Dysphagia and Masticatory Performance as a Mediator of the Xerostomia to Quality of Life Relation in the Older Population: A Structural Equation Model Approach

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Abstract

Background: The adverse impact of poor oral conditions in older adults on their quality of life is a public health problem. This study assessed the mediating effects of dental status, occlusal condition, dysphagia and masticatory performance on the association between xerostomia and oral health-related quality of life (OHRQoL) in the older population.

Methods: A total of 1100 representative community-dwelling adults aged 65 years and older were recruited from a large-scale survey conducted in Kaohsiung, Taiwan. Dental status and occlusal condition were performed by dentists. Information on demographics, physical function, xerostomia, and dysphagia was collected using face-to-face interview. Masticatory performance was evaluated using color-changeable chewing gum. OHRQoL was measured using Geriatric Oral Health Assessment Index.

Results: Comparing with non-xerostomia, participants with xerostomia had a 0.20 decrease in the level of OHRQoL ($p< .001$), and the direct effect was accounted for 83.3% of the total effect. The dysphagia and the masticatory performance were found to have a significant mediating effect on the association between xerostomia and OHRQoL (βs = 0.20 and −0.13, respectively; βs = 0.05 and −0.08, respectively) and 10.8% of the effect was attributed to dysphagia mediation. Furthermore, the functional teeth and occlusal condition had a significant mediating effect on the association between xerostomia and masticatory performance , and the functional teeth was accounted for 43.6% of the effect.

Conclusions: Xerostomia had the greatest effect on OHRQoL. The mediating role of dysphagia and masticatory performance on the association between xerostomia and OHRQoL was significant and deserves further attention. Older adults could improve their OHRQoL through a community-based oral function intervention. Our results further suggest that early screening for swallowing and masticatory function is essential to prevent or delay the onset of complications.

Background

Xerostomia is defined as subjective dryness of mouth, which can be a normal part of aging. Data regarding dry mouth from the last two decades have demonstrated an estimated prevalence ranging from 1% to 62% (1), with a higher prevalence among older people. When saliva flow is reduced, oral health problems such as dental caries and infections can develop (2). Evidence has indicated that xerostomia influences the occurrence of caries and consequently results in the loss of dentition (3). Xerostomia may also affect speech, chewing, swallowing, denture wearing, and oral health-related quality of life (OHRQoL) (4) , and may further result in decreased performance of activities of daily living (5).

Dysphagia is another common condition among older adults and can be exacerbated by the amount of saliva produced. A normal swallow entails oral, pharyngeal, and esophageal phases. In the oral phase, food is chewed with the teeth and is reduced to a smaller size bolus, which can easily pass to the oropharynx (upper part of the throat) and is prepared for swallowing (6). Mixing food to form a bolus during chewing requires saliva. Therefore, the saliva flow rate has a crucial effect on the oral phase in the swallowing process. Individuals with a high saliva flow rate require shorter swallowing intervals, which can prevent swallowing complications (7). Overall, the dry mouth sensation is perceived as a serious oral health complaint and has numerous effects on oral health, which may in turn have a negative effect on quality of life.

Compared with the number of studies on the effects of oral health and oral health-related quality of life (8), few studies have investigated the relationship between xerostomia and OHRQoL (9, 10). Understanding mediators can increase efficacy of intervention by emphasizing the key elements and reducing costs by removing unnecessary elements. Studies have identified relationships between dental status, oral function, and OHRQoL using multiple regression analysis (11, 12). However, structural equation model (SEM) is a stronger analytical method that can express direct and indirect effects separately and reflect complex relations visually by using a path diagram. Relationships between multiple independent variables and the outcomes can be analyzed simultaneously to determine whether a prespecified theoretical model is supported by empirical data (13). The present study used SEM to examine the pathway from xerostomia to OHRQoL with repect to some mediators in a comprehensive model in older people. We hypothesized that xerostomia is related to OHRQoL through the mediators of dental status, dysphagia, and masticatory performance.

Methods

A large-scale cross-sectional study was conducted involving community-dwelling participants aged 65 years and over in Kaohsiung, Taiwan in 2018. Stratified cluster sampling was used; community care centers were randomly selected on the basis of stratification of three geographic areas in Kaohsiung (urban, rural, and mountainous areas).

