist, patient, or even caregiver understandings and actions [8]. "The decision not to treat a condition or illness made on age considerations alone, or the seeking of advice from adult children without first talking with the older patient are, in many instances, examples of ageist behaviors" [8]. Dentists, dental team members, and even caregivers must be careful as many decisions may relate to providing or withholding treatment, especially when a patient may verbally or behaviorally refuse care. An ultimate decision must be made whether or not to override refusal. The role of the caregiver or family member is sometimes a burden of care, and professional altruism and empathy are necessary. For example, if a patient resists riding in the car to make an office visit, planning longer treatment sessions, which limit the need for multiple visits, will reduce caregiver burden substantially. Some cognitively impaired patients have better mental function and less disruptive behaviors at one time of day as opposed to others. For these patients, flexibility in scheduling visits during their "good" time (e.g., only morning visits) will reduce stress for the family caregiver, to say nothing of the dentist [8].

The specific question of declining capacity necessitates both a means for assessing capacity and methodologies for ensuring a patient with declining capacity is able to have autonomy in their treatment care decisions before capacity has indeed declined. While not particularly common in dental care settings, in medical care the advance directive is a customary means of predetermining a patient's wishes in the event they can no longer consent for themselves. Medicine also has options such as DNR or do not resuscitate orders. On the surface, DNRs may seem to have little relevance to clinical dental care not seemingly surrounding a matter of life or death. However, at their simplest understanding, a DNR order is a decision to not render treatment. Likely occurring much more frequently than clinicians care to admit, the decision to treat or not to treat health problems, including those related to the oral cavity, is made based largely upon the goal of maintaining function and comfort of older patients [8].

Although capacity assessment tools exist, most are not used in everyday healthcare practice, and many are considered time-consuming and insufficient at determining if patients really have the capacity to consent [6]. Some suggest the practicality, efficiency, acceptability, affordability, and sustainability of capacity assessment tools in dentistry makes their useage highly unlikely [6]. In the past, researchers have suggested that dental professionals ask the patient, "who would you like me to consult regarding your treatment if something should happen to you and you are no longer able to express your wishes" [8]. The patient's response is subsequently documented in the dental record. While this seems simple and satisfying on its surface, like most decisions with ethical implications, simplicity and experiences within ethical dimensions often present with more than what meets the eye. Thus, assessing a patient's ability to provide consent can be challenging for dentists under a variety of circumstances, including when capacity is affected by mental health status or is transient. With decisions of capacity and informed consent having legal and regulatory implications, the research is inconclusive as to the extent to which dental practitioners should become involved in legally declaring a patient capable or incapable [6].

Best practices within a dental care setting have yet to be clearly established; however, the literature recommends a medical referral for capacity evaluation if the dentist is unsure of the patient's ability to consent for treatment [9]. Accounting for older patients, in dental care settings, often declining additional information about treatment procedures, some scholars suggest geriatric patients should have 24 hours before any routine dental procedure to process the information provided in the consent forms [10]. Dentist and dental team members must be attuned to nonverbal cues from patients such as visible confusion and inconsistencies in the patient's behavior, and if the patient's decision-making capacity appears questionable, immediately involve family members or caregivers in the decision-making process [6].

Worth noting is the concept of geriatric assent, meaning agreement of someone not able to give legal consent to participate in the activity. Accounting for many of the same aforementioned challenges with informed consent and declining capacity, even garnering assent can be challenging. The geriatric assent process still involves the accumulating burden over time on caregivers who may choose to "shortcut" communication for the sake of decisional efficiency and expediency [11]. Despite office productivity goals and maximized efficiency, dentists and dental team members are ethically bound to promote assent, even when consent is unattainable or inconclusive. Promoting assent is a more proactive procedure than merely arranging for incompetent patients to passively abide by decisions for which they have had little or no input [11].

4 Elder Abuse, Evolving Technologies, and Changing Models of Care Delivery

Elder abuse is a multifaceted and pervasive public health issue, which includes physical, sexual, and emotional abuse, financial exploitation, and neglect (caregiver neglect and self-neglect) [12]. It is estimated that only a fraction of elder abuse cases

actually come to the attention of adult protective services [13]. Two-thirds of physical abuse cases result in injuries to the head, neck, and/or mouth—areas visible to oral healthcare providers during examination and treatment [14, 15]. Dentists, dental hygienists, dental therapists, dental assistants, and all dental team members are in a unique position to detect elder abuse and neglect.

As the practice of dentistry advances technologically, there arises an increased need to garner an ethical perspective as it relates to new and evolving treatment modalities. With the overwhelming increases and availability of both implants and digital dentistry, appropriating an ethical lens is necessary. Scholars have formulated an ethical framework for "responsibly practiced implantology" [16]. Among issues noted are supposed prevalence in potential placement of implants as a rationale for tooth extraction. This concept is specifically guarded against in that there is concerted effort in retaining natural dentition. "The mere option of replacing the tooth with an implant should not be the leading factor in the decision of whether or not to extract a tooth" [17].

Dental caries is still clearly a public health problem for many older Americans, such as those of lower socioeconomic status, with dementia, who are homebound, and who are institutionalized [5]. Studies have shown that the perceived need of dental care is reduced as functional dependency increases, and dental care use concurrently decreases, especially in those older adults who are institutionalized [18, 19]. Adequate access to dental care does not exist for many United States nursing home residents [18]. The dental treatment geriatric patients seek and ultimately receive is directly dependent on their self-perceived need, their financial ability to pay for that care, and issues such as transportation and documentation, rather than the normative need detected during an oral examination by a dentist [19]. It has been established that the majority of dental care for older adults takes place in private practices [5]. For functionally independent and older adults with frailty, minor modifications in office design or flow to allow for age-related changes allows private practitioners to treat this population [20].

Providing dental care for institutionalized geriatric patients presents both challenges and opportunities. With much emphasis on interprofessional and collaborative care, geriatric health and specifically oral health present a great opportunity for evolving models of care delivery. Although the geriatric population is increasing, institutionalization and nursing home utilization are declining, and there is a greater desire among seniors and their families to age in place [21]. One of the most significant developments in geriatric care is the shift to a model of care based in community living often termed adult day-care centers. The current generation of older adults wants to age in place, and they do not want to be institutionalized. Models, such as the Programs of All-inclusive Care for the Elders (PACE), have been gaining traction [21, 22]. Ethical duty and obligation implores that dentists and dental team members strive to be part of the interprofessional teams that care for older adults in these new models of care. The PACE is a managed care organization that provides comprehensive medical and social services to a population of frail, community-dwelling older adults, most of whom are dually eligible, having Medicare and Medicaid benefits, US government-based forms of healthcare

insurance for the poor and older adults, respectively [23]. The PACE actually has its origins with the work of a public health dentist and social worker in San Francisco in the 1970s who recognized a need for long-term care services that kept individuals in the community while maintaining a good quality of life [24, 25]. Effectiveness of a dental program in long-term care has been found to be contingent on dental care, routine and continual oral hygiene, and assessment [24]. In particular, they found routine oral hygiene and assessment were most important to a program's success and that simply providing dental services is insufficient to having an effective dental program [21].

PACE programs readily offer dental services, which often include partnering with a community dentist [26]. This can and often includes providing dental services on-site, affording more significant interaction between dental professionals and other members of the patient care team [27]. Physically including dentistry within PACE programs sites could allow community dentists to shadow, network, and refer complex, medically compromised geriatric patients. There are also advanced dental education programs or general practice residency programs who have partnered with hospitals that are connected to PACE facilities and programs [28]. Dental schools may also seek partnerships with local PACE programs to expose students to a model of collaborative team-based care in geriatrics [27].

Researchers have suggested that similar programs that care for the growing population of older adults who prefer to remain in the community should place an emphasis on routine oral hygiene care and should not make providing on-site dental care a sole focus of their programs. In addition, programs should have a coordinated system of referral to dentists. The proposed model suggests the important role that nurses and an interprofessional team can play as communicators and facilitators in this process. Lastly, a communal gathering location, such as the PACE center, is necessary to ensure a common location where members regularly congregate and health providers and nurses have access to individuals. This is where older adults can receive routine medical and dental assessments and obtain preventive home care products, such as fluoridated toothpaste and toothbrushes [21]. Opportunities abound for ethical practice among dentists and dental team members to forge creative partnerships for delivering collaborative care.

5 Barriers to Care: An Ethical Lens on Medical Mistrust and the History of Racism in Healthcare

Geriatric patients of certain demographic backgrounds and cultural identities may invoke yet another ethical dimension of care, namely, medical mistrust and the history of racism within healthcare delivery systems. Particularly in the United States, where denial of healthcare and even basic human rights were once fully legal, remnants of those historic atrocities still unfortunately remain. Particularly at a time when a patient's zip code (US postal codes) is the best predictor of health outcomes

[29], dentists and dental team members must wrestle with the long-lasting effects of structural racism within healthcare. This remains true particularly in geriatric populations who are of the age to have been born prior to, lived in, or were raised during legal American segregation. Many studies have shown that there are substantial racial differences in trust in healthcare providers and healthcare systems. African Americans were significantly more likely than Whites to report low trust in healthcare providers in this study [30, 31]. Even after controlling for sociodemographic, prior healthcare experiences, and structural characteristics of care, African American race had a significant effect on low trust in healthcare. However, different factors were associated with low trust among African Americans and Whites. Among African Americans, the source of medical care had a significant independent association with low trust, whereas among Whites, the number of annual healthcare visits was associated significantly with low trust. It is possible that different factors were associated with low trust among African Americans and Whites because of differences in healthcare experiences and sources of medical care between these populations" [30]. It has been suggested that among African Americans, previous experiences with healthcare providers and sources of medical care may be more important sources of distrust in healthcare providers than sociodemographic characteristics.

With the ever-evolving discoveries and medical mistrust that continued to be revealed, what once was merely folklore in nature has come to modern light as ethical lapses of monumental proportions. The research and subsequent book and movie detailing the origin of the commonly used HeLa cells underpins much of the practice of modern medicine in the United States. These "HeLa cells" originated from the flesh and blood of an African American woman named Henrietta Lacks. Her cells were taken for scientific purposes without any consent or foreknowledge from her, nor her family and loved ones. These cells were used for decades, even to this day. They have been involved in key discoveries in many fields including cancer, immunology, and infectious disease [32]. Even most recently, they have been used in research to develop vaccines aimed at combating the COVID-19 pandemic [33]. Yet another ethical abuse destined for the big screen involves the story of the first heart transplant in the segregated southern United States in 1968. This also involved the lack of informed consent to obtain the heart and kidneys of a black patient, Bruce Tucker, for the purposes of performing organ transplants for other recipients [34]. Actions such as these, and their subsequent lack of ethical and moral behavior, have direct linkages to communal mistrust, and some may argue an earned distrust, in healthcare, healthcare professionals, and healthcare delivery systems [35]. These historic ethical lapses are often in the memories and minds of minority geriatric patients that themselves have been participants, positively or negatively, within old institutions of segregation and overt racism.

While racism may or may not remain as overt within healthcare today, racial biases undoubtedly remain [36]. In fact, perceived racism particularly with older minority patients has been found to be a possible contributor to health disparities [37]. Within dentistry, healthcare providers' racial bias is also evident. Dentists' decision-making has been impacted by the race of the patient, resulting in a greater

likelihood of extractions (less root canal therapy recommendations) for Black patients presenting with a broken-down tooth and symptoms of irreversible pulpitis [38]. Showing that treatment planning decisions may indeed be subject to and/or influenced by racial bias. It is an ethical duty for dentists and dental team members to be self-aware, hopefully reducing the impact potential biases can have on the treatment and care patients receive. For a more in-depth discussion on the topic of health disparities, please refer to Chapter "Health Disparities in Oral Health".

All decisions that healthcare providers make are affected by their own cultural background as well as the background of the persons for whom the decisions are made [39]. Different ethnic groups have varied attitudes toward seeking help, proposing ideal solutions to problems, and even considering who is part of the family [40]. Often the most vulnerable and susceptible populations to disease have the most historic impediments to healthcare access [41]. Overall, while untreated dental caries in older Americans significantly has decreased, health disparities and inequities remain with higher prevalence of untreated dental caries in older African Americans and Hispanics Americans, those with lower incomes and less education and current or former smokers [5, 42]. Greater retention of teeth predisposes many older adults to a continual risk of both new and recurrent coronal and root caries and extends the risk for developing gingivitis and periodontal diseases [43]. This is particularly true of vulnerable populations most directly affected by a lack of access to oral healthcare. A barrier to care, in need of ethical exploration is also the issue of language. While not often seen as an ethical dilemma in its purest sense, the issue of language and potential language barriers that may exist between dental providers and patients is an ever-present ethical dimension. Though the number of Spanish-speaking providers in the United States is on the rise, studies have shown an increased presence of periodontal disease in Spanish-speaking older adults of Mexican ancestry despite having regular dental care at home [44]. While access to care issues are multivariate in nature, the ethical lens must also remain a consideration.

