Dysphagia and Masticatory Performance as a Mediator of the Xerostomia to Quality of Life Relation in the Older Population

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Research article

Keywords: xerostomia, dysphagia, masticatory performance, oral health-related quality of life, path analysis

Posted Date: September 3rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-29978/v2

Version of Record: A version of this preprint was published on December 2nd, 2020. See the published version at https://doi.org/10.1186/s12877-020-01901-4.

Abstract

Background: The impact of poor oral health in older adults affecting 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: Stratified cluster sampling method was used to recuit 1100 community-dwelling adults aged 65 years and older from Kaohsiung, Taiwan. Community care centers were randomly selected based on their geographic classifications (urban, rural, and mountainous areas). Assessments of dental status and occlusal condition were performed by dentists. Information on demographics, physical function, xerostomia dysphagia and depression 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. Hierarchical regression models were utilized to assess the relationship between OHRQoL and physical function, dental status and oral function in older adults. Path analysis was used to estimate direct and indirect pathways between xerostomia and OHRQoL.

Results: Participants with xerostomia had a 0.17 OHRQoL reduction ($p < .001$) comparing to the non-xerostomia, and the direct effect was accounted for 85.0% of the total effect. The dysphagia and the poor masticatory performance were found to have a significant mediating effect on the association between xerostomia and OHRQoL (βs = 0.17 and −0.09, respectively, both $p < .001$; βs = 0.05 and −0.08, respectively, both $p < .001$) moreover, potential mediating influences of the number of functional teeth (βs = −0.11 and −0.44, respectively, both $p < .001$) and poor occlusal condition (βs = 0.09 and 0.12, respectively, both $p < .05$) on the relationship between xerostomia and masticatory performance were obervered.

Conclusions: Dysphagia and poor masticatory performance may serve as a pathway of which xerostomia affects quality of life. Providing early oral function intervention may be a valuable and actionable target for older adults to maintain their quality of life. Our results further suggest that checkup and screening for oral dysfunction 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. People with xerostomia were found to have more decayed crown surfaces than those without xerostomia. And decayed crown surfaces can increase the risk of dental caries and further lead to tooth loss; and it has been shown that missing teeth is associated with subjective sensation of dry mouth (2). Xerostomia may also affect speech, chewing, swallowing, denture wearing, and oral health-related quality of life (OHRQoL) (3) , and further result in decreased performance of activities of daily living (4) Overall, xerostomia is considered 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.

A normal swallowing has been divided into three phases: oral, pharyngeal, and esophageal. In the oral phase, food is chewed and mixed with saliva to form bolus, which then can be passed to the oropharynx (upper part of the throat) and ready for swallowing. Forming a bolus during chewing requires saliva, therefore saliva is crucial in the oral phase (5). Swallowing dysfunction is another common condition observed among older adults and increases with age and frailty. Dysphagia is defined as any disruption in the swallowing process. However, physiological and functional changes in swallowing process due to aging are called presbyphagia. Neurogenic dysphagia is the dysphagia associated with neurological diseases, for example dementia, Parkinson's disease, or stroke (5). Moreover, physiological changes resulted from diseases such as head and neck cancer, cervical spine surgery and head injuries could also lead to dysphagia (6).

Masticatory performance may lead to changes in the diet of older adults affecting their nutrition intake. And if tooth loss is also present, it becomes more difficult for older adults to consume food. Loss of masticatory function is also associated with increased disability and mortality. Moreover, improvement of masticatory function can increase Quality of Life (QoL). A study in Japan shows that prevalence of dissatisfaction with daily life was 3.4 times greater in individuals only able to chew ≦4 types of food than in those who could chew 15 types; such dissatisfaction was 2.1 times higher in those who had 10–19 teeth than in those with ≧20 teeth (7). Therefore, improve chewing ability in older adults may increase satisfaction of daily living.

