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Cognitive status of edentate elders wearing complete denture: Does quality of denture matter?

Daiane Cerutti-Kopplin[a,*], Elham Emami[b], Juliana Balbinot Hilgert[a], Fernando Neves Hugo[a], Dalva Maria Pereira Padilha[a]

[a] Faculty of Dentistry, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil
[b] Faculty of Dentistry, Université de Montréal, Montreal, Canada

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ABSTRACT

Background: Emerging evidence suggests that an individual's level of mastication may play a role in their cognitive status. This suggests that in edentate individuals wearing complete denture, non-optimal mastication via inadequate denture could be related to cognitive status.
Objectives: To examine the impact of quality of denture on cognitive status of a sample of elderly edentate Brazilian individuals wearing complete denture.
Methods: This study is a cross-sectional analysis of data collected from 117 edentate elders (mean age 73.7 ± 5.6 years) wearing complete denture, in southern Brazil. Cognitive impairment was assessed using the Brazilian version of the mini-mental state examination (MMSE). Clinical examination was conducted to evaluate the quality of dentures by use of the FAD (functional assessment of dentures) instrument. Masticatory ability was assessed by self-reported questions.
Results: The mean MMSE score for the total sample was 23.1 (SD = 4.4) and was associated with age ($p = 0.001$), education ($p < 0.0001$), depressive symptoms ($p = 0.003$), as well as the masticatory ability ($p = 0.001$) and functional quality of dentures ($p < 0.0001$). Unsatisfactory masticatory ability was more frequent in edentate individuals with lower FAD score ($p < 0.0001$) and led to a lower MMSE total score. Unsatisfactory masticatory ability was associated with MMSE scores ($p = 0.002$) after adjustment.
Conclusion: The study results support the potential role of optimal functional quality of dentures in maintaining cognitive activity in elders. This association may be explained via mastication pathway.
Clinical significance: The potential beneficial effect of functional dentures on cognitive status via mastication could encourage preventive strategies to decrease substantial risk of morbidity in elders.

1. Introduction

Cognitive impairment is among the major public health concerns as a result of global increased life expectancy, and population aging [1]. Elders with this cognitive disorder suffer from memory loss, judgment impairment, and abnormal behavior [2,3], and are at risk for developing dementia, especially Alzheimer's disease [4]. The risk factors for cognitive impairment can be divided into two major categories: non-modifiable (e.g., age, sex, genetic factors, etc.) and modifiable (e.g., hypertension, diabetes, dietary habits, physical activity, cognitive activity) [5–7] risk factors. Despite extensive research, no definitive curative approach exists for this cognitive deficit [3].

Preventive interventions may potentially delay the onset of cognitive impairment among the elderly and thereby decrease the associated public health burden [5,8]. Poor oral health and non-optimal mastication have been introduced as potential modifiable risk factors for cognitive impairment [9–14]. In fact, the regular sensory stimulation in the course of mastication increases the cerebral blood flow and the number of pyramidal cells in the hippocampus [15–20]. This region of the brain is important for the formation and retrieval of episodic memory in humans [21,22]. Insufficient mastication capacity and lack of afferent stimulation by masticatory receptors may negatively impact the neurotransmitter function, and may lead to a decrease in amount of acetylcholine, which is responsible for the stimulation of electrical flow between the neurons [9,10].

Longitudinal cohort studies have linked poor oral health and cognitive impairment such as dementia and Alzheimer's disease

* Corresponding author at: Department of Preventive and Social Dentistry, Faculty of Dentistry, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil.
E-mail address: daianecerutti@hotmail.com (D. Cerutti-Kopplin).

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[13,23–25]. Accordingly, an association between tooth number and cognitive status has been reported [11,13,14,23–26]. Furthermore, a number of case-series suggest that restoration of tooth loss and masticatory function by adequate prosthesis can lead to an improvement in functional brain activity [17,20,27]. However, to our knowledge there is no solid evidence on the role of functional quality of denture in the cognitive status of edentate elders. Therefore, the objective of the present study was to test the hypothesis that quality of denture, via the mastication pathway, will influence the cognitive status in edentate elders.