6 The COVID-19 Global Pandemic and the Geriatric Patient: An Ethical Lens

Patients with pneumonia of unknown cause were reported in Wuhan, China, in December, 2019 [45]. Later named, COVID-19, the virus quickly spread across the global landscape, in short order being declared a pandemic by the World Health Organization [46]. "Due to the rapid spread of COVID-19, the risk of it causing significant fatality and the stress it poses for health care workers and its potential to overwhelm the capacity of health care systems resulted in many countries adopting measures to restrict human mobility, in an attempt to limit the spread of the disease" [47]. Dental care providers were required to halt all nonemergency treatment procedures due to the concern that many dental procedures may produce aerosols and

facilitate COVID-19 spread [48]. Older patients were thought to be highly susceptible, and one of the hardest hit populations were residents of long-term care facilities or geriatric patients who are institutionalized [49]. The earliest outbreak of COVID-19 in the United States was in a long-term care facility in the state of Washington, USA, which had a high fatality rate [50].

In addition to affecting long-term care facilities in unknown proportions, it has been established that PACE programs within the United States are on trend with the aging population's desire to age in place and even chose home-based care. This trend and choice, along with forced social distancing restrictions, has only increased with the effects of COVID-19 on long-term care and home care industries catering to older adults [23]. The COVID-19 pandemic has further exacerbated problems accessing oral healthcare for those populations already most at risk for oral disease. The pausing of care, while appropriate for some populations, may have seen a worsening of dental caries, periodontal disease, or even pathology for older populations. The soaring positivity rates of the virus has resulted in disruptions in the delivery of maintenance dental treatments for many geriatric patients who were forced to take indefinite hiatus in their oral care.

The COVID-19 pandemic has laid bare many of the healthcare inequities and disparities that have long gone unnoticed by the masses leading to a full mainstream understanding and public conversation [51]. Connecting to the history of medical mistrust by minority US populations, barriers to greater participation of Black people in COVID-19 trials still exist as well as the hesitancy in taking advantage of vaccine administration that are now widely available in most high-income countries [52–54]. Although the COVID-19 pandemic presents an additional ethical hurdle for geriatric patients and their dental providers, like other disruptions before, innovation is birthed. Greater acceptance for teledentistry, a move away from live patient board exams, and even an expansion of dental and dental hygiene scopes of practice to include vaccine administration are just a few of the many positive disrupters by which the COVID-19 pandemic has challenged the status quo [55–57].

7 Ethical Decision-Making: Principles and Embracing Narrative Ethics

Ethical decision-making for dentists can be relatively straightforward and simple or can delve into quite a complex process of weighing out options and various stakeholder viewpoints. Due to the ever-evolving complex nature of dentistry and dental practice, several models of ethical decision-making have been developed and utilized over time. Most models involve contemplation of ethical principles and include multiple considerations [1]. Professions, including dentistry, are largely defined as such in part because of self-governed and developed codes of ethics. A code of ethics defines the moral boundaries within which professional services may be ethically provided. Many dental organizations have codes of

ethical conduct for guidance of dentists in their practice. The American Dental Association (ADA) has five guiding and fundamental principles which are the following: patient autonomy, non-maleficence, beneficence, justice, and veracity (Fig. 1).

Many models and frameworks exist to aid healthcare practitioners in managing ethical challenges that arise during clinical care. The most classical understanding of dental ethics and ethical decision-making stems from the classic work of Ozar's Central Values of Dental Practice. These values are delineated as follows: (a) the patient's life and general health, (b) the patient's oral health, (c) the patient's autonomy, (d) the dentist's preferred patterns of practice, (e) esthetic values, and (f) efficiency in the use of resources [58]. Also widely used is the Four Box Model derived from Jonsen, Siegler, and Winslade, in which ethical problems are analyzed in the context of four domains: medical indications, patient preferences, quality of life, and contextual features (i.e., social, economic, legal, and administrative) [59]. Each topic can be approached through a set of specific questions with the goal of identifying the various circumstances of a given case and linking them to their underlying ethical principle [60].

One of the most recent developments in dental ethics has been the use of narrative ethics as a model for ethical decision-making. Narrative ethics is a different way of thinking about teaching ethics. While principle-based ethics is useful, it can tend to put ideas into specified boxes and silos. Narrative ethics enables one to deconstruct cases in a broader sense with the ethical choices made more easily subject to reflection and evaluation [61]. It also helps one think about an ethical scenario as a story, helping to better empathize with other persons' thoughts and feelings and enabling more thoughtful decision-making. Some critique put forth concerning narrative ethics has been the lack of appeal to rules, principles, or other ethical constructs [62].

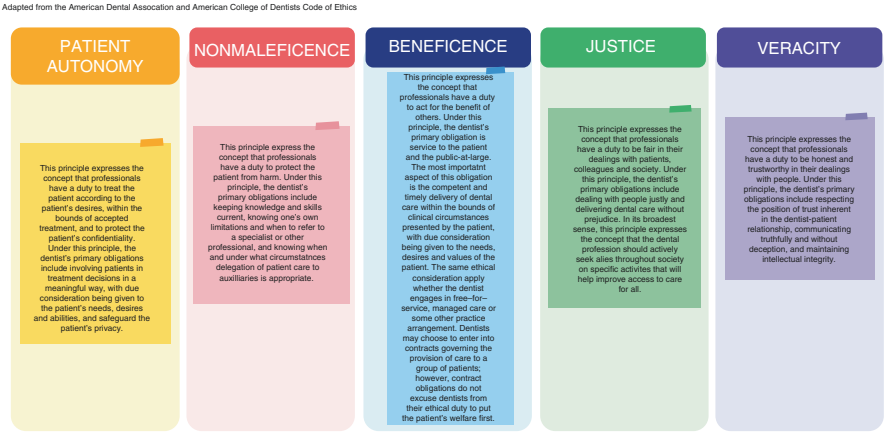

Fig. 1 Principles of dental ethics

Roucka and More have developed a specific narrative dental ethics decision-making model rubric and framework relying on both narrative and story as well incorporating consideration of classic healthcare ethical principles (Fig. 2 and Table 1). Their model includes the following: identifying the stakeholders, asking if harm was done to anyone and by whom, rating (4 being excellent 1 being poor) the outcome from the perspective of each stakeholder, inquiry of how the story makes one feel, determining if the circumstances give the perception of an optimal outcome, identifying flaws one may identify (breach of principles, procedural and/or ethical), and lastly, an attempt at rewriting the story to make the scenario such that an optimal outcome is perceived by all stakeholders [63].

The narrative dental ethics decision-making model allows for building of empathy, inspires self-reflection, encourages memory through emotional connection, and aids in illustrating various points of view. A narrative dental ethics approach also reminds the user that ethics and ethical decision-making are not conducted in a vacuum. Dentists bring their varying life experiences and perspectives to the proverbial ethical decision-making table. This would include, but not limited to, personal experience and upbringing, religious beliefs or the lack thereof, professional training and experiences, practice locations, patient expectations, social customs, societal norms, and more. These various life experiences and perspectives shape dentists understanding and well-being, ultimately affecting patient outcomes. Most assuredly, open consideration of ethical issues leads to improved quality of decisions [8], ultimately yielding a better life for geriatric patients and increased satisfaction and altruism for dentists and the dental care team.

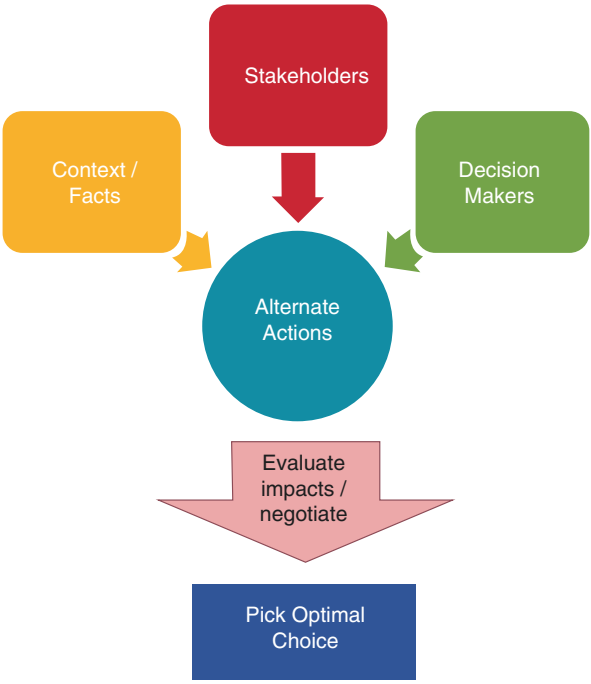

Fig. 2 The process of narrative ethics

Table 1 Roucka/More Narrative Ethics Rubric

List the Stakeholders in the scenario:	Was harm done to anyone? If so, to whom?	Rate the outcome of this scenario from the perspective of each stakeholder 4 – Excellent 3 – Good 2 – Average 1 – Poor	Answer the following questions: You are a beholder observing this scenario. In one word, how did the ending make you feel? (e.g. uneasy, happy, satisfied etc.) Do the circumstances give the perception of an optimal outcome? Yes or No	What flaws, (ethical concerns, violation of principles or professional lapses), if any, do you identify in this scenario? If you had to re-write this scenario to make it such that an excellent outcome was perceived by all stakeholders, how would it go? (be brief)

8 Conclusions

Providing care for the geriatric dental patient highlights numerous ethical issues, some applicable across the patient demographic but some highly specialized for elder care. Understanding and fully applying informed consent, particularly in the age of rising dementia and declining capacity; elder abuse, evolving technologies and changing models of care delivery; medical mistrust and history of racism in healthcare; and the effects of the global COVID 19 pandemic are all issues best seen through an ethical lens. Although a myriad of frameworks exist for ethical decision-making, the use of narrative ethics for dentists and dental team members offers much promise.

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Health Disparities in Oral Health

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1 The Older Adult Population

The United States has become increasingly diverse. In addition, the adult population is living longer and therefore growing. According to the 2010 US Census as reported by the Centers for Disease Control and Prevention (CDC), approximately 36% of the population belongs to a racial or ethnic minority group. In addition, it is projected that by 2060, people 65 and older will reach 98 million and comprise 24% of the population. The older population will represent just over one in five US residents by the end of 2060, up from one in seven in 2012. The increase in the number of the "oldest old" will be even more dramatic—those 85 and older are projected to more than triple from 5.9 million to 18.2 million, reaching 4.3 percent of the total population [1].

It is projected that between 2015 and 2060 the number of African American older adults in the United States will nearly triple, and the number of Hispanic older adults will more than quintuple, while the number of Whites will less than double. Specifically, it is estimated that the White population will expand from 37.4 million in 2015 to 55.2 million in 2060; Hispanics will expand from 3.7 million to 19.9 million; African Americans will expand from 4.2 million to 11.4 million; and other Non-Hispanics (Asians, Native Americans, Alaska Natives, and multicultural populations) will expand from 2.4 to 10.3 million [2]. With older adults living longer and the United Stated becoming more diverse, there is a potential for greater healthcare needs of this population.

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2 Oral Health in American and the Older Adult Population

The 2000 US Surgeon General's Report marked a historical landmark by including oral health in America. The major message of this report was that oral health is essential to the overall health and well-being of all Americans and can be achieved by all Americans. This report was a call to action to health professionals to design programs that promote oral health and prevent disease. While many challenges have been overcome, not all Americans are achieving the same degree of oral healthcare. Despite the safe and effective means of maintaining oral health that have benefited most Americans over the past half century, many still experience needless pain and suffering, complications that devastate overall health and well-being, and financial and social costs that diminish the quality of life and burden American society. What amounts to "a silent epidemic" of oral diseases is affecting the most vulnerable citizens—poor children, older adults, and many members of racial and ethnic minority groups [3].