Participants were excluded if they self-reported any of the following: (1) mental disorders, (2) expressive language disorders, (3) moderate or severe cognitive impairment, as determined by the short portable mental status questionnaire (14), or (4) high-to-total dependence with respect to performance of Activities of Daily Living (ADL) (15). The final analysis included 1,100 participants (response rate: 93.2%).

Based on the sample size criteria for SEM analysis, a large sample size was required because of the highly complex model with relatively many free parameters that we intended to use. The ideal sample size is generally considered to be 20 participants per free parameter (16). In this study, 220 was considered the minimum sample size because there were 11 free parameters to be estimated.

Instrument

A structured questionnaire was developed to collect data regarding demographics (i.e., age, gender, education level), oral function (i.e., xerostomia and dysphagia), physical function (i.e., frailty, sarcopenia), and OHRQoL. All items were reviewed by a panel of experts to assess content validity. The content validity index was 0.89-1.00. To ensure that the study participants understood the content, the questionnaires were pilot tested on 30 seniors. The reliability of each scale was assessed by examining internal consistency (Cronbach's α coefficient). Color-changeable chewing gum was used to assess masticatory performance (Xylitol, 3.0 g; Lotte, Saitama, Japan).

Dental Examination

Dental examinations were performed by seven dentists according to World Health Organization criteria. The kappa coefficient of tooth decay was 0.77 for interrater agreement. The Kendall's W coefficient for the plaque index was 0.87 for interrater agreement. The dental status and oral hygiene (i.e. plaque index and tongue coating) were recorded.

Oral Health-related Quality of Life

OHRQoL was measured using the Geriatric Oral Health Assessment Index (GOHAI), which is a 12-item instrument with three different domains: physical function (eating, speech, and swallowing), psychosocial function (worry or concern regarding oral health, dissatisfaction with appearance, self-consciousness regarding oral health, and avoidance of social interaction because of oral problems), and pain or discomfort (using medication to relieve pain or discomfort in the mouth). Each item was rated on a 5-point Likert scale ranging from, 1 (always) to 5 (never). The total score could range from 12 to 60 points, with a higher score indicating a more favorable OHRQoL. The Cronbach's alpha indicated an internal consistency of 0.75 for the scales.

Xerostomia

We used the shortened Xerostomia Inventory questionnaire to identify and classify dry mouth. Participants respond to five items: (1) My mouth feels dry when eating a meal, (2) My mouth feels dry, (3) I have difficulty eating dry foods, (4) I have difficulty swallowing certain foods, and (5) My lips feel dry. Each item was scored as 1 (never), 2 (occasionally), or 3 (often) (17). The sum score could range from 5 to 15 points, with a higher score reflecting a drier mouth feel. Participants with sums ≥10 points represented the top 50% of xerostomia sum scores (18). The Cronbach's alpha indicated an internal consistency of 0.88 for the scale.

Dysphagia

The dysphagia variable was measured using 15 question items in the Ohkuma questionnaire to quickly screen the community members; examples of questions include "Do you ever have difficulty when you swallow," "Do you ever have difficulty with coughing up phlegm during or after a meal," "Does it take you longer to eat a meal than before," "Do you feel that it is becoming difficult to eat solid foods," and "Do you ever have difficulty sleeping because of coughing during the night." (19). Responses could be "obviously" (numerous times), “slightly” (sometimes), or “no” (never). The seniors who had at least one severe symptom were classified as having dysphagia. The Cronbach’s alpha was 0.85, indicating satisfactory internal consistency.

Masticatory Performance

Masticatory performance was evaluated using color-changeable chewing gum. As chewing progresses, the gum changes to red because the yellow and blue dyes seep into saliva, and red appears because of citric acid elution (20). Participants were asked to chew for 2 minutes. The observer assessed the color of the gum subsequently, using a color chart with five color gradations ranging from 1 (very good) to 5 (very poor). The masticatory performance scoring was simplified into three categories, 1–3 = good, 4 = moderate, 5 = poor.

Occlusal Condition

Occlusal condition was measured using the Eichner index (21), which is used to measure posterior occlusal contacts of existing functional teeth in the premolar and molar regions—these are called supported zones. The posterior regions are divided into four supporting zones on both sides and are classified as Eichner’s A, B, or C category. Class A contacts 4 support regions; class B contacts 1-3 regions or the anterior region only; and class C does not have contact with any support region, although a few teeth may remain.