Previous studies have examined the relationship between dysphagia, oral health, masticatory performance and activities of daily living (8). QoL were found lower in patients with dysphagia (9). Older adults with subjective oral dryness are more likely to have problem chewing one or more types of foods and experience problems with daily life, such as eating or communicating (2). Although oral health has been found to associate with poorer quality of life (10, 11), it is still important to investigate whether other pathways could influence the quality of life perception. No previous study looks into mediators between xerostomia and OHRQoL, and explore the possible pathway within oral function variables. Understanding the effect of mediators can increase efficacy of early intervention by focusing on key elements and reduce costs by eliminating unnecessary ones. Previous studies have identified relationships between dental status, oral function, and OHRQoL by using multiple regression analysis (12, 13). Path analysis is a specific structural equation modelling (SEM) tool and can be used in place of several separate regressions to examine mediating effects within a single model (14). Path analysis also allows the testing of causal relationships among a set of observed variables, and has been shown as a powerful tool to identify factors mediating the association between exogenous variables and outcomes. This study employed path analysis 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 cross-sectional study was conducted involving community-dwelling participants aged 65 years and over in Kaohsiung, Taiwan from May 2018 to January 2019. This study adopted a multistage, stratified cluster sampling method to select subjects from elderly population. There are 39 districts in Kaohsiung City in three geographic classifications (urban, rural, and mountainous areas). In the first stage of sampling, 25 districts were randomly selected from the 39 districts using probability proportional to size sampling method. In the second stage, community care centers in those 25 districts were randomly selected. In the final stage, older adults aged 65 years or older were recruited from each community care centers selected. There were total of 1180 participants recruited from urban areas (n=609), rural area (n=555), and mountainous areas (n=16).

Participants were excluded if they self-reported any of the following: (a) mental disorders, (b) expressive language disorders, (c) moderate or severe cognitive impairment, which was determined by a short portable mental status questionnaire (SPMSQ) (15), or (d) high-to-total dependence with respect to performance of Activities of Daily Living (ADL) (16). 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 (17). 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 including demographics (i.e., age, sex, education level), mental depression, oral function (i.e., xerostomia and dysphagia), physical function (i.e., frailty, sarcopenia), and OHRQoL. All instruments were translated from English to Chinese and back-translated to English by bilingual research staff and then verified for accuracy by two senior researchers. 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/discomfort (using medication to relieve pain or discomfort in the mouth). The English version of GOHAI was translated into Chinese for the participants (GOHAI-T)(18). Each item in GOHAI 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

A condenced version of Xerostomia Inventory questionnaire was used to identify and classify mouth dryness. Participants respond to five items: (a) My mouth feels dry when eating a meal, (b) My mouth feels dry, (c) I have difficulty eating dry foods, (d) I have difficulty swallowing certain foods, and (e) My lips feel dry. Each item was scored as 1 (*never*), 2 (*occasionally*), or 3 (*often*) (19). 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 (20). 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." (21). 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 (22). 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 (23), 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 (24). 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

Physiological and psychologic/psychiatric state may be potential affected by oral health status. Hence, we examined age, sex, educational level, depression level, frailty and sarcopenia as our covariates. Moreover, since the data collection was designed to be self-reported, participants with cognitive impairment (moderate or severe cognitive impairment) were excluded from the study. Level of depression was assessed using the Geriatric Depression Scale (GDS) (25). Frailty was assessed using the Study of Osteoporotic Fractures index (SOF) (26). Sarcopenia was assessed using the SARC-F self-administered questionnaire (27). Finally, all the covirates collected during the study were retained in the final model of pathway analysis.

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 (28, 29). In the present study, the following criteria were used to define the goodness of model fit: $\chi^2/df < 3.00$, 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 (30). 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). The xerostomia group displayed poorer masticatory performance and more difficulty swallowing than the xerostomia-free group ($p < .001$). 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 ($p < .001$). Moreover, older adults with xerostomia exhibits higher depression rate than those without (25.8% and 7.1%, respectivley).

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, level of depression, frailty, and sarcopenia were entered as a first step and explain 12.24% of the variance in OHRQoL as measured by the sum of GOHAI scores (Model 1, Table 3). The additional variables related to dental status (i.e., removable denture, functional teeth) were entered as the second step in Model 2. Adding dental status-related variables in Model 2 explained 14.28% and increased the variance in OHRQoL by 2.04% (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. Adding oral hygiene variables reduced the variance in OHRQoL by 0.26% (Table 3). Finally, in Model 4, variables related to oral function (i.e., xerostomia, dysphagia, occlusal condition, masticatory performance) were added. Among participants, depression ($\beta = -4.14$, 95% CI: −5.71, −2.57), sarcopenia ($\beta = -2.54$, 95% CI: −4.63, −0.45), xerostomia ($\beta = -3.61$, 95% CI: −5.01, −2.22), dysphagia ($\beta = -2.40$, 95% CI: −3.67, −1.13) and having fewer than 20 functional teeth ($\beta = -1.85$, 95% CI: −3.21, −0.49) were significantly associated with OHRQoL. Adding oral function-related variables increased the variance in OHRQoL by 5.50%, and all variables explained 19.52% of the variance in OHRQoL (Table 3).