The report underscores that oral health is far more than just healthy teeth and that it is integral to general health. It encompasses all components of the oral cavity and head and neck regions. Oral soft tissue lesions, chronic oral-facial pain conditions, oral and pharyngeal (throat) cancers, birth defects such as cleft lip and palate, and scores of other diseases and disorders that affect the oral, dental, and craniofacial tissues must be considered in assessing the oral health status. Simply stated, one cannot be classified as healthy without oral health. Therefore, oral health and general health should not be interpreted as separate entities. Oral health is a critical component of health and must be included in the provision of healthcare and the design of community programs.

Oral health and disease have been associated with systemic diseases such as cardiovascular disease, immune disorders, microbial infections, and cancers. New research is pointing to the associations between chronic oral infections and heart and lung diseases, stroke, low birth weight, and premature births. Associations between gum (periodontal) disease and diabetes have also long been noted [4].

The 2020 US Surgeon Generals' Report will continue the initial work and focus of the 2000 Report. It will evaluate oral health and the interaction between oral health and general health throughout the life span, considering advances in science, healthcare integration, and social influences to articulate promising new directions for improving oral health and oral health equity across communities [5].

The nation's oral health has greatly improved since the 1960s [6]. Water fluoridation has played a significant role in improving the oral health status in America, and more emphasis has been placed on dental care prevention. As a result, over the last several decades, there has been a decline in caries levels and tooth loss. However, as the older adult population is living longer, they potentially may experience changes and problems in their oral health such as tooth decay, tooth loss, gum (periodontal) disease, dry mouth (xerostomia), chronic disease, and oral cancer and precancer conditions. These problems may cause pain, problems with chewing and

eating, and difficulty with smiling and communication, as well as have an impact on the longevity of life.

Nearly all adults (96%) aged 65 years or older have had a cavity; one in five have untreated tooth decay [7]. Total tooth loss is experienced in nearly one in five of adults aged 65 or older. Complete tooth loss is twice as prevalent among adults aged 75 and older (26%) compared with adults aged 65–74 (13%) [7]. A high percentage of older adults have gum (periodontal) disease. About two in three (68%) adults aged 65 years or older have gum (periodontal) disease [8]. The prevalence, however, varies among race and ethnic groups. For example, the oral health status of African Americans differs in comparison to other races/ethnicities. Forty-six (46%) percent of African American adults have decay as compared to twenty-seven (27%) percent of adults nationwide [9].

Most older Americans take both prescription and over-the-counter drugs; many of these medications can cause dry mouth (xerostomia). The reduced saliva flow increases the risk of cavities [8]. Cancers of the mouth (oral and pharyngeal cancers) are primarily diagnosed in older adults. The median age of diagnosis is 62 years [10]. In addition, African American men have a particularly high risk for this disease [11].

3 Social Determinants of Health

Social determinants of health (SDOH) are the conditions in the environments, where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks [12]. SDOH in older adults includes income, healthcare access, communities, and social support. The older adults impacted by factors relating to SDOH often find themselves experiencing financial hardships which creates a domino effect impacting healthcare, safe and affordable homes, and their ability to remain socially connected. People with steady employment are less likely to live in poverty and more likely to be healthy. Social determinants of health have disproportionately affected communities of color, particularly African American communities, for a long time. Research shows that systemic racism ensures that African American people are more likely to live in poorer neighborhoods with fewer social services, less access to healthy food, and a higher risk of exposure to environmental contaminants [13].

Older African Americans consistently have higher rates of major health problems than do non-Hispanic Whites. They also have the highest rates of functional limitations. While the gap in disease and disability rates diminishes with control studies for Black−White population differences in wealth and other socioeconomic characteristics, most studies continue to find that race has an independent effect on poor health. Older Hispanics clearly are disadvantaged socioeconomically, having very high rates of diabetes and obesity, and engaging less in exercise than non-Hispanic Whites. In addition, hypertension is at least as prevalent among Mexican American older adults as it is among the general older adult population.

Race affects the health of minorities throughout their life course through both perceived and structural mechanisms. Experiences of discrimination and implicit bias lead to increased stress, unhealthy adaptive behaviors, and historical trauma across all socioeconomic statuses [14].

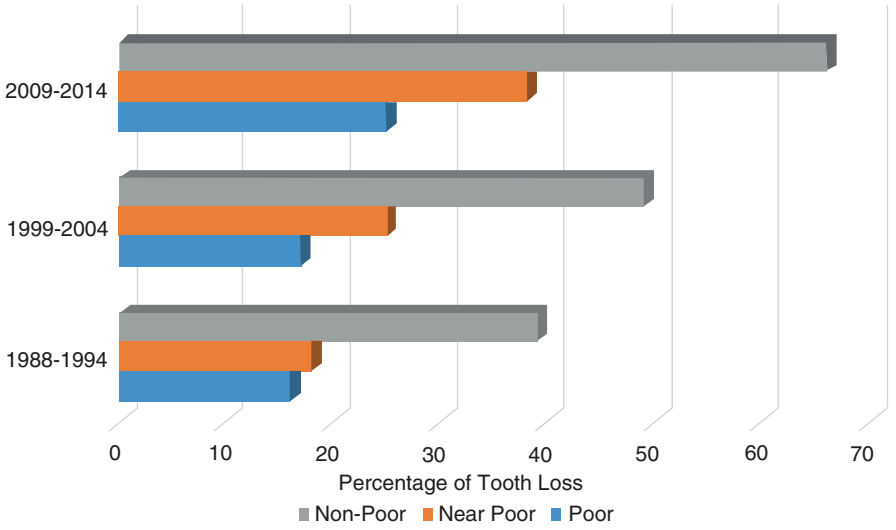
4 Health Disparities Defined

The US government defines health disparity as "a particular type of health difference that is closely linked with social or economic disadvantage" [15]. "Healthy People 2020" expands this definition and defines a *health disparity* as "a particular type of health difference that is closely linked with social, economic, and/or environmental disadvantage. Health disparities adversely affect groups of people who have systematically experienced greater obstacles to health based on their racial or ethnic group; religion; socioeconomic status; gender; age; mental health; cognitive, sensory, or physical disability; sexual orientation or gender identity; geographic location; or other characteristics historically linked to discrimination or exclusion" [16].

Health disparities across ethnic groups in the US society have been recognized for over 30 years. The federal government has established various entities in an effort to address health disparities in minority populations. In 1990, the National Institutes of Health (NIH) created the Office of Research on Minority Health (NIMHD, 2013). In 1993, Public Law 103-43, the Health Revitalization Act of 1993, established the Office of Research on Minority Health in the Office of the Director, NIH. In 2000, the National Center on Minority Health and Health Disparities was established by the passage of the Minority Health and Health Disparities Research and Education Act of 2000. The Institute of Medicine (IOM) of the National Academy of Sciences has released at least three reports examining health disparities in the United States (IOM, 2001, 2003, 2012). The 2003 IOM report defined health disparities as "racial or ethnic differences in the quality of healthcare that are not due to access-related factors, or clinical needs, preferences, and appropriateness of interventions." Despite this recognition and several studies identifying specific areas of disparity, differences in access to health services and quality treatment persist (IOM, 2012). More importantly, health disparities continue to exist and impact certain populations at a higher rate.

5 Health Disparities in Oral Health

Tooth retention is greater among nonpoor older adults. Older adults who are in poor and near poor poverty status levels show less tooth retention from 1994 to 2014 as indicated in the table below.



Health disparities significantly impact the oral and overall health of patients, and the older adult population is not exempt. Disparities in older adults vary across race, ethnicity, gender, and demographics. Certain populations have a higher prevalence for particular diseases, thus creating variations in health status and medical conditions. In addition, some minorities experience a disproportionate burden of preventable disease, death, and disability compared with non-minorities [17].

As adults age, oral health-related quality of life is negatively affected by tooth loss and tooth decay [18]. While improvements have helped to create a healthier society, studies have documented that the health and life expectancy of a patient can be associated with their dental health. It is estimated that over $45 billion is lost in productivity in the United States each year because of untreated oral disease [19]. In addition, nearly 18% of all working-age adults, and 29% of those with lower incomes, report that the appearance of their mouth and teeth affects their ability to interview for a job [20].

6 Dental Coverage

More people are unable to afford dental care than other types of healthcare [21]. In 2015, the percentage of people in the United States with no dental insurance was 29% overall and 62% for older adults [22]. The oral health for older adults is largely neglected by health policy makers. Many older Americans do not have dental insurance because they lost their benefits upon retirement. In addition, Medicare is the primary source of health coverage for older adults, but the program does not cover routine dental care [23]. Studies have linked a patient's oral health status to chronic disease such as diabetes and heart disease. The average

older adult who is retired lives on a fixed income. Surveys, particularly among minority older adults, indicate that dental services are sought more for emergency care versus preventive care due to the high costs for treatment. Many low-income adults do not have public dental insurance. Health services that are provided by states through the Medicaid program do not require that adult coverage be included. As a result, Medicaid programs' dental coverage varies widely from state to state. Many states that provide adult dental coverage through Medicaid programs have limited coverage for emergency services such as extractions. The Affordable Care Act, however, allowed for Medicaid expansion which permitted modifications that resulted in small increases in utilization among adults with public insurance. However, in many states, access is also a concern as many dentists do not accept Medicaid because of the low reimbursement rates. With the growing number of persons living longer with chronic diseases, some of which are linked to preventable oral health conditions such as gum (periodontal) disease, a multiprong approach is needed. Firstly, policy makers must work to develop and pass legislation that will move from just emergency or optional care benefits to adding comprehensive oral and preventive care as an integral part of Medicaid and Medicare programs. Secondly, healthcare providers must continue in the quest to provide optimal care to older adults reducing tooth loss and the number living with gum (periodontal) disease.

7 Health Literacy

According to the World Health Organization (WHO) Health Policy 1998, "Oral health literacy implies the achievement of a level of knowledge, personal skills and confidence to take action to improve oral health by changing personal lifestyles and living conditions" [24].

Some of the greatest disparities in oral health literacy occur among racial and ethnic minority groups from different cultural backgrounds and those who do not speak English as a first language. Results from the National Assessment of Adult Literacy demonstrated that Hispanic adults have the lowest average oral health literacy scores of all racial/ethnic groups, followed by African American and then American Indian/Alaska Native adults [25]. People with low oral health literacy and limited English proficiency are twice as likely as individuals without these barriers to report poor oral health status. One study found that 74% of Spanish-speaking patients have less-than-adequate oral health literacy as compared to 7% of English-speaking patients. Cultural beliefs may also impact communication between patients and providers and affect a patient's ability to follow instructions [26].

Oral health literacy challenges may impact older adults more than other age groups. On average, adults age 65 and older have lower oral health literacy than adults under the age of 65. Low oral health literacy among older adults is associated with increased reports of poor physical functioning, pain, limitations of daily activities, and poor mental health status [27]. For a more in-depth discussion on this topic, please refer to the chapter "The Role of Oral Health Literacy and Shared Decision Making."

8 Living Conditions and Disabilities

It is well-documented that oral care to the older population living at home or in nursing homes, assisted living, or other care facilities is lacking. The older population living in nursing homes will include the medically compromised, physically and intellectually disabled. Older adults who have disabilities may experience challenges, such as limited manual dexterity that inhibits proper oral hygiene; masticatory challenges that negatively affect the oral flora and processing of food; or prescription medicines that impact the oral cavity. As the older population living in nursing home increases, the principles of dental health are becoming increasingly relevant for members of the dental team, medical team, health educators, social workers, and others. More than 1 million nursing home residents faced the greatest barriers to accessing dental care of any population group. Barriers to appropriate oral care in long-term care facilities include poorly organized processes and policies, a lower priority of dental care, care provider's lack of knowledge of oral care, and an adequate number of care providers (both dental and non-dental). Long-term care residences are also less likely to have access to comprehensive dental care. Impaired mobility, lack of ability, and motivation to perform oral care are identified as additional barriers [28–31].

According to multiple studies, not only is there an inadequate number of care providers both dental and non-dental but it is also how prepared they feel in providing oral care services. *The Caregivers' Perceived Comfort Regarding Oral Care Delivery: A Pilot Study* found 56% of caregivers did not feel comfortable providing appropriate oral care due to lack of experience, lack of training, and being uncomfortable with oral hygiene in general. One study showed that 80% of the non-dental caregivers reported that many of the older adults living in care facilities did not open their mouths, bite the toothbrush, or refused oral care completely. Also, the non-dental caregivers have many duties and stated they were too busy and would eliminate mouthcare as part of their patient's care. This further emphasizes that oral health is not a priority in the daily activities of non-dental caregivers.