Dental Status

Variables related to dental status were the numbers of remaining natural teeth, functional teeth, fixed artificial teeth, and complete and removable partial dentures. The number of functional teeth was defined as the number of natural teeth, excluding teeth with grade Ⅲ mobility and residual roots and including fixed artificial teeth (i.e., abutment teeth, bridge, implant-supported prostheses).

Oral Hygiene Status

Plaque index recorded plaque scores for four surfaces (buccal, lingual, mesial, and distal) of tooth numbers 12, 16, 24, 32, 36, and 44; scores ranged from 0 to 3. Tongue coating was assessed using the Winkel tongue coating index (22). The tongue was divided into six areas (three posterior, three anterior), and coating was scored as 0 = no coating, 1 = light coating, and 2 = severe coating; scores could range from 0 to 12 points.

Covariates

Covariates examined in this study were age, gender, educational level, frailty and sarcopenia. Frailty was assessed using the Study of Osteoporotic Fractures index (23). Sarcopenia was assessed using the SARC-F self-administered questionnaire (24).

Data Collection

The data were collected by well-trained interviewers during face-to-face interviews, following a standard protocol. To prevent information bias from occurring during interviewing, each interviewer was asked to attend a 1-hour training course regarding the standard process and criteria of data collection. The data collection process included three stops. First, a dentist performed the dental examination and a dental hygienist recorded the dental status, plaque index score, and tongue coating score. Second, the structured questionnaire was administered by an interviewer in Mandarin or Taiwanese. The entire interview process took approximately 30–45 minutes. Finally, the research staff collected data regarding masticatory performance by asking participants to chew color-changeable chewing gum and data regarding physical function and frailty.

Statistical Analysis

Stata 13.1 (StataCorp LP, College Station, Texas, USA) was used for statistical analysis. Participants were divided into two groups by xerostomia status. The demographic characteristics, dental status, oral function, and physical function were compared between two groups using chi-square tests and two-sample t tests. A multiple linear regression model was adjusted using the hierarchical method to obtain a predictive model of OHRQoL. To adjust the final model, changes in the adjusted R^2 and F values were considered for each new independent variable added, and the variance inflation factor (VIF) was used to assess multicollinearity among all the independent variables. Path analysis was then used to test a model exploring the relationship between xerostomia, dental status, oral function, and OHRQoL and to identify both direct and indirect relationships in the model. Path analysis is a specific tool of SEM analysis that analyzes the assumed relations of the multivariate data simultaneously. SEM is one of the most favored statistical techniques in the social sciences and has become popular in dental science (25, 26). In the present study, the following criteria were used to define the goodness of model fit: χ^2/df <3.00, Root Mean Square Error of Approximation (RMSEA) <0.08, and Comparative Fit Index (CFI) ≥0.90. To obtain an acceptable model, initial fit, modification (using MI method in STATA), and rafting steps were performed (27). After estimating the full model, nonsignificant direct paths were removed to generate a statistically parsimonious model, which was re-estimated and compared with the full model using a chi-square test. Finally, all the steps were repeated until the model was a good fit. Significance was set at $p < 0.05$ for all statistical tests.

Results

Table 1 summarizes the characteristics of participants arranged by xerostomia status. In total, 19.5% were men, with a mean age of 77.4 ± 5.9 years, and 80.5% were women, with a mean age of 76.4 ± 6.7 years. Sigfinicantly higher percentage of participants in xerostomia group reported fewer than 20 natural teeth and functional teeth (59.4% and 54.%, respectively) compared to those in xerostomia-free group (39.9% and 35.2%, respectivley). Furthermore, sigifnicantly higher percentage of participant in xerostomia group was observed in class B and class C in the occlusal condition (44.5% and 30.5%, respectivley) compared to those in xerostomia-free group (37.5% and 19.2%, respectivley). Regarding oral function and physical function, the xerostomia group displayed poorer masticatory performance, more difficulty swallowing, and less strength than the xerostomia-free group. With regard to frailty, 39.1% and 6.3% of the older people with xerostomia had prefrailty and frailty respectively, compared with 17.0% and 1.4% in the xerostomia-free group ($p < .001$). The sum scores of GOHAI were 53.6 ± 6.4 in the xerostomia-free group and 47.4 ± 9.0 in the xerostomia group ($p < .001$).

