Oral Health and Aging

Christie-Michele Hogue
Jorge G. Ruiz
Editors

Springer

Oral Health and Aging

Christie-Michele Hogue • Jorge G. Ruiz
Editors

Oral Health and Aging

Springer

Editors
Christie-Michele Hogue
Department of Dental Services - VA Healthcare System, Division of Geriatrics and Gerontology, Emory University School of Medicine
Atlanta, GA, USA

Jorge G. Ruiz
Geriatric Research, Education and Clinical Center (GRECC)
Miami VA Healthcare System
Miami, FL, USA

Division of Geriatrics and Palliative Care
University of Miami Miller School of Medicine
Miami, FL, USA

ISBN 978-3-030-85992-3 ISBN 978-3-030-85993-0 (eBook)
https://doi.org/10.1007/978-3-030-85993-0

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Contributors

Rebecca H. Affoo, PhD, CCC-SLP, SLP-Reg, SLP(C) School of Communication Sciences and Disorders, Faculty of Health, Dalhousie University, Halifax, NS, Canada

Joyce A. Barbour, DDS, MBA Meharry Medical College, Nashville, TN, USA

Elisabeth Casañas, DDS, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Akhilanand Chaurasia, MDS Department of Oral Medicine and Radiology, Faculty of Dental Sciences, King George's Medical University, Lucknow, UP, India

Cristiane DaMata, BDS, MFD RCSI, MPH, PhD Cork University Dental School and Hospital, University College Cork, Cork, Ireland

Lorenzo de Arriba, DDS, MD, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Ronald L. Ettinger, BDS, MDS, DDSc, DDSc(hc) Department of Prosthodontics, College of Dentistry, University of Iowa, Iowa City, IA, USA

Cherae M. Farmer-Dixon, DDS, MSPH, MBA Meharry Medical College, Nashville, TN, USA

Marlena Fernandez, MD Miami VA Healthcare System, Geriatric Research, Education and Clinical Center (GRECC), Miami, FL, USA

José González-Serrano, DDS, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Shauna Hachey, MHS, RDH School of Dental Hygiene, Faculty of Dentistry, Dalhousie University, Halifax, NS, Canada

Iriana Hammel, MD Miami VA Healthcare System, Geriatric Research, Education and Clinical Center, Miami, FL, USA

Division of Geriatrics and Palliative Medicine, University of Miami Miller School of Medicine, Miami, FL, USA

Valerie Hart, MD University of Miami/Jackson Health System, Miami, FL, USA

Martina Hayes, BDS, MFDS RCSEd, PgDipTLHE, PhD Cork University Dental School and Hospital, University College Cork, Cork, Ireland

Gonzalo Hernández, DDS, MD, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Christie-Michele Hogue, DDS, AGSF Department of Dental Services - VA Healthcare System, Division of Geriatrics and Gerontology, Emory University School of Medicine, Atlanta, GA, USA

Samantha Honeywell, MS, RD, CNSC Department of Clinical and Preventive Nutrition Sciences, School of Health Professions, Rutgers, The State University of New Jersey, Newark, NJ, USA

Ezekiel Ijaopo, MD, MPH, MRCP-UK, DGM, MSc Combined Geriatric Medicine/Hospice and Palliative Medicine Fellow, University of Miami/Jackson Health System, Miami, FL, USA

Atsuko Kurosu, PhD Department of Medicine, School of Medicine and Public Health, University of Wisconsin–Madison, Madison, WI, USA

Ira Lamster, DDS MMSc School of Dental Medicine, Stony Brook University, Stony Brook, NY, USA

Nadia Laniado, DDS MPH MSc Department of Dentistry, Albert Einstein College of Medicine, Bronx, NY, USA

Liran Levin, DMD Faculty of Medicine and Dentistry, University of Alberta, Edmonton, AB, Canada

Rosa María López-Pintor, DDS, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Leonardo Marchini, DDS, MSD, PhD Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, Iowa City, IA, USA

Lucía Ramírez Martínez-Acitores, DDS Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Gerry McKenna, BDS,PhD,FDS(Rest Dent)RSCEd,FHEA Centre for Public Health, Queen's University Belfast, Belfast, Northern Ireland, UK

Natasha Resendes, MD Miami VA Healthcare System, Geriatric Research, Education and Clinical Center (GRECC), Miami, FL, USA

Department of Medical Education, University of Miami Miller School of Medicine, Miami, FL, USA

Nicole Rogus-Pulia, PhD, CCC-SLP Division of Geriatrics and Gerontology, Department of Medicine, School of Medicine and Public Health, University of Wisconsin–Madison, Madison, WI, USA