The Commission on Dental Accreditation (CODA) standards for Predoctoral Dental Education Programs do not include a standard that specifically addresses the older adult population. There is however, a standard that states "Graduates must be competent in providing oral health care within the scope of general dentistry to patients in all stages of life," which allows dental schools to determine how to provide care to the older population. A study conducted by the American Dental Education Association (ADEA) showed fewer graduates who felt prepared to care for the older adult population despite the amount of content on geriatrics that was presented and considered appropriate [28–31].

9 Tooth Decay

Older Americans with the poorest oral health tend to be those who are economically disadvantaged, lack insurance, and are members of racial and ethnic minorities. They experience more tooth decay and tooth loss. Over 40% of low-income and non-Hispanic

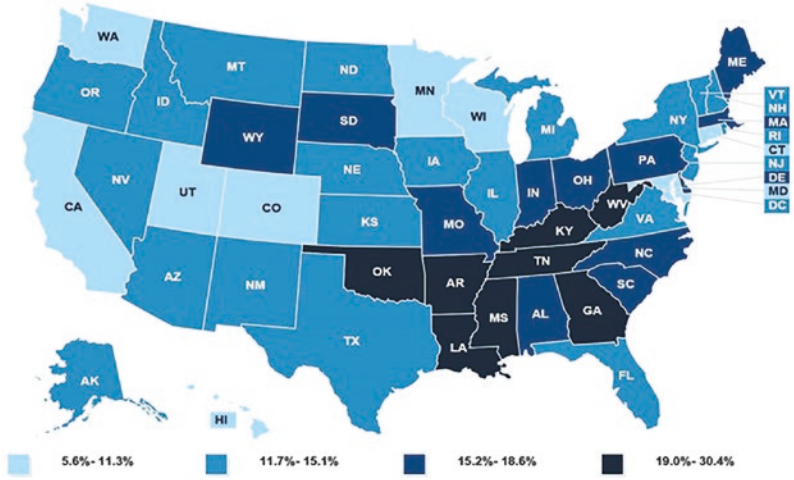
Black adults have untreated tooth decay, which has a large impact on quality of life and productivity [32]. The CDC's Oral Health Surveillance Report: "Trends in Dental Caries and Sealants, Tooth Retention, and Edentulism, United States 1999–2004, 2011–2016" indicates that more than nine in ten older adults have had cavities and one in six have untreated cavities. Older non-Hispanic Black or Mexican American adults have 2–3 times the rate of untreated cavities as older non-Hispanic White adults. The report also noted the impact of educational level and tooth decay in older adults stating, "Older adults with less than a high school education have untreated cavities at nearly 3 times the rate of adults with at least some college education" [33]. For a more in-depth discussion on this topic, please refer to the chapter "Management of Caries in Older Adults."

10 Tooth Loss

Seventeen percent of older adults have lost all their teeth. Having missing teeth or wearing dentures can affect nutrition, because people without teeth or with dentures often prefer soft, easily chewed foods instead of foods such as fresh fruits and vegetables – which are basic elements of a healthy diet. Low-income older adults, those with less than a high school education, or those who are current smokers are more than three (3) times as likely to have lost all of their teeth as compared to adults with higher incomes, with more than a high school education, or who have never smoked. Additionally, often the loss of teeth leads to embarrassment and low self-esteem, which results in contributing to loneliness and social isolation [33].

According to the 2020 US Surgeon General's Preliminary Report, the percentage of adults 65 and older experiencing tooth loss has declined from 1988 to 2014 by 18%. However, disparities still remain among lower-income adults by 34%. This disproportionately affects some adults according to where they live.

Older adults living in MS, TN, GA, AR, KY, WV, and OK in comparison to other throughout the US percentage of tooth loss



Source: Kaiser Family Foundation analysis of the Center for Disease Control and Prevention (CDC)'s Behavioral Risk Factor Surveillance System (BRFSS)2016 Survey Results

11 Gum Disease

Gum (periodontal) disease is a common oral disease among older adults. Recent data reported by the CDC indicated that 42% of adults have some form of gum disease. Among adults aged 65 and older, the rate of gum disease increases to 60%. Severe gum disease is most common among adults aged 65 or older, Mexican American, and non-Hispanic Black adults as compared to non-Hispanic Whites, and people who smoke [34]. Important to note however, is with proper diagnosis and treatment, the disease can be reversed. For a more in-depth discussion on this topic, please refer to the chapter "Management of Periodontal Disease in Older Adults."

12 Dry Mouth

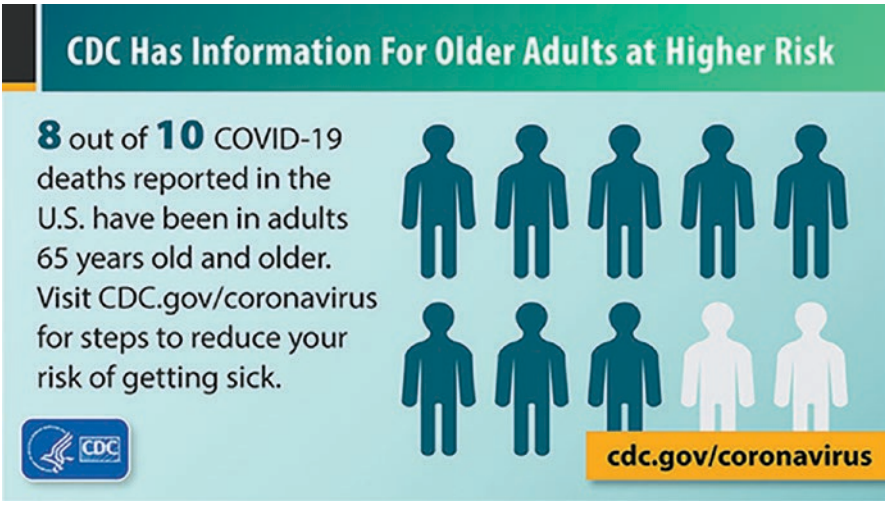
Dry mouth or xerostomia is a condition in which the salivary glands in the mouth do not make enough saliva. The primary role of the saliva is to protect the oral tissue by keeping it moist. The reduction in salivary flow increases the risk of oral diseases and tooth decay as well the difficulty in eating, chewing, and communicating [8, 35]. And while dry mouth is not a normal part of aging, it is a common concern in the older adult population and is mostly related to adverse effects from medications (prescription and over the counter), dehydration, electrolyte and fluid balance, and changes in saliva. The greatest risks have been associated with drugs used for urinary incontinence, hypertension, and antidepressants [36]. For a more in-depth discussion on xerostomia, please refer to the chapter "Xerostomia and Hyposalivation ".

13 Oral Cancer/Precancer

Cancers of the mouth and precancer lesions such as leukoplakia are more commonly seen in older adults. The average age for diagnosis is 62 years. A review of the literature suggests that tobacco use and alcohol consumption are high-risk factors in oral cancer and precancer. Men are twice as likely to experience head and neck cancers than women. The 5-year survival rate for oral pharyngeal (throat) cancers is lower among Black men (41%) than White men (62%) [37–39]. Tobacco use is the most important determinant of oral cancer and precancerous lesions, but excessive consumption of alcohol, diet, and personal hygiene can be contributing factors as well [39].

14 COVID-19

According to the CDC, older adults are at a higher risk for contracting the virus and requiring hospitalization. Also, documented is that eight out of ten COVID-19 deaths reported were in persons 65 years or older.



The CDC has also reported that the COVID-19 pandemic has disproportionately impacted populations with preexisting conditions, such as hypertension, cardiovascular disease, obesity, asthma, and cancer, many of whom are older adults and/or minorities. Minorities disproportionately have higher prevalence of many of these medical conditions. The percent of cases for racial and ethnic minority groups is higher than the percent of these populations within the total US population.

The US Census Bureau 2018 Community Survey compared the racial and ethnic disparities in COVID cases in comparison to the percent of the total US population:

Illnesses

- White people represent a majority of the US population (60%), followed by Hispanic or Latino people (18%), non-Hispanic Black people (12%), non-Hispanic Asian people (6%), non-Hispanic people who identify with more than one race (3%), American Indian or Alaska Native people (1%), and Native Hawaiian or other Pacific Islander people (less than 1%).
- White people represent 67% of COVID illnesses, followed by non-Hispanic Black people (12%), Hispanic or Latino people (11%), non-Hispanic Asian people (3%), and American Indian or Alaska Native people (1%). Among people aged less than 50 years, and notably among children aged less than 18 years, a noticeably higher percent of COVID-19 cases is among Hispanic or Latino people compared with the percent of the total US population.

Deaths

Like the data reported on COVID illnesses, COVID-related death indicates similar disparities. Data on race and ethnicity for more than 90% of people who died from COVID-19 reveal that the percent of Hispanic or Latino, non-Hispanic Black, and non-Hispanic American Indian or Alaska Native people who have died from COVID-19 is higher than the percent of these racial and ethnic groups among the total US population. This disparity is even greater when the percentages are

age-standardized (adjusted for differences in the age distribution across racial and ethnic groups). Hispanic or Latino, non-Hispanic Black, and non-Hispanic American Indian or Alaska Native people also have a disproportionate burden of COVID-19 deaths among specific age groups across the life span – children, youth, adults, and older adults.

CDC COVID tracking data indicates that Black people represent 12% of the US population and 23% of COVID-related deaths; Hispanic or Latino people are 20% of the US population and 38% COVID related deaths; and American Indian or Alaska Native people are 1% of the US population and 3% of COVID related deaths.

15 Summary

As oral health continues to be recognized as an integral part of overall health, it is paramount that special attention be paid to the oral health of the older adult population. To ensure continued progress, efforts must continue that expand the current workforce, improve the ability of providers to communicate with their patients, and empower the older adult to communicate their understanding of their dental care.

Federal policy makers must design legislation that will fill the gap of insurance coverage for older adults by providing Medicare oral health coverage for all. If we are to improve the oral health of all older adults, we must not only recognize the health disparities and social determinants of health but also implement strategies for improvement.

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Frailty and Oral Health

Jorge G. Ruiz and Christie-Michele Hogue

1 Physical Frailty

Frailty is a geriatric syndrome characterized by individual's vulnerability to stressors resulting from physiological reserve losses across multiple body systems [1, 2]. Frailty is common in older adults. A meta-analysis of population studies around the world has shown that the prevalence of frailty ranges between 12% and 24% of people over 50 years [3]. The syndrome is even more common in institutionalized populations and homebound. As a multisystemic disorder, frailty is bound to also involve oral health structures and functions. Frailty is associated with the aging process, but their exact pathophysiological mechanisms are incompletely understood. Investigators have proposed various causes and mechanistic pathways leading to the onset of frailty. Among the proposed mechanisms are age-related changes in the immune system or immunosenescence, defined as the deterioration of the immune response with aging [4], and inflammaging, a state of low-grade chronic inflammation [5]. In addition to the effects of reduced inactivity and nutritional intake, and associated anabolic resistance, these immune system changes may cause sarcopenia, the age-related loss of muscle mass, function, and strength, which may represent a key precursor to the development of frailty [6, 7]. Impairment of

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physiological stress responses may also contribute to the onset of frailty, and improvement in these mechanisms may improve resilience [8]. Independent risk factors for the onset of frailty include among others, older age, African-American race, Hispanic ethnicity [9], lower education, lower socioeconomic status, obesity, poor functional status, inactivity [10], medical and psychological multimorbidity [11], and polypharmacy [12–14]. Frailty is associated with a higher risk of adverse health-care outcomes including disability [15, 16], morbidity [11, 17], surgical complications including impaired wound healing and infections [18], increased health-care utilization [19], and mortality [20, 21]. There is an association between frailty and cognitive impairment with as much as half of all older adults with frailty suffering from cognitive impairment. For a more in-depth discussion on the topic of dementia, please refer to chapter "The 3 Ds: Dementia, Delirium and Depression in Oral Health."