As displayed in Figure 1, we hypothesized a pathway from xerostomia to OHRQoL through the mediators. The exogenous variables were xerostomia and covariates (i.e., age, sex, educational level, level of depression, frailty, sarcopenia). 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) =0.937, $p = 0.33$, RMSEA = 0.000, and CFI = 1.00. The result of the path analysis indicated that xerostomia ($\beta_s = -0.17$) had the strongest total effects on OHRQoL. The dysphagia had a significantly mediating effect on the association between xerostomia and OHRQoL ($\beta_s = 0.17$ and −0.09, respectively, both $p < .001$). Moreover, the poor masticatory performance had a significantly mediating effect on the association between xerostomia and OHRQoL (βs = 0.05 and −0.08, respectively, both $p <$

.05). Potential mediating influences of the number of functional teeth ($\beta s = -0.11$ and -0.44, respectively, both $p < .001$) and poor occlusal condition ($\beta s = 0.09$ and 0.12, respectively, both $p < .05$) on the relationship between xerostomia and masticatory performance were also observed.

Table 4 presents the standardized path coefficients for the model. Xerostomia both directly and indirectly influenced OHRQoL and was accounted for 21.5% of OHRQoL. The direct effect ($\beta_S = -0.17$, $p < .001$) was accounted for 85.0% of the total pathway; the indirect effect which combined with two pathways, dysphagia and masticatory performance ($\beta_S = -0.03$, $p < .001$), was accounted for 15.0% of the total pathway. Furthermore, xerostomia both directly and indirectly influenced masticatory and was accounted for 38.7% of masticatory performance. The direct effect ($\beta s = 0.05$, $p < .05$) was accounted for 45.0% of the total pathway, while the indirect effect which combined with two pathways, the number of functional teeth and poor occlusal condition($\beta_S = 0.06$, $p < .001$), was accounted for 55.0% of the total pathway. However, the number of functional teeth and poor occlusal condition was found to have no direct effects on OHRQoL through dysphagia.

Discussion

Unlike previous studies which used regression model to investigate the relationship between oral health status and QoL (31), this study examined a pathway linking oral function to quality of life, and identify the mediator in model. By solving a chain of relations between an exogenous variable and an outcome, how the effect of one variable is transmitted to another variable can be better understood. Path analysis may also help us structuralize the whole framework and establish different possible pathway which could provide researchers and policy makers with different intervention strategies options. In this study, we found the variable exhibiting the strongest direct negative effect on OHRQoL was xerostomia of older adults. According to path model, the mediating role of dysphagia and masticatory performance may strongly mediate the effect of xerostomia on OHRQoL. This highlights the need to prevent xerostomia and reduce both of its direct effects on quality of life and indirect effects on older adults' satisfaction of life via dysphagia and masticatory performance. Eliminating the mediating effect of dysphagia and masticatory performance could prevent xerostomia from influencing quality of life. Moreover, mediating effects were observed for number of functional teeth and poor occlusal condition on the association between xerostomia and masticatory performance. The direct effects of functional teeth and occlusal condition on masticatory performance is in agreement with previous study, which showed that individuals with fewer pairs of opposing teeth are thought to be substantially at increased risk for chewing difficulties (32).

Dysphagia was found 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 is impacted by the volume of saliva. Concordantly, swallowing may decrease during sleep because of the decrease in salivary secretions (33). 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. A decline in oral functions could lead to negative self-perception of oral health as defined by level of OHRQoL. Thus, we demonstrate that the association between xerostomia and quality of life could be mediated through the effect of swallowing function.

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 (34). 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 (35). Several studies have also indicated that older people with fewer total and posterior natural teeth were more likely to experience chewing difficulty (36). 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 (37). 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.