2. Methods

2.1. Study design and participants

This manuscript reports the results of cross-sectional analysis of selected data collected at the second follow-up of an ongoing cohort study on the association of oral health, nutritional status, and quality of life of community-dwelling elders in the city of Carlos Barbosa, Southern Brazil. The design of the main study has been presented in detail in previous publications [28,29]. In brief, participants were randomly selected from the municipality register of persons aged 60 years or over. Potential participants were invited to participate in the cohort study by phone call or personal contact. From a total of 396 participants present at second follow up, this cross-sectional study included data from edentate participants wearing maxillary and mandibular complete dentures, who have undergone both functional assessment of dentures (FAD) [30] and mini-mental state examination (MMSE) ($n = 117$) [31]. The State University of Campinas Institutional Review Board approved the study protocol. All study participants gave written informed consent before the study.

2.2. Assessment of cognitive status, quality of denture, and masticatory ability

Cognitive status was assessed with the Brazilian version of the mini-mental state examination (MMSE), with higher scores indicating better cognitive status [32]. A trained and calibrated dentist assessed the functional quality of denture as well the history of complete tooth loss for completely edentate elders. The quality of dentures was clinically examined by use of the FAD (functional assessment of dentures) validated instrument [30]. The FAD measure has nine items, which allow the evaluation of the freeway space, occlusion, retention, and stability of dentures. The total range of the scale is 0–9 points, with higher scores indicating better functional quality. Furthermore, masticatory ability was self-assessed by the use of a composite measure (changes in dietary intake, avoiding hard-to-chew foods, and chewing only soft foods because of difficult chewing) [33,34].

2.3. Assessment of co-variates

Information on socio-demographic characteristics (age, sex, years of education, income), lifestyle factors (physical and mental activity, alcohol use, and smoking status), and medical history (diabetes, hypertension, heart disease) was obtained using self-administered questionnaires [28]. The geriatric depression scale (GDS) [35] and the short-form mini nutritional assessment (MNA) [36] were used for screening depressive symptoms and nutritional status, respectively.

2.4. Statistical analysis

In order to obtain frequency counts, percentages, and means, and to test for normality, the data were subjected to descriptive statistical tests. Independent t-test, one-way ANOVA, and Pearson correlation were used to test group-differences and the association between the independent variables and cognitive status. The total 9-item FAD score was calculated in continuous format and was included in the bivariate analyses (Table 1). Masticatory ability was considered as unsatisfactory if 2 of the 3 items of the composite variable were confirmatory.

Linear regression models were used to examine the effect of explanatory variables on cognitive status after adjusting for statistically significant confounders. Independent variables with results $p \leq 0.05$ from univariate analyses were incorporated into

Table 1
Bivariate analyses: association between mini-mental state examination (MMSE) score and sample characteristics ($n = 117$).

Variables	Mean (SD)	r	*p-value
Age	73.70 (5.55)	-0.297	0.001
Years of complete tooth loss	35.93 (11.65)	0.022	0.811
Functional assessment of dentures	5.68 (2.07)	0.547	<0.0001
	n (%)	MMSE Mean (SD)	**p-value
Sex			
Male	25 (21.4)	23.80 (5.48)	0.396
Female	92 (78.6)	22.96 (4.05)	
Education			
≤Elementary school	91 (77.8)	22.45 (4.38)	<0.0001
>Elementary school	26 (22.2)	25.54 (1.97)	
Income			
<2Brazilian minimum wage	71 (60.7)	22.80 (4.70)	0.308
≥2Brazilian minimum wage	46 (38.3)	23.65 (3.84)	
Marital Status			
Married/stable	82 (70.1)	23.32 (4.41)	0.498
Single	35 (39.9)	22.71 (4.36)	
Place of residence			
Rural	47 (40.2)	23.13 (4.14)	0.985
Urban	70 (59.8)	23.14 (4.57)	
Depressive symptoms			
No	99 (94.6)	23.64 (3.99)	0.003
Yes	18 (15.4)	20.39 (5.41)	
Diabetes			
No	94 (80.3)	23.31 (4.35)	0.236
Yes	21 (19.7)	22.05 (4.54)	
Hypertension			
No	33 (28.2)	24.15 (3.79)	0.117
Yes	84 (71.8)	22.74 (4.55)	
Heart disease			
No	90 (76.9)	23.44 (4.10)	0.166
Yes	27 (23.1)	22.11 (5.17)	
Nutrition status			
Normal	84 (71.8)	23.07 (4.53)	0.791
At risk of malnutrition	33 (27.3)	23.31 (4.03)	
Medication intake			
<3 per day	42 (35.9)	24.00 (3.52)	0.111
≥3per day	75 (64.1)	22.65 (4.75)	
Smoking status			
Never	98 (83.8)	23.04 (4.30)	0.494
Current	8 (6.8)	22.38 (7.05)	
Former	11 (9.4)	24.55 (2.38)	
Alcohol consumer			
No	82 (70.1)	22.95 (4.13)	0.486
Yes	35 (29.9)	23.57 (4.96)	
Mental activity			
Yes	89 (76.1)	23.40 (4.21)	0.240
No	28 (23.9)	22.29 (4.86)	
Physical activity			
Yes	59 (50.4)	23.69 (3.99)	0.165
No	58 (49.6)	22.57 (4.72)	
Masticatory ability			
Satisfactory	85 (72.6)	23.98 (3.88)	0.001
Unsatisfactory	32 (27.4)	20.91 (4.90)	
Functional assessment of dentures			
Adequate (total score ≥6)	62 (53.0)	24.7 (3.2)	<0.0001
Inadequate (total score <6)	55 (47.0)	21.4 (4.9)	