2 Recognizing Frailty

There are currently two major conceptualizations of frailty: the frailty phenotype, which requires the presence of three or more of five components, weight loss, exhaustion, weakness, slowness, and low physical activity [2], and the deficit accumulation model, which combines symptoms, diseases, conditions, disability, and diagnostic tests into a score called the frailty index (FI) [22]. We will refer to both conceptualizations as they often complement each other when approaching older adults with oral pathology. It is important to distinguish frailty from multimorbidity, defined as the presence of two or more chronic conditions, and disability, the need for assistance with activities of daily living (ADLs). Although frailty may often coexist with these two conditions, frailty is a dynamic state of vulnerability that may predispose individuals to both multimorbidity and disability. The recognition of frailty may take the form of questionnaires or scales administered in health-care settings. Several reliable and valid self-report questionnaires have been developed for the evaluation of frailty in diverse care settings. They vary in the number of items included, whether administered face-to-face or self-completed during a clinical encounter or delivered by mail [23, 24]. The FRAIL scale is an example of a validated questionnaire based on the frailty phenotype and deficit accumulation models that consists of five questions assessing fatigue, resistance, ambulation, illnesses, and loss of weight (Table 1). The frail score ranges from 0 to 5 (i.e., 1 point for each component; 0 = best to 5 = worst) and patients are assigned into three categories: robust (0 points), prefrail (1–2 points), and frail (3–5 points) [25]. Physical performance assessments may include the timed get up and go test, the 6-minute walk test, the short physical performance battery (SPPB), or the measurement of handgrip strength. These assessments may not be practical for most dental health professionals, who may not have the time to administer these instruments to older individuals. Most recently, automated tools have assisted clinicians in identifying older persons with frailty. In comparison to the administration of time-consuming

Table 1 The FRAIL scale

Criteria	Question	Scoring
*F*atigue	How much of the time during the past 4 weeks did you feel tired?	1 = All of the time; 2 = most of the time; 3 = some of the time; 4 = a little of the time; and 5 = none of the time ≥3 = 0 points ≤2 = 1 point
*R*esistance	Do you have any difficulty walking up ten steps without resting and without using aids	No = 0 points Yes = 1 point
*A*mbulation	Do you have any difficulty walking several hundred yards alone without aids?	No = 0 points Yes = 1 point
*I*llnesses	Did a doctor ever tell you that you have (illness)?	0–4 = 0 points 5–11 = 1 point
*L*oss of weight	How much do you weigh with your clothes on but without shoes (current weight)?; 1 year ago, how much did you weigh without your shoes and with your clothes on?	<5% = 0 points ≥5% loss of weight = 1 point

From Ref. [25]

questionnaires which are subject to interrater variability, automated screenings can have a significant impact on early detection and the subsequent implementation of evidence-based interventions for frailty in primary care settings.

3 Evidence-Based Strategies to Manage Frailty

Evidence-based treatments for frailty include among others multicomponent exercise and physical activity programs, the Mediterranean and high protein diet, and the use of vitamin D for those individuals that are deficient [26]. An umbrella systematic review of seven systematic reviews including 58 relevant trials and involving 6927 participants summarized the evidence of the efficacy of exercise at improving physical function in older adults with frailty. Most of the included trials examined mobility, physical performance, gait speed, muscle strength, and balance. The overall conclusion of the review was that an optimal combination of intensity, duration, and frequency of exercise interventions may lead to improvements in physical function in these patients. Multicomponent interventions should be performed up to three times per week for 45–60 minutes per exercise session with a gradual increase from moderate- to high-intensity exercise. The exercise programs may last for at least 2 months but preferably for 6 months [27]. Adherence to a Mediterranean-style diet is associated with a lower risk for mortality, cognitive decline, and dementia. Whether adherence to a Mediterranean-style diet protects against the onset of age-related frailty is not known. A meta-analysis of longitudinal analyses showed that higher adherence to a Mediterranean-style diet was associated with lower odds of developing frailty compared with those with lower adherence

[28]. Another meta-analysis of ten studies, seven cross-sectional, and three longitudinal studies including 50,284 older adults from three different continents demonstrated that a high protein intake was negatively associated with frailty status in older adults [29]. Whether providing protein supplements prevent the development of frailty or ameliorates the burden of frailty is not settled as randomized controlled trials have not been completed. A systematic review of a seven studies (17,815 participants) revealed that a low level of vitamin D was significantly associated with the onset of frailty [30]. The use of vitamin D supplements is recommended only in those individuals with documented deficiency. The evidence on other interventions is small or mixed. For a more complete review, please refer to recent comprehensive reviews [26, 31].

4 The Concept of "Oral Frailty"

In 2018, Japanese investigators introduced the concept of oral frailty, defined as a reversible, age-related, decline in oral function [32]. The six key criteria for the diagnosis of this condition include impaired masticatory function, decreased articulatory oral motor skills (oral diadochokinesis), difficulties eating tough food, swallowing difficulty, low tongue pressure, and having less than 20 teeth (Table 2). One or two of the six criteria define oral prefrailty whereas more than three criteria define oral frailty [32]. The evaluation of oral frailty relies on a combination of subjective and objective instrumented oral assessments which may not be feasible for most practicing dental professionals. An 8-item oral frailty checklist represents a more practical alternative to assess oral frailty in clinical settings [34]. The concept of oral frailty does not enjoy wide acceptance outside of Japan. Recent research suggests that oral frailty was not only associated with physical frailty but that it may be a predictor of physical frailty in cohort studies [32, 35]. The research also revealed that oral frailty was associated with poor nutritional status [34, 36]. However, there are no controlled trials that look at whether treating oral frailty improves clinical outcomes in those with frailty or prevent the development of frailty in older adults. In much the same way we would not call age-related or acquired changes in the

Table 2 Oral frailty

Oral condition	Measurement
Number of remaining teeth (<20)	Oral exam
Chewing ability	Color-changing chewing gum
Oral diadochokinesis	Repetitive articulation of syllables as quickly as possible
Tongue pressure	Balloon probe and manometer
Difficulties eating tough foods	Single question about difficulties eating tough foods compared to 6 months ago (yes/no)
Difficulties in swallowing	Two questions about choking with liquids and experiencing dry mouth (yes/no)

From Refs. [32, 33]

heart, liver, or kidneys, cardiac frailty, liver frailty, or renal frailty, respectively, it would not be advisable to call the age-related changes in oral function, oral frailty. Adding the noun "frailty" to any organ or system dysfunction risks confusion and defies the growing body of evidence that demonstrates the multisystemic nature of physical frailty [2, 37, 38]. The term "oral hypofunction" was proposed by major dental societies [39] and represents a preferable term when referring to oral health issues in the assessment and management of older adults with frailty. Still, the clustered criteria have merit and demonstrates a good scientific basis.

5 Frailty and Oral Health: A Bidirectional Relationship

The suggestion of a bidirectional relationship between oral hypofunction and frailty is plausible and credible. The multisystemic involvement that characterizes frailty may lead to structural and functional alterations which may impair the individual's inability to respond to external stressors. Older adults may in turn become weak, tired, and functionally and cognitively impaired. These deficits may translate into a reduction in the individuals' performance of self-care oral behaviors (toothbrushing, flossing, diet, etc.) aimed at achieving adequate oral health promotion and prevention of poor dental outcomes. However, the evidence in this regard is practically nonexistent. Studying older adults who had recently become frail and were adherent to health oral behaviors at baseline would be a reasonable step. Seeing how frailty contributes to future deterioration of self-care behaviors in turn leading to poor oral health-care outcomes in these patients may confirm the independent role of frailty. On the other hand, most of the research evidence comes from cross-sectional and longitudinal studies showing that baseline oral hypofunction is longitudinally associated with the onset of frailty. Chronic impairment of masticatory and swallowing functions may result in reduced oral intake, reduced protein intake, anorexia of aging, impaired oral health, and loss of acuity in taste, smell, and sight, consequently contributing to muscle catabolism and eventually sarcopenia. A cause of sarcopenia is a low intake of dietary protein which has been associated with a loss of body muscle mass, function, and strength [40]. In fact, epidemiological studies have shown that protein intake has been inversely associated with frailty [41]. Whether interventions aimed at correcting these apparently reversible deficits in oral hypofunction would alter the course of the condition and interrupt the development of frailty is unknown.

6 Practical Considerations for Oral Health-Care Professionals

The dental professional plays a very important role in the recognition and management of older adults with frailty. As we have seen, oral health professionals will often care for older adults with frailty and related oral hypofunction. As reviewed

earlier in this chapter, the older individual may have developed frailty as a result of untreated or unrecognized oral health conditions. On the other hand, the dental professional may face an older person who does not seem to be appropriately responding to the oral plan of care. The management of older adults with frailty should be part of joint team effort that includes dentist, primary care clinicians, and other professionals. In long-term care settings, interprofessional teams may also include in addition to dental professionals an expanded team of physicians, pharmacists, nurses, dieticians, speech pathologists, and occupational and physical therapists. As recommended by experts, the first step of any overall strategy is the recognition of physical frailty [26]. The complex needs and findings in these patients demand that a team approach be a key component of the approach for these patients. However, many older adults may present to the dental office with frailty that may have gone unrecognized in primary care settings. We suggest that given the high prevalence of frailty in community settings, a quick approach may involve the use of self-administered questionnaires such as the FRAIL scale [25]. The FRAIL scale can be mailed to the patients in anticipation of dental appointments, or the patient or caregiver may complete it in the office waiting areas. Frailty assessment can assist in gathering essential clinical information that can be incorporated into the patients' dental care plan [42]. Prompt notification of primary care clinicians will ensure adequate follow-up for these individuals. Table 3 describes interventions aimed at specific aspects of frailty in patients with oral health needs. We categorized these interventions into those addressing oral hypofunction and those related to physical frailty. For those patients lacking access to regular dental care, physicians may incorporate oral screenings as a part of the patient's overall workup. If these clinicians identify an oral health condition, they may initiate a referral to a dentist when appropriate. As discussed in chapters "Health Disparities and Oral Health" and "Barriers to Access to Dental Care," not all older adults would have routine access to adequate dental care. For the oral health professional, recommendations may include particular attention to the prescription of medications, closer follow-up, modified diets, exercise and physical activity, and oral health promotion activities.

7 Future Research

More research is needed into the bidirectional relationship of frailty and oral hypofunction. As we have seen in this chapter, the associations between oral hypofunction and physical frailty have not been explored exhaustively. Existing and future prospective cohort studies may incorporate assessments of oral hypofunction into the overall evaluation of older adults without frailty at baseline. These longitudinal studies may further clarify how oral hypofunction may contribute to the development of incident frailty in older individuals. We need randomized controlled trials of lifestyle interventions aimed at improving oral hypofunction and how these approaches may lower the incidence or ameliorate the burden of frailty. Investigators may study whether progression to frailty in those older persons without evidence of

Table 3 Specific interventions for older adults with oral health needs and frailty

Features	Intervention
Oral hypofunction ("oral frailty")	
Impaired masticatory function	Extend number of masticatory cycles (duration of oral food management); xerostomia treatment; address tooth losses; orthodontist evaluation [43]
Oral diadochokinesis	Pronunciation and singing exercises; speech pathology evaluation [39, 44]
Difficulties eating tough food	Choose foods that are soft and palatable (i.e., soft mechanical diets); minced textures; cut food in small pieces [45, 46]
Swallowing difficulty	Adaptive eating aids; mealtime supervision for safe eating; proper techniques for safe eating assistance; texture-modified foods; speech pathology evaluation
Low tongue pressure	Tongue resistance training; jaw opening exercises; self-exercise of oral function; Shaker exercise; referral to speech pathology for tongue-strengthening protocols [39, 47–49]
Less than 20 teeth	Dental implants; removable dentures; prosthodontic rehabilitation; dietetic evaluation [50]
Physical frailty	
Weakness	Adapted eating utensils; resistance exercise training; assistance with meals; dietetic evaluation [51]
Slow walking speed	Allow more time for patients in the office; arrange special transportation; physical therapy evaluation [52]
Self-reported exhaustion	Extend duration of food management; frequent, small meals [51]
Unintentional weight loss	Mediterranean, high protein diets; protein-caloric supplements; dietetic evaluation [53, 54]
Low physical activity	Multicomponent exercise program [26, 27]

oral pathology at baseline may lead over time to declines in the performance of oral self-care activities that may in turn cause impairment of oral structures and function. The other areas are how to adapt lifestyle and therapeutic approaches to the needs of older adults with frailty with special consideration to the role of caregivers.