Table 2 displays the results of the hierarchical linear regression analysis used to analyze the relationship of physical function, dental status, and oral function on the level of OHRQoL when adjusted for the other independent variables. No multicollinearity among all the independent variables were identified. Demographic factors, frailty, and sarcopenia were entered as a first step and explain 7.59% of the variance in OHRQoL as measured by the sum of GOHAI scores (Model 1, Table 3). The factors significantly associated with OHRQoL were frailty and sarcopenia for older people. The additional variables related to dental status (i.e., removable denture, functional teeth) were entered as the second step in Model 2. Variables significantly associated with OHRQoL were frailty, sarcopenia, and fewer than 20 functional teeth. Adding dental status-related variables in Model 2 explained 9.59% (F = 12.74, $p < .001$) and increased the variance in OHRQoL by 2.00% (Table 3). Oral hygiene variables (i.e., plaque index and tongue coating) were included in Model 3; no significant differences were found in the GOHAI scores. Variables significantly associated with OHRQoL were frailty, sarcopenia, and fewer than 20 functional teeth. Adding oral hygiene variables increased the variance in OHRQoL by 0.31% (Table 3). Finally, in Model 4, variables related to oral function (i.e., xerostomia, dysphagia, occlusal condition, masticatory performance) were added. Among participants, being prefrail (β = −1.37, 95% CI: −2.45, −0.30), frailty (β = −5.21, 95% CI: −8.36, −2.05), sarcopenia (β = −3.07, 95% CI: −5.17, −0.96) and having fewer than 20 functional teeth (β= −1.77, 95% CI: −3.14, −0.40) were determined to be significantly associated with OHRQoL. Furthermore, participants with xerostomia and dysphagia had lower OHRQoL scores compared with participants without these (β = −4.18, 95% CI: −5.58, −2.78 and β = −2.90, 95% CI: −4.18, −1.62). Adding oral function-related variables increased the variance in OHRQoL by 7.18%, and all variables explained 17.08% of the variance in OHRQoL (Table 3).

Table 4 presents the standardized path coefficients for the model. We analyzed the data using SEM to explore the mediators of the effect of xerostomia on level of OHRQoL. Xerostomia both directly and indirectly influenced OHRQoL; the direct effect ($\beta_s = -0.20$, $P < .001$) accounted for 83.3% (−0.20/−0.24 = 0.833) of the total pathway; the indirect effect was combined with two pathways, dysphagia and masticatory performance ($\beta_s = -0.04$, $p < .001$), which accounted for 16.7% (−0.04/−0.24 = 0.166) of the total pathway. The specific indirect effect of xerostomia on OHRQoL, as mediated by dysphagia, was −0.026 (0.20 × −0.13 = −0.026); the percentage of the total effect was 10.8% (−0.026/−0.24 = 0.108). The effect mediated by masticatory performance was −0.004 (0.05 × −0.08 = −0.004); the percentage of the total effect was 1.7% (−0.004/−0.24 = 0.017). Furthermore, the number of functional teeth and occlusal condition mediated the significant association (β_S = 0.06) of xerostomia and masticatory performance; the direct effect accounted for 45.5% (0.05/0.11 = 0.455), whereas the total indirect pathway accounted for 54.5% (0.06/0.11 = 0.545) of the total effect from xerostomia to masticatory performance. The number of functional teeth mediation explained 43.6% (0.048/0.11 = 0.436) of the effect. However, taking dysphagia and masticatory performance into account, the number of functional teeth and the occlusal condition had no direct effects on OHRQoL through dysphagia, whereas either dysphagia (β_S = −0.13) or masticatory performance (β_S = −0.08) had direct effects on OHRQoL.

As displayed in Figure 1, we hypothesized a pathway from xerostomia to OHRQoL through the mediators. The exogenous variables were xerostomia, frailty, sarcopenia, and covariates (i.e., age, gender, educational level). The endogenous mediator variables were dental status, occlusal condition, dysphagia, and masticatory performance. Overall, the hypothesized model fit was good, with a goodness of fit of χ^2 (1) = 1.09, p = 0.29, RMSEA = 0.009, and CFI = 1.00. All the direct and indirect effects accounted for 16.0% (displayed in Table 4) of OHRQoL. The result of the path analysis indicated that xerostomia (β_S = −0.24) had the strongest total effects on OHRQoL. The dysphagia had a significantly mediating effect on the association between xerostomia and OHRQoL (β_S = 0.20 and −0.13, respectively, both p< .001). Moreover, the masticatory performance had a significantly mediating effect on the association between xerostomia and OHRQoL (β_S = 0.05 and −0.08, respectively, both p< .05). Figure 1 also shows that potential mediating influences of the number of functional teeth (β_S = −0.11 and −0.44, respectively, both p< .001) and occlusal condition (β_S = 0.09 and 0.12, respectively, both p< .05) on the relationship between xerostomia and masticatory performance.