* Pearson correlation.
** t-test.

the regression analyses. Collinearity between the variables was verified and goodness of fit was ensured [37]. The level of statistical significance was set at $p \leq 0.05$. The analyses were carried out using the SPSS package for statistical analysis (version 20 SPSS Inc., Chicago, IL, USA).

3. Results

The sample was comprised of 92 (78.6%) women and 25 (21.4%) men. The mean age of the sample population was 73.7 (SD 5.6) years, with a median of 73 years. Among the individuals, 77.8% reported elementary school as the highest level of education, 60.7% lived in an urban area, most of them were married (70.1%), and 60.7% had a monthly income of less than two times the Brazilian minimum wage (±540 USD).

The total FAD mean score was 5.7 ± 2.1, and according to this clinical measure the majority of elders (80%) had adequate maxillary denture, however 67.5% of participants had non-retentive and non-stable mandibular dentures. Unsatisfactory masticatory ability was more frequent in completely edentate individuals with lower FAD total score ($p < 0.001$) and led to a lower MMSE total score. Fig. 1 shows a different linear relationship between MMSE total score and FAD total score across the groups based on satisfactory or unsatisfactory masticatory ability, indicating an interaction between FAD total score and masticatory ability.

The mean of MMSE score in the total sample was 23.1 (SD = 4.4) and was associated with age ($p = 0.001$), education ($p < 0.0001$), and depressive symptoms ($p = 0.003$), as well as perceived masticatory disability ($p = 0.001$) and functional quality of dentures ($p < 0.0001$). Table 2 shows the final model of the regression analyses on the risk factors of cognitive status in this group. According to this model, perceived masticatory disability was associated with cognitive status ($p = 0.002$) after adjusting for significant risk factors including age, years of education, and depression. The final model predicted about 25% of the variation of the MMSE score ($R^2 = 0.246$). Masticatory disability contributed to about six percent changes in MMSE score ($\Delta R^2 = 0.063$, $p = 0.002$).

4. Discussion

This study was performed to test the hypothesis that cognitive status is influenced by the quality of dentures via masticatory ability. In line with our hypothesis, the results suggested that the cognitive status of elders might be influenced by the quality of their dentures. The mechanism that may explain such an association is the masticatory pathway, as suggested by previous animal studies [15,16,38] showing that impaired masticatory function leads to the impairment of learning and spatial memory. Interestingly, these studies were able to show a temporal and dose-response association, which supports a causal relationship [38].

Our study results are in line with the results of case-series [17,20,27], cross-sectional [33], and longitudinal cohort studies [13,23,25], indicating that the quality of dentures [17,20,27], masticatory disability [33], and use of dentures [13,23,25] can be considered as an early marker of physical and cognitive status of elders in different populations. These studies included samples of elders from the United States [13,23], Sweden [33], and Japan [25], with follow-up periods from 4 [25] to 18 years [13]. However, similar to other studies, the oral health variable only explained a relatively small percentage of decline in cognitive status after adjusting for covariates such as socio-demographics, depressive symptoms, and health behaviors.

According to the literature, the association of oral health and cognitive status could be bidirectional and different pathways can be used to explain this link [9,10]. These include systemic inflammation caused by periodontal disease; masticatory deficiency due to tooth loss, and nutritional pathway [9,10]. On the other hand, individuals with cognitive impairment tend to have poorer oral hygiene than healthy patients, which can increase the risk of oral diseases in this population.