8 Conclusions

This chapter reviewed the concept of physical frailty in the context of oral health care for older adults. Frailty, a state of vulnerability to stressors resulting from physiological reserve losses across multiple body systems, is common in older adults and is associated with poor health-care outcomes. The concept of oral hypofunction ("oral frailty") is still in evolution but there is evidence of its predictive ability for physical frailty. Oral health professionals will often encounter patients with frailty in their practices and thereby play a vital role in their evaluation and management. Recognizing frailty is the first step. Primary care clinicians may have already

identified older adults with frailty. However, most patient may go unrecognized in which case the use of simple self-administered instruments such as the FRAIL scale may assist oral health professionals in the identification of these patients. Information about the patients' frailty status can then be incorporated into the dental care plan. Oral health professionals may implement several general and specific strategies aimed at preventing the development frailty or mitigating its future complications.

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The Role of Oral Health Literacy and Shared Decision Making

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Mrs. Geneva Williams is a 69-year-old African American woman referred to an endodontist with the chief complaint of throbbing pain for the past 5 days associated with sensitivity and occasional pain in the right region of her lower posterior teeth. The pain kept her awake at night and was originating from the lower right side of her face with radiating pain to her right ear. On clinical examination, the patient had a defective occlusal amalgam restoration. A pulp test suggested irreversible pulpitis. Radiographically, the recurrent caries encroached the pulp. She has a history of well-controlled hypertension, osteoarthritis, and mild hypothyroidism. As a result of the oral pain, Mrs. Williams had modified her diet, eating predominantly soft foods, high in carbohydrates.

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1 Definitions

Health literacy is defined as the capacity to obtain, process, and use basic health information and services needed to make healthcare decisions [1]. It encompasses the skills of listening, reading, integrating, and evaluating health information, analyzing risks, and applying these skills to situations arising when receiving health care [2, 3]. Health literacy is a multidimensional process, including system demands and complexities as well as the skills and abilities of individuals. Health literacy is a dynamic concept that may change with the individual's mental or emotional state, illness, and life stressors [4]. Health literacy also consists of two essential and closely intertwined skills: numeracy and graphical literacy. Numeracy is a set of quantitative abilities needed by patients to comprehend, manage, and manipulate numerical expressions of probability about healthcare information [5, 6]. Lastly, graphical literacy constitutes the ability to comprehend basic graphical representations used to present quantitative health-related information, an increasingly important skill in the era of Internet-based health care [7, 8]. Health literacy may be a labile state, fluctuating with a patient's emotional state, health status, life stressors, or cognitive status, such as in patients with dementia or delirium [9]. In the field of oral health care, oral health literacy (OHL) has emerged as an extension of the overarching concept of health literacy. OHL is the degree to which individuals can obtain, understand, and process oral health information and services necessary for appropriate decisions as they relate to their oral health [10]. Health literacy, specifically as it relates to oral health, is a complex and multifaceted concept, the definition of which is constantly evolving.

Mrs. Williams had completed a high school education and had retired from her job as a postal worker 7 years ago. She reported these symptoms to her dentist who then recommended she seeks further evaluation by an endodontist. Mrs. Williams visited the endodontist who recommended root canal treatment. He explained the risks and benefits of the oral procedure going over multiple studies demonstrating its effectiveness. She told the dentist that she will want to discuss the issue with her older daughter. The endodontist explained that should she not get the procedure, her condition will continue to worsen, and she will have continued pain and possibly need an extraction. Upon returning home, Mrs. Williams told her oldest daughter that she will not undergo the proposed procedure. She is confused and reports "I didn't know other options were available, this was the only way to feel better." She is upset and wonders if she made the right choice.

2 Extent of the Problem

Investigators have reported a high prevalence of inadequate health literacy [11–13] and numeracy [14, 15] in older individuals. The reasons for this differential are various but among the most common are generational differences related to lower levels

of educational achievement [16, 17]. However, age itself may not be an independent risk factor for inadequate health literacy. Factors that represent more important contributors to the higher levels of inadequate health literacy in older adults include multimorbidity, frailty, polypharmacy, and cognitive and sensory impairments [17]. Research shows that after controlling for cognitive ability, age is no longer associated with health literacy [11, 16, 18, 19]. Studies have also documented higher levels of inadequate health literacy and numeracy in minority older populations contributing to further healthcare disparities [11, 19–25].

Mrs. Williams' daughter convinces her mother to see the endodontist once again and promises to accompany her to the next appointment. One week later, both patient and daughter returned to the dental office. The endodontist had recently learned that inadequate health literacy is a serious and common problem in the older population, especially among minorities. He apologizes to Mrs. Williams stating that he may have been a little "too technical" in his explanation of the procedure. He obtains permission to ask her a question to assess her ability to understand health information. To the question "How confident are you filling out medical or dental forms by yourself?" Mrs. Williams replies that her daughter often helps her complete healthcare forms and that she usually accompanies her to medical appointments. However, this has become more difficult as her daughter had just started a new job.

3 Recognition

The identification of health literacy is the first step in the implementation of interventions aimed at mitigating the consequences associated with this problem. Researchers in diverse healthcare fields have developed several instruments to assess health literacy deficits. The most widely instruments are the Rapid Estimate of Adult Literacy in Medicine (REALM), the Test of Functional Health Literacy in Adults (TOFHLA), and the Newest Vital Sign (NVS). The REALM is a word recognition test that is highly dependent on the individual's educational level, and health knowledge and experience, or crystallized intelligence [26], potentially resulting in an underestimation of inadequate health literacy [27, 28]. The TOFHLA is a valid and reliable measure of health literacy that includes 67 items assessing reading comprehension of healthcare information and health numeracy. It takes 22 min to administer [29]. The TOFHLA is one of the commonly used instruments in the health literacy research literature. A shorter version, the S-TOFHLA, has eight items and takes 7–12 min to administer. It was significantly associated with knowledge about medical facts and clinical outcomes [30]. The Newest Vital Sign (NVS) is the most recent addition to the portfolio of health literacy assessment instruments [31]. It consists of a nutritional label and six associated questions. The cutoff for appropriate health literacy is four or more correct answers and it takes approximately 3 min to complete. The instrument is reliable and has demonstrated internal consistency [31]. The NVS and TOHFLA are strongly correlated with each

other reflecting fluid intelligence and independence from the effects of education [27, 32]. A common advantage for both the NVS and S-TOFHLA is that these instruments not only assess reading ability and comprehension but also assess health numeracy [29, 33]. The advantages of the NVS as the preferred instrument to assess health literacy are its brevity and ability to discriminate among high scoring individuals [27].

Oral health investigators have developed or adapted existing health literacy instruments to focus on oral health information. Most of these new oral health literacy tools have used general health literacy instruments as reference standards for their validation. Table 1 shows some of the most common oral health literacy tools in English, organized in ascending order of administration time. The Two-Stage Rapid Estimate of Adult Literacy in Dentistry (TS-REALD) seems like a valid and reliable instrument that according to the authors takes only 1 min to administer. However, despite appearing as a rapid, simple, and practical measure of oral health literacy, the TS-REALD may not be ready for wider use in older populations. The TS-REALD was only validated in women, and the authors did not report the age of the study participants, limiting its applicability [34]. The Rapid Estimate of Adult Literacy in Dentistry-30 (REALD-30) is by far the most studied instrument in the oral health literature [35]. The REALD-30 is a reading comprehension instrument that consists of 30-word recognition items with increasing levels of difficulty [36]. A limitation of the REALD-30 is that it does not include assessments of numeracy, or graph literacy. Another disadvantage is that the REALD-30 may overestimate levels of adequate oral health literacy [37]. The Rapid Estimate of Adult Literacy in Medicine and Dentistry (REALM-D) represent an adaptation of the widely used REALM. As its predecessor instrument, it tests the individual's ability to recognize and pronounce medical and dental words as measures of comprehension [38]. The REALM-D seems relatively efficient and feasible, but the mean age of the participants in the original study suggests that during the validation study, the investigator did not enroll many older individuals [38, 39]. The Oral Health Literacy Instrument (OHLI) is another oral instrument testing reading comprehension and numeracy. However, the OHLI can be quite cumbersome and lengthy to administer [40]. The Test of Functional Health Literacy in Dentistry (TOFHLiD) is also a reading comprehension test adapted from the original TOFHLA. The TOFHLiD was originally validated with the parents of children receiving dental care and did not include anybody in the older age group [41]. Furthermore, this test takes the longest to administer making impractical as a health literacy screen for most dental practices.

Although useful for research purposes, most of the oral health literacy tools described earlier may not be feasible for implementation by busy dental practices. A group in the USA validated the single screening question "How confident are you filling out medical forms by yourself?" to assess patients for inadequate health literacy [42]. Although not yet validated in oral healthcare settings, it represents a practical, feasible, and ecologically valid approach to screen for inadequate health literacy in dental offices. The question could be conceivably be adapted to use "dental" instead of "medical" forms.

Table 1 Properties of selected oral health literacy instruments (English) [35]

Instrument	Participants, type of test, number of items, and scoring	Participants in the validation	Reliability and validity	Time it takes to administer (minutes)	Country
Two- Stage Rapid Estimate of Adult Literacy in Dentistry (TS-REALD) [34]	11 items Score: possible range: 0–9 (raw score – transformed)	Adults: age not reported! (women)	Content validation Concurrent validity: newest vital Sign ($r = 0.51$), and REALD ($r = 0.96$) Reliability: Cronbach's $\alpha > 0.85$.	1	USA
Rapid Estimate of Adult Literacy in Dentistry-30 (REALD-30) [36]	Word recognition, 30 items Score: 0–30 (lowest to highest literacy)	Adults: mean age 44.7 years (SD = 14.6), age range not reported	Content validation Concurrent validity: REALM ($r = 0.86$) and TOHFLA ($r = 0.64$) Predictive validity: oral health related quality of life Reliability: Cronbach's $\alpha = 0.87$	5	USA
Rapid Estimate of Adult Literacy in Medicine and Dentistry (REALM-D) [38, 39]	Word recognition, 84 words Score: 0–84 (lowest to highest literacy)	Adults: 19–87 (mean age: 41 years)	Content validation Concurrent validity: REALM-66 ($r = 0.99$) Predictive validity: confidence filling out medical forms Reliability: Cronbach's $\alpha = 0.958$	5–7	USA
Oral Health Literacy Instrument (OHLI) [40]	57 items Score: possible range: 0–100 (0–59, inadequate HL; 60–74, marginal HL; and 75–100, adequate HL)	Adults 19–69 (mean age: 39 years)	Content validation Concurrent validity: TOFHLA ($r = 0.61$) and discriminate oral knowledge ($r = 0.57$). Reliability: Cronbach's $\alpha = 0.898$	20	Canada
Test of Functional Health Literacy in Dentistry (TOFHLiD) [41]	68 reading comprehension, 12 numeracy items Score: weighted score 0–100	Adults: 26–59 (median age: 35 years)	Content validation Concurrent validity: REALD-99 ($r = 0.82$) Reliability: Cronbach's $\alpha = 0.63$–0.86	30	USA

4 Consequences of Inadequate Health Literacy

Patients with inadequate health literacy suffer from poorer health status, unhealthy behaviors, and worse clinical outcomes than those individuals demonstrating adequate levels of health literacy. Research studies have documented poor knowledge

of disease [43], poor patient-physician communication [44, 45], lower adherence to healthy behaviors [20], impaired self-management skills [46], worse self-perception of health status [47], disability [48], worse clinical outcomes [49–51], diminished ability to participate in shared decision-making [52], and higher healthcare utilization [47, 53]. Regarding oral health, studies have also shown poor oral healthcare outcomes. Using the REALD-20, a study showed that patients with higher OHL had two more teeth on average than those in the lowest score range. This same study also showed a significant association between lower plaque scores and higher REALD-20 scores before and after treatment [54]. The number of missing and filled teeth were significantly higher in those patients with inadequate literacy as compared with participants with adequate levels of health literacy. Limited OHL is also linked to the presence of biofilm in younger adults [55] and severe periodontitis [56]. In terms of healthcare utilization, having lower health literacy was associated with a twofold increase in missed dental appointments [56] and a higher number of emergency dental visits [55]. Others reported higher rates of dental anxiety in individuals with lower levels of OHL [10], dissatisfaction with their own oral health care [57], and impaired quality of life [55]. These studies show that there is an association between lack of OHL and dental outcomes.