Discussion

Two major strengths of our study were identified. First, this is the first study to measure the potential mediating influences of dental status and oral function on the relationship between xerostomia and OHRQoL in older adults by using pathway analysis in SEM to estimate the direct and indirect effects, which enabled consideration of complicated relationships. Second, all confounding effects from multiple physical and oral function variables were considered in the assessments. In this study, we found that xerostomia had a negative direct effect on OHRQoL. Notably, the mediating role of dysphagia and masticatory performance may strongly mediated affect the relationship between xerostomia and OHRQoL. Moreover, potential mediating effects were observed for number of functional teeth and occlusal condition on the association between xerostomia and masticatory performance.

Dysphagia is the principal mediator of the effect of xerostomia on OHRQoL, followed by masticatory performance. The indirect pathway of the effect of xerostomia through dysphagia may be caused by the motion of swallowing, which depends on the volume of saliva. Concordantly, swallowing may decrease during sleep because of the decrease in salivary secretions (28). Overall, strong evidence suggests that saliva is critical in both the frequency and efficiency of swallowing. Insufficient saliva may cause impaired swallowing, which can degrade the quality of life. Dysphagia affects OHRQoL because an inability to swallow comfortably may influence swallowing safety and efficiency. A decline in oral health functions could lead to negative self-perception of oral health as defined by level of OHRQoL.

As indicated by our results, masticatory performance is another potential mediator between xerostomia and QoL. People with xerostomia may have multiple oral and dental deficits, such as dental caries and periodontal disease, resulting in a loss of teeth (2). We used color-changeable chewing gum to determine masticatory performance and revealed that older people with fewer than 20 functional teeth were more likely to have a poor masticatory function. Our results also found potential mediating effects for number of functional teeth and occlusal condition on the association between xerostomia and masticatory performance. The numbers of functional teeth and occlusal forces were significantly related to the objective masticatory function, which was consistent with previous studies (29). Several studies have also indicated that older people with fewer total and posterior natural teeth were more likely to experience chewing difficulty (30). Indisputably, the number of residual teeth is paramount to mastication. In Japan, a study demonstrated that retaining more than 20 teeth is necessary for retention of effective masticatory ability (31). With multiple tooth loss in older people, it is not unreasonable to expect that low masticatory ability may affect dietary choices and may therefore reducing quality of life. Due to impaired masticatory ability, older people are unable to eat a whatever they like and present with an especially low intake of meat, fruits and vegetables. Therefore, impaired masticatory ability is vital for life satisfaction among the older population.

Oral exercise to improve the rate of oral diadochokinesis is effective (32). Limiting xerostomia, dysphagia and poor masticatory performance by performing oral exercises (i.e., neck exercises, massage of the salivary glands, vocal exercises) may reduce the effects of the direct and indirect pathway on QoL. A stady reported significiant increase in salivarly flow after oral exercise by massaging of the salivary gland for 10 mintues, 3 times daily (32). In addition, vocal exercise by pronouncing the syllables /pa/, /ta/, or /ka/ involves the use of the front (lips), middle (tip of the tongue), and back of the mouth (posterior tongue), respectively and this exercise could effectively train of oral function (33). The monosyllable /ka/ requires repetitive elevation of the posterior tongue, which is closely related to the swallowing motion, while syllable /ta/ is most closely related to the chewing motion because it brings the tip of the tongue into contact with the teeth and gum. The number of teeth is crucial to masticatory function; however, the tongue is also vital to mastication and is correlated with older people's ability to mix food because the tip of the tongue is largely involved in the masticatory movement. Therefore, increased tongue movement in older people may compensate for decreased mastication. Furthermore, developing a simple examination that uses oral diadochokinesis to identify the preclinical sign of dysphagia could help community-dwelling older people avoid dysphagia and reduced quality of life. By using an oral diadochokinesis test, we can easily diagnose hypofunctional oral diadochokinesis when at least one of the three syllables was below 6 times.