The results of the moderated mediation analysis highlight that dysphagia represents a more important pathway among those with xerostomia than among those without. There are feasible ways to relieve symptoms of xerostomia in older adults, those include local measures such as use of artificial saliva sprays, lozenges, and gels. Frequent sips of water, chewing sugar-free gum or sucking on sugar-free candy, avoiding caffeine, tobacco, alcohol and dry or hard to chew foods may also help to relieve symptoms of xerostomia (38). In addition, massaging the three paired major salivary glands (parotid, submandibular, and sublingual) could significiantly increase salivarly flow. Massaging these three salivary glands for 10 minutes, 3 times daily before each meal may also decrease the subjective sensation of thirst. Moreover, performing oral exercises (i.e., neck exercises, massaging salivary glands, vocal exercises) may reduce the effects of the direct and indirect pathway on QoL. Oral exercise is effective in improving the rate of oral diadochokinesis and reducing xerostomia, dysphagia and poor masticatory performance (39). 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 (40). 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, a cross-sectional design restricts interpretation of the causal processes underlying these oral health outcomes; possible reverse causality cannot be ruled out. However, xerostomia influences the masticatory performance and declines in relation to a reduction in salivary secretion which affect the transport mechanism of ingested food or liquid (41). Further longitudinal study is needed to examine possible temporal relationships. 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. Fourth, questionnaire used to evaluate the dryness of the mouth and dysphagia was not considered an objective method. However, due to the number of participants and their physical location, using questionnaire is a more feasible option is this study. Previous studies have validated using the self-report scales to assess dry mouth and dysphagia present high validity and reliability (42, 43). Future study is suggested to use a more objective method to evaluate oral function, such saliva flow rate measurement, and Video-Fluoroscopic swallowing test. Fifth, social and cultural variables were not considered in the model, owing to population varies in social, economic, cultural, technological characteristics which could associate with physical conditions. Poor oral health such as dysphagia may be prevalent in some segement of society which lead to dehydration, malnutrition even early mortality. Further studies are needed to identify potential mediators of the relationship by which oral health factors influencing QoL in a broader framework. Lastly, older adults were recrutied in Kaohsiung city representing only a subgroup of the public which can not be generalized to other population.

Conclusions

Our findings suggest that 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 oral 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. 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. Referral to oral health specialists for older adults to improve the functional teeth and bite strength is also recommended.

Abbreviations

ADL: Activities of Daily Living

CFI: Comparative Fit Index

GDS: Geriatric Depression Scale

GOHAI: Geriatric Oral Health Assessment Index

OHRQoL: oral health-related quality of life

RMSEA: Root Mean Square Error of Approximation

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

SEM: structural equation model

SOF: Study of Osteoporotic Fractures Index

SPMSQ: short portable mental status questionnaire

VIF: variance inflation factor

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.

Funding

This work was supported by the National Health Research Institutes, Taiwan (ROC) [grant number NHRI-107AI-PHCO-03181808]. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Authors' contributions

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

Acknowledgements

Not applicable

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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
Depression	102	9.3	69	7.1	33	25.8	<.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 depression, 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)
Depression	-5.76	(-7.25, -4.27)	-5.78	(-7.25, -4.31)	-5.23	(-6.80, -3.66)	-4.14	(-5.71, -2.57)
Frailty								
Pre-frailty vs. robust	-1.62	(-2.65, -0.58)	-1.50	(-2.53, -0.48)	-1.41	(-2.50, -0.32)	-0.91	(-1.98, 0.17)
Frailty vs. robust	-1.73	(-4.77, 1.31)	-1.46	(-4.47, 1.55)	-2.39	(-5.72, 0.93)	-2.77	(-6.01, 0.47)
Sarcopenia	-3.34	(-5.28, -1.40)	-3.25	(-5.17, -1.33)	-3.22	(-5.35, -1.09)	-2.54	(-4.63, -0.45)
Removable denture (yes)			0.27	(-0.85, 1.39)	0.25	(-0.94, 1.34)	0.62	(-0.56, 1.80)
Functional teeth (<20 teeth)			-2.36	(-3.52, -1.20)	-2.34	(-0.87, 1.37)	-1.85	(-3.21, -0.49)
PI					0.31	(-0.53, 1.14)	0.29	(-0.54, 1.11)
Tongue coating					0.07	(-0.06, 0.20)	0.04	(-0.09, 0.17)
Xerostomia							-3.61	(-5.01, -2.22)
Dysphagia							-2.40	(-3.67, -1.13)
Occlusal condition								
B vs. A							-0.90	(-1.97, 0.17)
C vs. A							0.57	(-1.62, 2.76)
Masticatory								
Moderate vs. good							-0.71	(-1.64, 0.21)
Poor vs. good							-1.10	(-2.43, 0.23)

PI: Plaque index

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

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

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

Model 4: This model included demographic factors, depression, 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 depression, physical function, dental status, oral hygiene and oral function

Variables	Multiple R.	Adjust R^2 (%)	R^2 (%)	R^2 change (%)	Sig. change		
Model 1	0.35	11.59	12.24	12.24	F change =	18.82	p <.001
Model 2	0.38	13.49	14.28	2.04	F change =	17.94	p <.001
Model 3	0.37	12.87	14.02	-0.26	F change =	12.16	p <.001
Model 4	0.44	17.88	19.52	5.50	F change =	11.86	p <.001