Swallowing and Salivary Bioscience Laboratory, Geriatric Research Education and Clinical Center (GRECC), William S. Middleton Memorial Veterans Hospital, Madison, WI, USA

Jorge G. Ruiz, MD Miami VA Healthcare System, Geriatric Research, Education and Clinical Center (GRECC), Miami, FL, USA

Division of Geriatrics and Palliative Medicine, University of Miami Miller School of Medicine, Miami, FL, USA

Carlos S. Smith, DDS, MDiv, FACD Department of Dental Public Health and Policy, VCU School of Dentistry, Richmond, VA, USA

Moira B. Smith, BDS, PhD, PGDipSci DPH Department of Public Health, University of Otago, Wellington, New Zealand

Machelle Fleming Thompson, RDH, BS, MSPH Meharry Medical College, Nashville, TN, USA

W. Murray Thomson, PhD Sir John Walsh Research Institute, Faculty of Dentistry, The University of Otago, Dunedin, New Zealand

Jaisri R. Thoppay, DDS, MBA, MS Center for Integrative Oral Health, Winter Park, FL, USA

Dominique Tosi, MD Miami VA Healthcare System, Geriatric Research, Education and Clinical Center (GRECC), Miami, FL, USA

Department of Medical Education, University of Miami Miller School of Medicine, Miami, FL, USA

Riva Touger-Decker, PhD, RD,CDN, FADA Rutgers School of Dental Medicine, Newark, NJ, USA

Julia Serrano Valle, DDS, PhD Department of Dental Clinical Specialties, School of Dentistry, Complutense University, Madrid, Spain

Janet Yellowitz, DMD, MPH, FASGD, DABSCD University of Maryland School of Dentistry, Baltimore, MD, USA

Khin Zaw, MD Palliative Medicine Program, Miami VA Healthcare System, Miami, FL, USA

Division of Geriatrics and Palliative Medicine, University of Miami Miller School of Medicine, Miami, FL, USA

Rena Zelig, DCN, RDN, CDCES, CSG Department of Clinical and Preventive Nutrition Sciences, School of Health Professions, Rutgers, The State University of New Jersey, Newark, NJ, USA

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.

E. Ijaopo
Combined Geriatric Medicine/Hospice and Palliative Medicine Fellow, University of Miami/Jackson Health System, Miami, FL, USA

C.-M. Hogue (✉)
Department of Dental Services - VA Healthcare System, Division of Geriatrics and Gerontology, Emory University School of Medicine, Atlanta, GA, USA
e-mail: christie.michele.hogue@emory.edu

C.-M. Hogue, J. G. Ruiz (eds.), *Oral Health and Aging*,
https://doi.org/10.1007/978-3-030-85993-0_1

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.

References

1. Khare A, Thahriani A, Chauhan AS, Khare A. Age changes in oral tissues. Heal Talk. July–August 2015, 2015 ed. p. 41–50.
2. Akimoto K. Observations on the structural changes according to aging of oral mucous membrane in the elderly--structure of buccal mucous membrane in the vicinity of angulus oris. Kokubyo Gakkai zasshi. J Stomatol Soc Jpn. 2004;71(2):80–94.