Some possible limitations should be noted. First, data were analyzed according to hypothetical pathways; these may be more accurate than previous regression model studies, but our cross-sectional design restricts interpretation of the causal processes underlying these oral health outcomes. Second, because of language barriers, interviewers had to switch between Mandarin and Taiwanese, which may have caused interviewer bias. However, interviewers were trained before the survey to minimize this bias. Third, we did not evaluate tongue pressure among the older people, which is also related to swallowing motion.

Conclusions

Our findings may provide a deeper understanding of the pathways between xerostomia and quality of life of the aging population. The result of the path analysis indicated that xerostomia had the greatest effect on OHRQoL. Notably, dysphagia is the principal mediator of the effect of xerostomia on OHRQoL, followed by masticatory performance. The mediating role of dysphagia and masticatory performance on the association between xerostomia and OHRQoL was significant and deserves further attention. The community-based educational program targeting on improvements in mastication, salivation, and swallowing functions in older people may be a prmosing strategy to improve their OHRQoL. In addition, Our results further suggest that early screening for swallowing and masticatory function is essential to prevent or delay the onset of complications. While providing early screening for older people, preliminary sign of dysphagia could be determine through assessment tools by specialists which can help older adults early discover swallowing problem. In terms of clinical implication, our findings identified that the numbers of functional teeth and occlusal condition are the mediators of xerostomia to masticatory performance. Referral to oral health specialists to improve the functional teeth and bite strength for older people is also advisable. It is recommended that government and health agencies provide oral health services for the older adults in the community settings, including regular dental inspections and oral function (i.e. xerostomia, chewing and swallowing) screening.

Abbreviations

OHRQoL: oral health-related quality of life

SEM: structural equation model

ADL: Activities of Daily Living

GOHAI: Geriatric Oral Health Assessment Index

SARC-F: strength, assistance in walking, rising from a chair, climbing stairs, and falls

VIF: variance inflation factor

RMSEA: Root Mean Square Error of Approximation

CFI: Comparative Fit Index

Declarations

Ethics approval and consent to participate

The Institutional Review Board of Kaohsiung Medical University Hospital approved this protocol (KMUHIRB-E(I)-20170270, KMUHIRB-E(I)-20180122). All participants provided written informed consent before participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to maintain participant privacy and confidentiality requirements but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TYL: Primary writer of the manuscript. JHC: Conceptualization, resources, review and editing of the manuscript. JKD: Conceptualization, resources and validation. YCL: Visualization and writing original draft of manuscript. PSH: Study design and interpretation of data. CHL: Formal analysis and editing of manuscript. CYH: Review and editing of manuscript. HLH: Conceptualization, funding acquisition, review and editing of the manuscirpt.

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Tables

Table 1. Basic information according to xerostomia group (n=1,100)

Variables	Total		Xerostomia-free (n=972)		Xerostomia (n=128)		*P*
	n	%	n	%	n	%	
Age (M±SD)†	74.1±6.4		73.8±6.3		76.6±6.6		<.001
Gender							0.016
Men	314	28.6	289	29.7	25	19.5	
Women	786	71.5	683	70.3	103	80.5	
Education level							<.001
Illiterate/ Elementary school	506	46.0	428	44.0	78	60.9	
Junior high/ High school	369	33.6	336	34.6	33	25.8	
Above technical school/ College	225	20.5	208	21.4	17	13.3	
BMI (M±SD)†	24.3±3.5		24.3±3.5		24.2±3.8		0.715
Number of natural teeth							<.001
< 20 teeth	464	42.2	388	39.9	76	59.4	
≥ 20 teeth	636	57.8	584	60.1	52	40.6	
Number of functional teeth							<.001
< 20 teeth	688	62.6	342	35.2	70	54.7	
≥ 20 teeth	412	37.5	630	64.8	58	45.3	
Occlusal condition							<.001
A	453	41.2	421	43.3	32	25.0	
B	421	38.3	364	37.5	57	44.5	
C	226	20.6	187	19.2	39	30.5	
Implant	47	4.3	45	4.6	2	1.6	0.107
Edentulous	100	9.1	82	8.4	18	14.1	0.037
Removable denture							
CD	211	19.2	176	18.1	35	27.3	0.013
RPD	326	29.6	274	28.2	52	40.6	0.004
PI (0- 3) (M±SD)†	0.9±0.5		0.9±0.5		0.9±0.8		0.985
Tongue coating (0-12) (M±SD)†	4.5±3.4		4.5±3.4		4.0±3.4		0.072
Masticatory performance							<.001
Good	380	35.0	354	36.9	26	20.5	
Moderate	412	37.9	365	38.0	47	37.0	
Poor	295	27.1	241	25.1	54	42.5	
Dysphagia	148	13.5	105	10.8	43	33.6	<.001
Sarcopenia	54	4.9	34	3.5	20	15.6	<.001
Frailty							<.001
Robust	863	78.5	793	81.6	70	54.7	
Pre-frailty	215	19.6	165	17.0	50	39.1	
Frailty	22	2.0	14	1.4	8	6.3	
GOHAI (M±SD) (0-60) †	52.8±7.0		53.6±6.4		47.4±9.0		<.001