The endodontist outlines the risks, benefits, and possible adverse outcomes of the root canal intervention. The dentist uses lay language and graphic illustrations to explain the root canal procedure to save the tooth. He also discusses alternatives to the root canal, including tooth extraction, natural remedies (eliminating processed sugars from her diet, eating high-quality protein and avoiding grains), and irrigating the tooth canal with a calcium hydroxide solution, and he also presents the option of no treatment, explaining this could lead to further recurrent infections. The endodontist wants to make sure that Mrs. Williams understood the procedure and alternatives, so he asks: "Ms. Geneva, I want to be sure that I did a good job explaining the root canal procedure. Would you mind please explaining back to me what we discussed?" After clarifying misunderstandings, the specialist is confident that Mrs. Williams had understood the benefits and burdens associated with the root canal as well as the alternatives he presented. After asking her daughter's opinion, Ms. Williams agrees to undergo the root canal. Together, they decide on a plan of care for her. She feels supported and confident in their joint decision.

5 Shared Decision-Making and Health Literacy in Dentistry

Shared decision-making (SDM) is the process by which patients and healthcare professionals make assessment and management healthcare decisions together, incorporating the best available evidence [58, 59]. SDM involves a bidirectional information flow between the clinician and the patient, patient knowledge of treatment options, and physician elicitation of patient preferences. Shared

decision-making builds a dentist-patient partnership, working on the oral health problems at hand by laying out the available diagnostic and therapeutic options, including that of no treatment. During the process the dentist explains the benefits and risks, eliciting the patient's views and preferences on these options and agreeing on a joint course of action. SDM aims to empower patients to make better healthcare decisions [60–62]. Adequate levels of health literacy are a prerequisite for active participation in the decision-making process [63]. Unfortunately, individuals with inadequate health literacy are less likely to participate in SDM [52, 64, 65]. Although many patients would prefer to play a collaborative role, those with inadequate health literacy most often played a passive role in decision-making [52]. Recent reviews revealed the paucity of studies investigating the process of shared decision-making in dentistry [62, 66]. Small cross-sectional studies of adult patients in dental practices showed that in general patients prefer to play a more active and collaborative role in dental care decision-making [67, 68]. Other studies have addressed how to facilitate SDM by using decisional aids [69–72]. Despite the recognition by oral health experts of the importance of health literacy in SDM [73, 74], there are no studies that specifically examine this topic. On a routine basis, dental professionals will face issues related to assessment and management interventions that will demand patient involvement in the decision-making process. As we have seen throughout this chapter, older adults are a group at higher risk for demonstrating inadequate levels of health literacy. Extrapolating from the large healthcare research literature, we can anticipate that older patients with poor health literacy may not fully engage in the shared decision-making process or comprehend the benefits and risks of proposed dental interventions. In the next section, we will outline interventions designed to improve the process of shared decision-making for patients with inadequate health literacy.

Mrs. Williams undergoes the procedure as recommended by the endodontist. There are no post-procedure complications. She's a little sore afterward but glad that it's over. The endodontist sends her home with age-friendly patient education materials including images explaining post root canal care. He follows up with her by telephone the next day to discuss how she's doing.

6 Interventions

Older adults are high-risk groups for the presence of inadequate health literacy. It is therefore incumbent upon dentists to implement interventions that facilitate dentist-patient communication and improve the process of shared decision among in patients with inadequate health literacy. The American Dental Association has formulated guidelines aimed at improving communication and shared decision-making tools for patients with inadequate health literacy [75]. We complement these recommendations with those of experts in other healthcare fields [76–78].

6.1 Universal Precautions

Given the high prevalence of inadequate health literacy in older adults, it is reasonable to widely implement "lowest common denominator" approaches to address the problem of inadequate health literacy. The US Agency for Healthcare Research and Quality developed the Health Literacy Universal Precautions Toolkit to improve clinician-patient communication in patients with different levels of health literacy [79]. The implementation of universal precautions implies a dental practice commitment to make changes that improve communication and foster older patients' involvement in shared decision-making regardless of their level of health literacy. The interventions may consist of staff training on the principles of communication and SDM, as well as some of the recommendations in this section.

6.2 Teach-Back

The teach-back is a technique in which a patient is prompted to restate information previously conveyed by a clinician with the purpose of ensuring patient recall and understanding [45, 80]. This involves asking a patient to explain in their own words the diagnosis or treatment plan. The provider then can correct any errors or fill gaps in understanding. A growing body of evidence supports the use of the teach-back technique in improving patients' knowledge, self-management skills, and adherence [81]. It may not add additional time to the dental encounter.

6.3 Age-Friendly Written Materials

Age-related changes in visual and cognitive performance may impair older adults' ability to read and understand patient education materials [82, 83]. These changes may be further amplified by the effects of multimorbidity, frailty, and disability. The US the Centers for Medicare and Medicaid Services (CMS) has produced a toolkit with a set of evidence-based guidelines on how to design age-friendly reading materials (Table 2) [84]. Clinicians can use the US Centers for Disease Control (CDC) Clear Communication Index (Index), which provides evidence-based criteria to assess public communication products [85].

6.4 Image-Based Materials (Pictograms)

Pictograms are graphical, nonverbal symbols that are used to convey healtcare information [86]. Figure 1 shows an example of a pictogram explaining the use of a medication. Pictograms may overcome health literacy deficits and improve comprehension, recall, and adherence by patients with inadequate health literacy. Most of

Table 2 Guidelines for preparing age-friendly written materials [84]

Content Use advance organizers Emphasize what patients want and need to know Create content culturally appropriate Repeat new concepts and summarize the most important points. Ensure content accurate and up to date Include information about who produced the resource and when	*Organization* Pace readers by grouping content into meaningful chunks Pay attention to the orderly presentation of information Use headings and subheadings Make headings specific and informative Provide patient friendly navigational aids throughout the document (e.g., table of contents, signs, etc.)
Writing style Write in a conversational style Use the active voice Make sentences simple and short. Be direct, specific, and concrete Give the context first, and incorporate definitions into the text Create cohesion Use words that are familiar and culturally appropriate Use technical terms only when readers need to know them Write as simply as you can	*Motivation* Use a positive and friendly tone Use devices to get readers actively involved with the material Give specific instructions that are culturally appropriate Refer to trustworthy sources of information (government, healthcare organizations) Assist in reading and interpreting health statistics Offer help support or how to obtain additional information

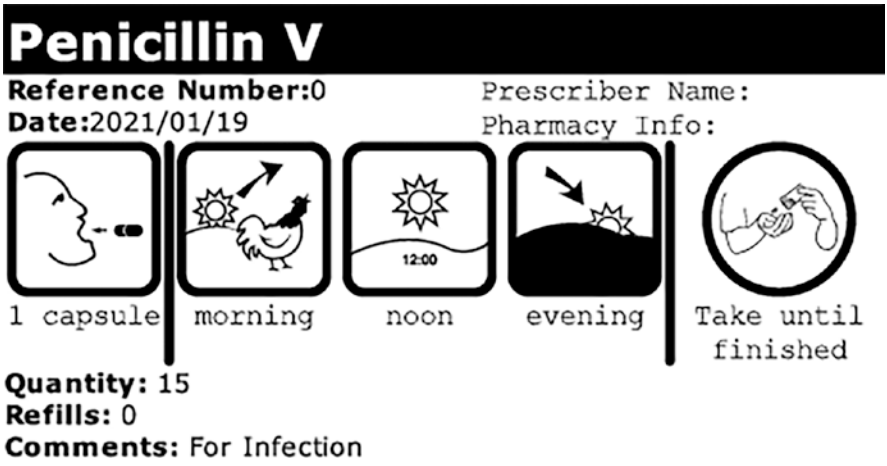

Fig. 1 Pictogram with medication instructions

the research comes from the medication adherence literature. The evidence on the effectiveness of pictograms for older adults with inadequate health is mostly positive in terms of improving patients' medication adherence [86, 87]. In conjunction with other modalities, the judicious use of pictograms may help dentists convey

healthcare information to their older patients. These tools have been shown to improve patients' recall as well as their adherence to medical treatment [80].

6.5 Decision Aids

These are tools designed to assist individuals participation in the shared decision making process by fostering deliberation of healthcare options between patients, caregivers, and the healthcare professional. The goal of using decision aids is to help patients make informed decisions regarding their healthcare [88]. Dental practitioners can take advantage of decision aids to improve patients' knowledge, comprehension of risk perceptions, and participation in shared decision-making [75]. There is growing evidence of the efficacy of decision aids for improving decision-making in patients with inadequate health literacy [89].

6.6 Caregivers

Recruiting caregivers to assist older patients can go a long way in mitigating the negative effects associated with inadequate health literacy. Older patients become increasingly dependent on caregivers for assistance with their daily care and when interfacing with healthcare professionals. Caregivers' working familiarity with the oral healthcare of their loved ones may be useful in ameliorating the effect of the patient's limited health literacy. Dental professionals must be careful in ensuring that the caregivers have in fact an adequate level of health literacy [90].

7 Practical Considerations for Oral Healthcare Professionals

Time constraints are a barrier for oral healthcare professionals seeking to assess older patients for OHL. However, incorporating a practical and efficient approach may be feasible to implement in a busy dental practice. It is certainly important to be sensitive and avoid stigmatizing language when dealing with older patients who may have inadequate health literacy. Office staff may begin the screening of patients in the waiting area by asking the single question "How confident are you filling out medical/dental forms by yourself?" Staff can then document in the chart those with suspected inadequate health literacy. Thereafter, the dental professional could ask the patients for permission to include available caregivers during the encounter. Caregiver participation may occur on-site or by telephone or secure video conferencing. Keeping handy in the dental office age-appropriate written educational materials that include pictograms allows for further reinforcement of dental information. When discussing proposed diagnostic and therapeutic interventions, decisional aids that may include graphics may assist during shared decision-making

After a week, the patient returns to the dental clinic for her endodontic follow-up visit. The outcome was successful after the procedure with resolution of Mrs. Williams' severe oral discomfort. The patient was advised to receive a full coverage restoration when she returns for her 1-month follow-up visit. A follow-up radiograph after 4 months revealed no periapical changes, and Mrs. Williams is asymptomatic.

8 Future Research

There are multiple gaps in the study of oral health literacy in older adults. However, three priority areas deserve special attention: assessment, impact on dental practice access and satisfaction; and interventions. Regarding the assessment of oral health literacy, this chapter reviewed existing instruments meeting most validity and reliability criteria. However, these instruments may not be feasible in busy dental practices. The obvious advantage of the single question screener for health literacy is its rapid administration. Although validated with medical patients, it has yet to be evaluated with older adult populations in dental settings. Future studies may address the correlation of the single question with existing oral health literacy instruments. The growing diversity of the older population will also demand that investigators develop and validate culturally sensitive tools to measure oral health literacy in the persons' native language. A related research area is the evaluation of the impact that inadequate health literacy has on access to dental care services. Practicing dentists are already dealing with older adults suffering from more oral diseases and associated multimorbidity, cognitive impairment, and disability which may prolong the duration of dental encounters [91]. Inadequate health literacy may pose an additional barrier to the care of older adults. An important area of investigation will be the study of dental providers' attitudes toward older adults with inadequate health literacy. On the patient side, there are other important research gaps. More studies are needed about the experiences of older persons with inadequate health literacy and how that dynamic affects access to dental services and the shared decision-making process. We discussed several different strategies to overcome the challenges of health literacy for older persons. Unfortunately, most of the interventions are based on expert opinion lacking a solid grounding on research evidence. Health literacy is a multidimensional construct and is unlikely that single interventions will suffice. Evaluating multicomponent strategies consisting of combinations of individual approaches may represent a more efficacious and cost-effective approach to deal with the burdens associated with inadequate health literacy in older adults.

9 Conclusions

Inadequate oral health literacy is prevalent in older adults and is associated with dental complications and increased utilization. There are validated instruments that can assist dentists is the assessment of their older patients' levels of health literacy.

A single question screener may be a quick approach to identifying older patients with inadequate health literacy. Adequate levels of health literacy are a prerequisite for active participation in the decision-making process. There are many options that may facilitate the shared decision-making process in patients with inadequate levels of health literacy. An overall commitment to universal precautions, use of the teach-back technique, age-friendly materials, pictograms, and decision aids may mitigate the problems associated with inadequate health literacy. Involving caregivers to help patient during dental encounters may serve to further assist patients during the process. More research is needed into the assessment of oral health literacy, its impact on dental practice access and patient satisfaction, and in the design of multicompetent interventions targeting this important problem.