3. Breustedt A. Age-induced changes in the oral mucosa and their therapeutic consequences. Int Dent J. 1983;33(3):272–80.
4. Lamster IB, Asadourian L, Del Carmen T, Friedman PK. The aging mouth: differentiating normal aging from disease. Periodontology 2000. 2016;72(1):96–107.
5. Sulyanto R. Effects of aging on the mouth and teeth: MERCK MANUAL consumer version; 2020 [updated Feb. 2020; cited 2021]. Available from: https://www.merckmanuals.com/home/mouth-and-dental-disorders/biology-of-the-mouth-and-teeth/effects-of-aging-on-the-mouth-and-teeth.
6. Murray PE, Stanley HR, Matthews JB, Sloan AJ, Smith AJ. Age-related odontometric changes of human teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002;93(4):474–82.
7. Huttner EA, Machado DC, De Oliveira RB, Antunes AGF, Hebling E. Effects of human aging on periodontal tissues. Spec Care Dentist. 2009;29(4):149–55.
8. Krieger E, Hornikel S, Wehrbein H. Age-related changes of fibroblast density in the human periodontal ligament. Head Face Med. 2013;9(1):1–4.
9. Lim WH, Liu B, Mah SJ, Chen S, Helms JA. The molecular and cellular effects of ageing on the periodontal ligament. J Clin Periodontol. 2014;41(10):935–42.
10. Arai K, Tanaka S, Yamamoto-Sawamura T, Sone K, Miyaishi O, Sumi Y. Aging changes in the periodontal bone of F344/N rat. Arch Gerontol Geriatr. 2005;40(3):225–9.
11. Razak PA, Richard KJ, Thankachan RP, Hafiz KA, Kumar KN, Sameer K. Geriatric oral health: a review article. J Int Oral Health: JIOH. 2014;6(6):110.
12. Xu F, Laguna L, Sarkar A. Aging-related changes in quantity and quality of saliva: where do we stand in our understanding? J Texture Stud. 2019;50(1):27–35.
13. Vissink A, Spijkervet FKL, Amerongen AVN. Aging and saliva: a review of the literature. Spec Care Dentist. 1996;16(3):95–103.
14. Nakayama M. Histological study on aging changes in the human tongue. Nippon Jibiinkoka Gakkai Kaiho. 1991;94(4):541–55.
15. Sasaki M. Histomorphometric analysis of age-related changes in epithelial thickness and Langerhans cell density of the human tongue. Tohoku J Exp Med. 1994;173(3):321–36.
16. Watanabe Y, Hirano H, Arai H, Morishita S, Ohara Y, Edahiro A, et al. Relationship between frailty and oral function in community-dwelling elderly adults. J Am Geriatr Soc. 2017;65(1):66–76.
17. Yamaguchi K, Hara K, Nakagawa K, Namiki C, Ariya C, Yoshimi K, et al. Association of aging and tooth loss with masseter muscle characteristics: an ultrasonographic study. Clin Oral Investig. 2020:1–8.
18. Koshino H, Hirai T, Ishijima T, Ikeda Y. Tongue motor skills and masticatory performance in adult dentates, elderly dentates, and complete denture wearers. J Prosthet Dent. 1997;77(2):147–52.
19. Fucile S, Wright PM, Chan I, Yee S, Langlais M-E, Gisel EG. Functional oral-motor skills: do they change with age? Dysphagia. 1998;13(4):195–201.
20. Hiramatsu T, Kataoka H, Osaki M, Hagino H. Effect of aging on oral and swallowing function after meal consumption. Clin Interv Aging. 2015;10:229.
21. Crow HC, Ship JA. Tongue strength and endurance in different aged individuals. J Gerontol Ser A Biol Med Sci. 1996;51(5):M247–M50.
22. Park J-S, Oh D-H, Chang M. Comparison of maximal tongue strength and tongue strength used during swallowing in relation to age in healthy adults. J Phys Ther Sci. 2016;28(2):442–5.
23. Iyota K, Mizutani S, Oku S, Asao M, Futatsuki T, Inoue R, et al. A cross-sectional study of age-related changes in oral function in healthy Japanese individuals. Int J Environ Res Public Health. 2020;17(4):1376.
24. Jungheim M, Schwemmle C, Miller S, Kühn D, Ptok M. Swallowing and dysphagia in the elderly. HNO. 2014;62(9):644–51.
25. Hill MW. The influence of aging on skin and oral mucosa 1. Gerodontology. 1984;3(1):35–45.
26. Bishara SE, Jakobsen JR, Treder JE, Stasl MJ. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood: a longitudinal study. Am J Orthod Dentofac Orthop. 1989;95(1):46–59.