chi-square test; †two sample t test

BMI: Body mass index, PI: Plaque index, CD: Complete denture, RPD: Removable complete denture

Table 2. Hierarchical linear regression analysis of GOHAI scores associated with physical function, dental status, oral hygiene and oral function

	Model 1	Model 2	Model 3	Model 4
Variables	β(95 % CI)	β(95 % CI)	β(95 % CI)	β(95 % CI)
Frailty				
Pre-frailty vs. robust	-2.47(-3.50, -1.43)	-2.37(-3.40, -1.34)	-2.15(-3.23, -1.06)	-1.37(-2.45, -0.30)
Frailty vs. robust	-5.28(-8.25, -2.31)	-5.02(-7.96, -2.07)	-5.55(-8.81, -2.29)	-5.21(-8.36, -2.05)
Sarcopenia	-4.27(-6.24, -2.30)	-4.19(-6.14, -2.23)	-4.07(-6.23, -1.90)	-3.07(-5.17, -0.96)
Removable denture (yes)		0.89(-0.95, 1.33)	0.20(-0.94, 1.34)	0.54(-0.65, 1.73)
Functional teeth (<20 teeth)		-2.29(-3.48, -1.11)	-2.34(-3.59, -1.09)	-1.77(-3.14, -0.40)
PI			0.32(-0.54, 1.17)	0.27(-0.57, 1.10)
Tongue coating			0.05(-0.08, 0.19)	0.02(-0.11, 0.15)
Xerostomia				-4.18(-5.58, -2.78)
Dysphagia				-2.90(-4.18, -1.62)
Occlusal condition				
B vs. A				-0.76(-1.84, 0.32)
C vs. A				0.56(-1.66, 2.78)
Masticatory				
Moderate vs. good				-0.63(-1.57, 0.31)
Poor vs. good				-1.02(-2.36, 0.33)

PI: Plaque index

Model 1: This model included demographic factors, frailty and sarcopenia.

Model 2: This model included demographic factors frailty, sarcopenia, removable denture and functional teeth.

Model 3: This model included demographic factors, frailty, sarcopenia, removable denture, functional teeth, plaque index and tongue coating.

Model 4: This model included demographic factors, frailty, sarcopenia, removable denture, functional teeth, plaque index, tongue coating, xerostomia, dysphagia, occlusal condition and masticatory performance.

Table 3. Summary of hierarchical linear regression models of GOHAI scores associated with physical function, dental status, oral hygiene and oral function

Variables	Multiple R.	Adjust R^2 (%)	R^2 (%)	R^2 change (%)	Sig. change		
Model 1	0.28	6.99	7.59	7.59	F change =	12.70	$p < .001$
Model 2	0.31	8.84	9.59	2.00	F change =	12.74	$p < .001$
Model 3	0.31	8.80	9.90	0.31	F change =	8.97	$p < .001$
Model 4	0.41	15.48	17.08	7.18	F change =	10.70	$p < .001$

Model 1: This model included demographic factors, frailty and sarcopenia.

Model 2: This model included demographic factors frailty, sarcopenia, removable denture and functional teeth.

Model 3: This model included demographic factors, frailty, sarcopenia, removable denture, functional teeth, plaque index and tongue coating.

Model 4: This model included demographic factors, frailty, sarcopenia, removable denture, functional teeth, plaque index, tongue coating, xerostomia, dysphagia, occlusal condition and masticatory performance.