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Barriers to Access to Dental Care

Janet Yellowitz

1 Introduction

As a group, older adults are at increased risk for oral diseases and many are not regular users of professional dental services. While oral health is essential to one's general health and well-being, it is often neglected, increasing one's risk of a wide range of diseases. Maintaining one's dentition into later years increases ones' risk of having oral disease. Even without any natural teeth, older adults remain at increased risk for oral cancer. Quality of life can be influenced by a functional and esthetic mouth free of discomfort. Older adults with a healthy mouth are reported to have better general health, treatment outcomes, nutritional status, and quality of life [1].

Although the majority of oral diseases can be prevented or treated, older adults suffer disproportionately from oral and dental diseases and often have limited access to oral health care. Many older adults are unwilling or unable to receive routine care, which is complicated by having poor access to care. A combination of these factors can result in a high prevalence of oral health problems in older adults which increases their risk for general and oral complications. While the population of older adults is diverse and heterogeneous, many experience extensive oral disease, due to the cumulative effect of oral disease(s) throughout their lifetime. This unfortunate situation becomes more complicated when faced with multiple barriers to care.

It is not one's age that determines use of dental services, but rather utilization of care is the result of social, behavioral, health, and economic factors. Many older adults experience limited access to oral health due to a wide range of barriers, the topic of this chapter. Individually, these factors can become unique barriers to accessing care for older adults. Barriers to professional oral health care include but

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are not limited to no perceived need, place of residence, dentition status, economic factors, education level, lack of knowledge, fear, health literacy, social isolation, professional attitudes, lack of effective oral health policies, insurance, transportation, availability, accessibility, and characteristics of dental providers. Each of these variables can impact older adults' use of dental services. Some of these factors serve as barriers while other can enable access to care. Generally, it is not a single deterrent but rather a combination of barriers that affect the receipt of care. Addressing these barriers is critical if we are to improve older adults' health and their access to and use of oral health-care services in the future.

This chapter will address key barriers that impact dental care utilization by community-dwelling older adults. Each barrier can play a role in older adults' use of dental services, and when multiple barriers are present, attempting to address them can become unsurmountable to older adults. Understanding barriers to care can help dental and dental public health communities be better prepared to address the many confounding factors impeding the use of dental services by older adults.

2 Age-Related Changes, the Presence of Pain, and Self-Perceived Needs

Many older adults do not seek professional dental care primarily because they believe that they do not have any treatment needs, and this is primarily related to them having no dental pain. Older adults with natural teeth often do not experience pain or have a reduced pain sensation in their teeth as a result of age-related physiologic changes, especially to the dental pulp. With advancing years, the pulp tissue in the teeth of older adults is often reduced or obliterated. Associated with the reduction of pulp tissue is a decreased sensitivity of the pulp to disease. This physiologic change occurs in response to the development of reparative dentin, which reduces the size, volume, and contents of the pulp. This change typically occurs following years of occlusal forces, restorations, and trauma. The decreased pulpal sensitivity occurs even in the presence of extensive dental caries and/or periodontal disease and serves as a key barrier to the dental care for older adults, especially for those who only seek care when dental pain is present. While this information is not new to dental professionals, much of the public is unaware of these changes. Dental professionals need to inform patients of all ages of the impending changes that can occur as they age and the impact of aging on their oral cavity. Having a well-informed populace will assist older adults to be better informed when making decisions about determining their need for professional dental services.

Seeking routine preventive oral care on a regular basis decreases one's risk for disease by instituting early preventive and/or treatment strategies. Rather than waiting for pain to present, older adults can reduce the risk of severe, debilitating disease from occurring by seeking preventive dental care. Unfortunately, some older adults

will not seek out care even when they are having pain or discomfort, while some mistakenly believe that they will have no dental needs when they are older. In a 2017 study, over 50% of respondents had not attended a dentist in over 36 months, for the reasons that "I have no problem or need for treatment" (62%) and "I have no teeth, and therefore I have no need to go" (54%) [2].

Older adults' attitudes related to their need for care are often related to negative childhood experiences and long-standing family beliefs. While dental professionals recommend routine preventive care, some older adults believe the message to be self-serving and choose to wait for pain to occur before seeking treatment. Some older adults choose to live with dental discomfort rather than to seek care, attributing their pain and discomfort to an inevitability of dental decline with age or simply as a problem of aging, not preventable disease. Individuals seeking care typically do so with the belief that their situation will get worse without professional help.

3 The Presence and Absence of Natural Teeth

For many older adults, having natural teeth is strongly associated with having professional dental services, while having no natural teeth (edentulous) is associated with infrequent dental care. Older adults often identify dental professionals to be solely focused on caring for problems associated with their teeth, and many seem to live with the assumption that having no natural teeth means they have no need to see a dentist.

Decades ago, following the delivery of a complete set of dentures, dentists told patients that they did not have to return unless they had a problem. With advances in science, the message to new denture wearers changed to telling them they needed to return for routine checkups. Some denture patients are informed that being edentulous does not reduce their risk for oral cancer and soft tissue pathology and that they could benefit from a routine evaluation, with possible modification of their dental prosthesis. However, most new denture wearers do not return for a preventive examination until posed with a dental problem. A 2017 report of the Medical Expenditure Panel Survey found that only 16% of edentulous adults 50 years and older self-reported a dental visit during the previous 12 months, compared to 52% of those with natural teeth [3].

4 Dental Fear and Communication Between Older Adults and Providers

Communication between dentists and patients is a critical aspect of providing optimum care. Yet physical, psychological, and literacy issues of both patients and professionals can present as barriers to effective communication. For successful

implementation of oral health-care services for older adults, there is a need to understand and respond to their oral health beliefs, perceived needs, and preferred type of care services, all of which are shaped by their cultural beliefs and values. This poses challenges to oral health-care providers, especially when serving a diverse older adult population with people coming from different cultural backgrounds.

Older adults who report fear as a major barrier for seeking dental care are more likely to seek care for pain than for preventive services. Dental fear originates from multiple sources including but not limited to their oral health knowledge, previous unpleasant or painful dental experience, being unfamiliar with dental disease, pain, dental procedures, dental professionals, as well as the cost of care. A fear of dentistry may occur as the result of a dental professional not clearly explaining treatment recommendations, causing discomfort, or not ensuring the patient comprehends the treatment plan. Having appropriate information about treatment options, consequences, and costs of care helps older adults make informed decisions and to address their comfort with receiving care. Both dental professionals and older adults need to address the patients' fears and concerns associated with dental care. By addressing older adults' fears of dental care, dental professionals can help to ensure older adults are able to maintain good oral health and be sufficiently comfortable in a dental office.

While dental professionals' knowledge, attitudes, and comfort can influence older adults' use of dental services, it is important to address the patient's concerns about the extent and purpose of proposed treatments. Most dental professionals recommend a minimum of semiannual preventive care visits and may explain the specific purpose of the next dental visits. In addition, dental professionals need to explain to patients their risk for oral disease as well as to explain the need for professional oral health care is lifelong. Older adults benefit from a clear understanding of the many consequences of oral disease and their role in disease management. Were the public better informed of this message, they may be able to address some of their dental fears and hesitancies about dental care.

5 Oral Health-Care Professional Perspectives

Dental professionals can be both enablers and barriers to access to oral health care for older adults. Barriers to health care include the attitudes of providers as well as being the result of experiences providing care to older adults. Oral health-care providers have reported the challenges of delivering care to older adults to include inadequate training, lack of experience, and the need for additional time and loss revenue to treat older adults in private practice. Although not unique to caring for older adults, a dental professional with a friendly, polite, respectful, and friendly demeanor is valued and endears patients, which can help them to overcome their fears so to return to the provider. Recognizing individual's fears and concerns, taking time to talk with patients, and providing a relaxed environment can help to reduce patient hesitancy.

6 Cost of Care and Dental Insurance

All health care, including oral health care is costly, especially for those on a fixed income. The cost of dental care is a major barrier to dental care for older adults and is further complicated by the limited availability of cost-effective dental insurance for older adults. Choosing to spend money on health care when on a fixed income can impact all parts of one's life – as decisions to spend money involve the consideration of many factors including need, risk, benefit, and time justification.

While adults 65 years and older are the least likely cohort to be covered by private dental insurance, those with dental insurance are 2.5 times more likely to make a regular dental visit compared to those without insurance [4]. Similarly, having supplemental medical insurance increases an older adult's chance of using dental services, possibly because the person can divert some of the savings from their medical care to their out-of-pocket dental expenses [5]. In the United States, adults without health-care insurance, without a personal health-care provider, who had delayed medical care because of cost, and who had their last medical visit longer than 12 months ago had greater odds of not having a dental visit within the last 12 months [6]. While some dental professionals choose to offer reduced fees or payment plans to older adults for their care, this is not a universal practice and has an undetermined impact on the decision to obtain care. For older adults on a fixed income as well as those without dental insurance, choosing to obtain routine preventive dental care can be cost prohibited.

Not having private or public dental insurance can seriously impact the use of dental services. While dental insurance can be purchased while employed, it is only available to retired adults as a postretirement dental benefit, spousal coverage, or through certain Medicare Advantage plans in the United States. In general, most dental insurance plans directed to older adults contain limited benefits. An additional barrier to care for older adults with dental insurance is their limited awareness or ability to understand the insurance benefits. Without a clear understanding of their insurance benefits, many choose not to seek out dental care. In the United States, many aging adults delay routine and needed dental care because they think there is a dental benefit in the Medicare program. In a recent study of older adults' knowledge, only 34% of respondents knew that dental care is not included in Medicare [7]. A similar lack of knowledge or being unaware they are eligible for dental benefits occurs in older adults covered by the Medical Assistance or Medicaid program.

7 Geographic Residence

The location of older adults' residence is associated with their oral health status and dental service utilization, with many older adults geographically isolated from healthcare services. The location of older adult's residence becomes an important barrier to

consider given that the proportion of older adults is higher in rural than urban areas and their numbers are expected to increase in the next decade [8]. Studies in several countries have documented that residence in rural areas is associated with more unmet dental needs and lower dental utilization rates than for those living in urban areas [9, 10].

In general, older adults living in rural areas are similar to those who self-report dental fear, that is, they are less likely to visit a dentist in the past year compared to those with a higher education and those who have seen the dentist in their past [11]. Older adults in rural areas are also more likely to report a functional problem and to rate their health as poor [8]. Similarly, rural older adults with lower financial resources are more likely to delay seeking care.

8 Transportation

Access to available transportation is a barrier to health care for many older adults. Transportation is a basic but a necessary step for ongoing health-care and medication access. Without transportation, delays in treatment occur, the use of home remedies increases, and disease exacerbations accumulate and worsen health outcomes [12]. In some communities, low-cost transportation services are available to those who meet eligibility criteria, such as those who have a disability that limits mobility, which can present as an important barrier for those with lower incomes or who do not meet the specific criteria [13]. In some communities, older adults have access to reduced fees for transportation. Poorer populations face more barriers to health-care access in general, and transportation barriers are no exception. Older adults with a lower socioeconomic status (SES) have greater challenges with transportation to health care than those with a higher SES.

Urban and rural locations often differ in transportation options, cost of transportation, and availability of and distance to health-care providers. People living in rural areas report more problems with transportation and travel distance to health-care providers and have a higher burden of travel for health care when measured by distance and time traveled. In general, older adults living in rural areas and those who self-report dental fear were less likely to visit a dentist in the past year compared to those with a secondary or higher education and those with filled tooth surfaces who tend to see the dentist more often [11].

9 Conclusions

Reducing barriers to dental care for older adults will improve access to oral health care. Helping older adults' access oral health services can ultimately improve their oral health status which will improve their general health. With the use of preventive dental visits, oral diseases can be addressed as well as the oral manifestations of systemic disease [6].

Older adults suffer disproportionately from oral disease and limited access to oral health care. Many older adults are either unwilling or unable to receive routine care, putting them at greater risk for general and oral complications. Some present with extensive oral disease, the cumulative effects of disease throughout their lifetime, an even more complicated situation when older adults who are frail, homebound, or in long-term care institutions. To optimally care for this aging cohort, oral health professionals need to be knowledgeable about age-related changes and the many health and cognitive conditions commonly found in older adults. For many providers, additional didactic and clinical training in delivering oral health care to older adults is needed.

While many barriers to good dental health of older adults include systemic health conditions, chronic diseases, limited resources, health literacy, and limitations in activities of daily living, more research is needed to know if alternative models of care, such as mobile dental vans or the presence of more dental professionals, would be successful.

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