27. Emami E, de Souza RF, Kabawat M, Feine JS. The impact of edentulism on oral and general health. Int J Dent. 2013;2013:498305.
28. Griffin SO, Jones JA, Brunson D, Griffin PM, Bailey WD. Burden of oral disease among older adults and implications for public health priorities. Am J Public Health. 2012;102(3):411–8.
29. Tiwari T, Scarbro S, Bryant LL, Puma J. Factors associated with tooth loss in older adults in rural Colorado. J Community Health. 2016;41(3):476–81.
30. Dye BA, Weatherspoon DJ, Mitnik GL. Tooth loss among older adults according to poverty status in the United States from 1999 through 2004 and 2009 through 2014. J Am Dent Assoc. 2019;150(1):9–23.e3.
31. Gaio EJ, Haas AN, Carrard VC, Oppermann RV, Albandar J, Susin C. Oral health status in elders from South Brazil: a population-based study. Gerodontology. 2012;29(3):214–23.
32. Moon J-H, Heo S-J, Jung J-H. Factors influencing self-rated oral health in elderly people residing in the community: results from the Korea community health survey, 2016. Osong Public Health Res Perspect. 2020;11(4):245.
33. Nagler RM, Hershkovich O. Age-related changes in unstimulated salivary function and composition and its relations to medications and oral sensorial complaints. Aging Clin Exp Res. 2005;17(5):358–66.
34. Kikutani T, Tamura F, Nishiwaki K, Kodama M, Suda M, Fukui T, et al. Oral motor function and masticatory performance in the community-dwelling elderly. Odontology. 2009;97(1):38–42.
35. Cullins MJ, Connor NP. Alterations of intrinsic tongue muscle properties with aging. Muscle Nerve. 2017;56(6):E119–E25.
36. Yamada A, Kanazawa M, Komagamine Y, Minakuchi S. Association between tongue and lip functions and masticatory performance in young dentate adults. J Oral Rehabil. 2015;42(11):833–9.
37. Kilian M, Chapple I, Hannig M, Marsh P, Meuric V, Pedersen A, et al. The oral microbiome–an update for oral healthcare professionals. Br Dent J. 2016;221(10):657–66.
38. Deo PN, Deshmukh R. Oral microbiome: unveiling the fundamentals. J Oral Maxillofac Pathol: JOMFP. 2019;23(1):122.
39. Zapata HJ, Quagliarello VJ. The microbiota and microbiome in aging: potential implications in health and age-related diseases. J Am Geriatr Soc. 2015;63(4):776–81.
40. Belibasakis GN. Microbiological changes of the ageing oral cavity. Arch Oral Biol. 2018;96:230–2.
41. Iwauchi M, Horigome A, Ishikawa K, Mikuni A, Nakano M, Xiao JZ, et al. Relationship between oral and gut microbiota in elderly people. Immun Inflammation Dis. 2019;7(3):229–36.
42. Odamaki T, Kato K, Sugahara H, Hashikura N, Takahashi S, Xiao J-Z, et al. Age-related changes in gut microbiota composition from newborn to centenarian: a cross-sectional study. BMC Microbiol. 2016;16(1):1–12.
43. Conlon MA, Bird AR. The impact of diet and lifestyle on gut microbiota and human health. Nutrients. 2015;7(1):17–44.
44. Cullen CM, Aneja KK, Beyhan S, Cho CE, Woloszynek S, Convertino M, et al. Emerging priorities for microbiome research. Front Microbiol. 2020;11:136.
45. Imhann F, Vich Vila A, Bonder MJ, Lopez Manosalva AG, Koonen DP, Fu J, et al. The influence of proton pump inhibitors and other commonly used medication on the gut microbiota. Gut Microbes. 2017;8(4):351–8.
46. Jackson MA, Goodrich JK, Maxan M-E, Freedberg DE, Abrams JA, Poole AC, et al. Proton pump inhibitors alter the composition of the gut microbiota. Gut. 2016;65(5):749–56.
47. Lee IC, Yang YH, Ho PS, Lee IC. Chewing ability, nutritional status and quality of life. J Oral Rehabil. 2014;41(2):79–86.
48. Motokawa K, Mikami Y, Shirobe M, Edahiro A, Ohara Y, Iwasaki M, et al. Relationship between chewing ability and nutritional status in Japanese older adults: a cross-sectional Study. Int J Environ Res Public Health. 2021;18(3):1216.
49. Samnieng P, Ueno M, Shinada K, Zaitsu T, Wright FAC, Kawaguchi Y. Oral health status and chewing ability is related to mini-nutritional assessment results in an older adult population in Thailand. J Nutr Gerontol Geriatr. 2011;30(3):291–304.

50. Tada A, Miura H. Association of mastication and factors affecting masticatory function with obesity in adults: a systematic review. BMC Oral Health. 2018;18(1):1–8.
51. Brennan DS, Spencer AJ, Roberts-Thomson KF. Tooth loss, chewing ability and quality of life. Qual Life Res. 2008;17(2):227–35.
52. Ohara Y, Hirano H, Watanabe Y, Edahiro A, Sato E, Shinkai S, et al. Masseter muscle tension and chewing ability in older persons. Geriatr Gerontol Int. 2013;13(2):372–7.
53. Mayil M, Keser G, Demir A, Pekiner FN. Assessment of masseter muscle appearance and thickness in edentulous and dentate patients by ultrasonography. Open Dent J. 2018;12:723.
54. Kossioni AE. The association of poor oral health parameters with malnutrition in older adults: a review considering the potential implications for cognitive impairment. Nutrients. 2018;10(11):1709.
55. Sahyoun NR, Lin C-L, Krall E. Nutritional status of the older adult is associated with dentition status. J Am Diet Assoc. 2003;103(1):61–6.
56. Sheiham A, Steele J. Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people? Public Health Nutr. 2001;4(3):797–803.
57. Ijaopo E, Ijaopo R. A review of oral health in older adults: key to improving nutrition and quality of life. OBM Geriatr. 2018;2:1.