Table 4. Standardized effects of physical function, dental status and oral function on GOHAI with correlated errors

Outcomes	Direct effect	Indirect effect	Total effect	R^2 (%)
Functional teeth				15.0%
Xerostomia Functional teeth	-0.11***	–	-0.11***	
Occlusal condition				14.1%
XerostomiaOcclusal condition	0.09**	–	0.09**	
Dysphagia				10.0%
Functional teeth Dysphagia	0.08	–	0.08	
Occlusal condition Dysphagia	0.10	–	0.10	
Xerostomia Dysphagia	0.20***	0.0004	0.20***	
Masticatory performance				38.9%
Functional teeth Masticatory	-0.44***	–	-0.44***	
Occlusal conditionMasticatory	0.12*	–	0.12*	
Xerostomia Masticatory	0.05*	0.06***	0.11***	
GOHAI				16.0%
Functional teeth GOHAI	0.04-	-0.03	0.07	
Occlusal condition GOHAI	-0.03	-0.02*	-0.06	
Dysphagia GOHAI	-0.13***	–	-0.13***	
Masticatory GOHAI	-0.08*	–	-0.08*	
Xerostomia GOHAI	-0.20***	-0.04***	-0.24***	

The covariates including age, gender and education.

R^2: the variance of endogenous variables that is explained

*p<0.05, **p<0.01, ***p<0.001.

Figures

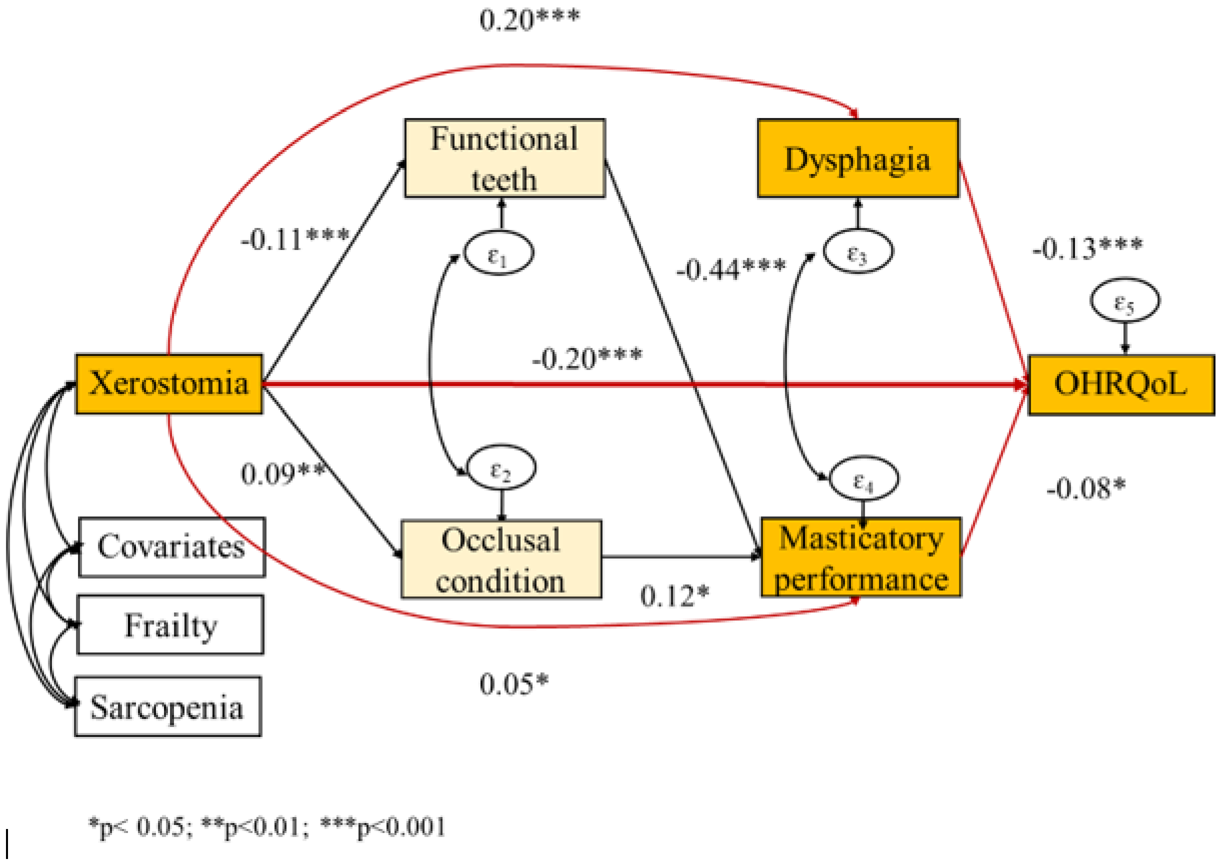

Figure 1

SEM framework