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

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

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

Model 4: This model included demographic factors, depression, 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							14.7%
Xerostomia Functional teeth	-0.11	***	–		-0.11	***	
Occlusal condition							13.6%
XerostomiaOcclusal condition	0.09	**	–		0.09	**	
Dysphagia							12.5%
Functional teeth Dysphagia	0.09		–		0.09		
Occlusal condition Dysphagia	0.10		–		0.10		
Xerostomia Dysphagia	0.17	***	–		0.17	***	
Masticatory performance							38.7%
Functional teeth Masticatory	-0.44	***	–		-0.44	***	
Occlusal conditionMasticatory	0.12	*	–		0.12	*	
Xerostomia Masticatory	0.05	*	0.06	***	0.11	***	
GOHAI							21.5%
Functional teeth GOHAI	0.04		0.03		0.07		
Occlusal condition GOHAI	-0.04		-0.02	*	-0.06		
Dysphagia GOHAI	-0.09	***	–		-0.09	***	
Masticatory GOHAI	-0.08	*	–		-0.08	*	
Xerostomia GOHAI	-0.17	***	-0.03	***	-0.20	***	

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

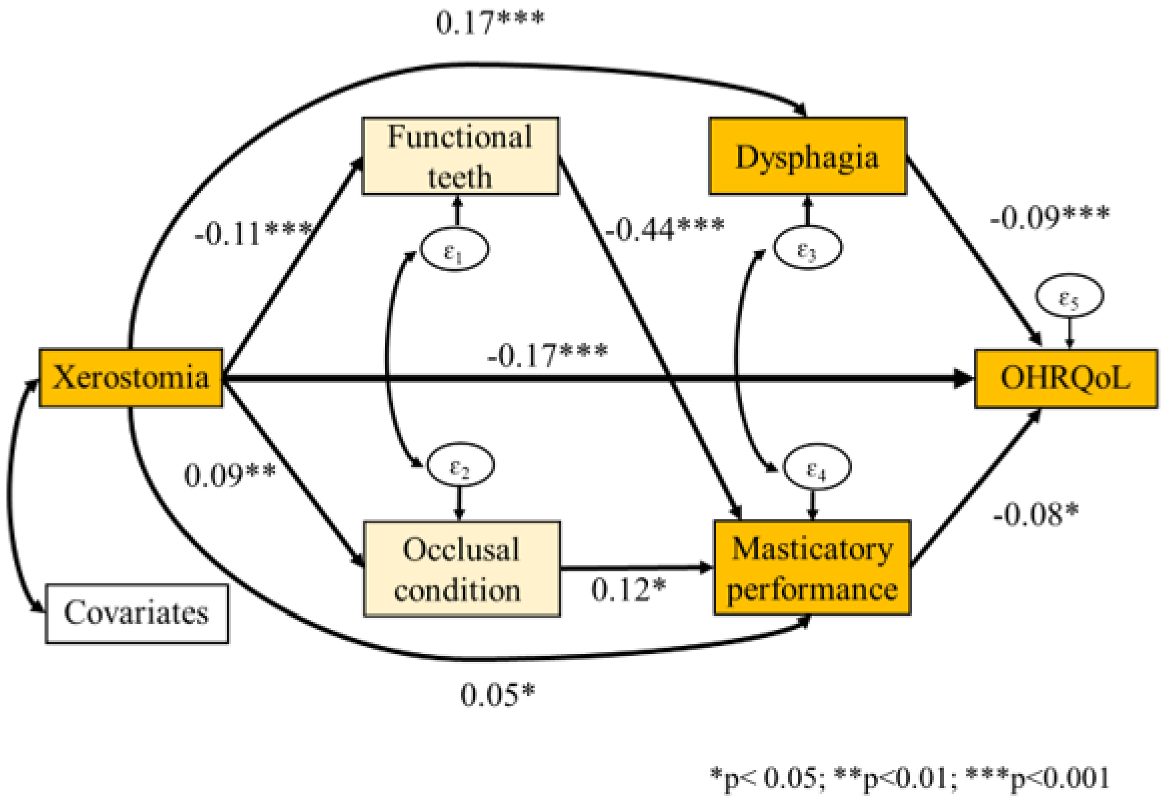

Figure 1

Path analysis framework