In a recent study done by Peres et al. [39], edentate Brazilians were 3.3 times more likely to be at risk for severe cognitive impairments than those having 10 or more teeth. Similarly, Tsakos et al. [26] used a generalized equations model and showed that tooth loss was independently associated with cognitive decline in a cohort of English community-dwelling individuals aged 50 and older who were followed for 10 years. Yamamoto et al. [25] followed a cohort of 4425 elderly Japanese individuals for four years and showed that having few teeth without any denture was associated with higher risk of dementia after adjusting for potential confounders.

According to Ono et al. [9], although in edentate individuals there is no sensory input from teeth and the periodontal ligaments, masticatory sensory stimulus can be transmitted from the masticatory muscles, temporomandibular joint, and mucous membrane to the hippocampus and via the trigeminal nerve. However, it should be noted that elders with cognitive impairment

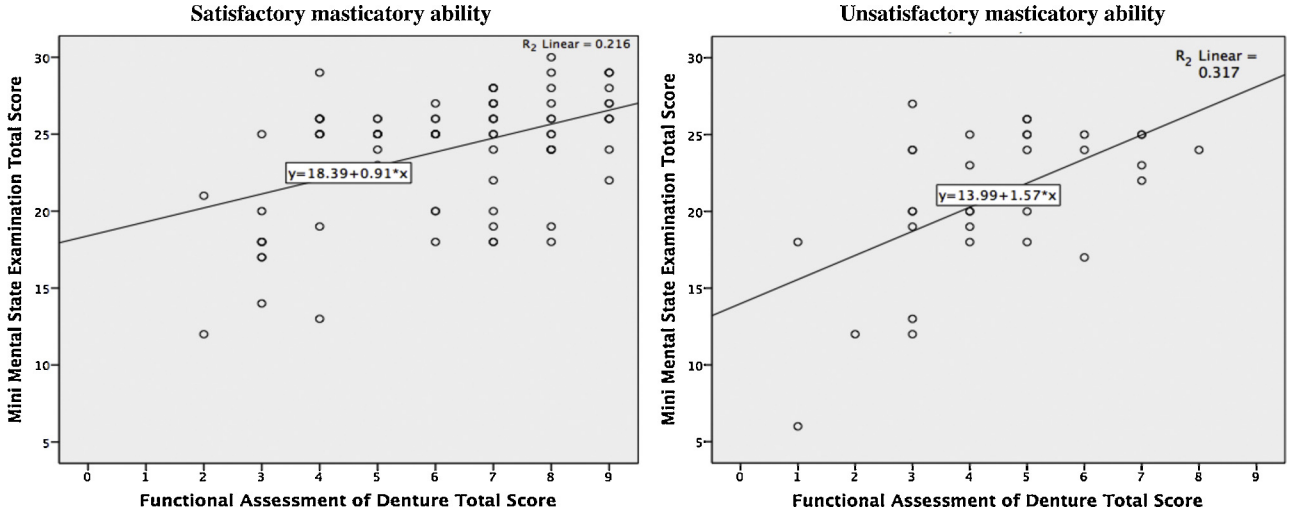

Fig. 1. Scatter plots of functional assessment of dentures total score on mini-mental state examination total score for individuals with satisfactory masticatory ability and with unsatisfactory masticatory ability.

Table 2
Multivariate analyses: association between mini-mental state examination (MMSE) score, age, education, depressive symptoms, and masticatory ability with linear regression ($n = 117$).

Dependent variable	Independent variables	B	SE B	95.0% CI for B	Beta	p-value
MMSE score	(Constant)	38.855	4.714	29.52 to 48.20		<0.0001
	Age	−0.174	0.065	−0.32 to − 0.05	−0.220	0.008
	≤Elementary school	−2.329	0.86	−4.03 to −0.63	−0.222	0.008
	With depressive symptoms	−2.778	0.978	−4.72 to −0.84	−0.230	0.005
	Unsatisfactory masticatory ability	−2.479	0.798	−4.06 to −0.90	−0.253	0.002

Note: Adjusted $R^2 = 0.151$ ($p < 0.001$) for step 1 (contains age and education). $\Delta R^2 = 5.8\%$ ($p = 0.001$) for step 2 (added depressive symptoms). $\Delta R^2 = 6.3\%$ ($p = 0.002$) for step 3 (added masticatory ability). Adjusted $R^2 = 0.246$ for last step.

could have decreased masticatory capacity because of age-related atrophy of mastication muscles, or other pathways such as reduced ability to chew food, sensory feedback via gingival tissues in the absence of periodontal receptors, and associated reduced force production [40]. Thus functional quality of dentures appeared to be an important factor in helping to preserve bone and muscle tissue. If this is the case, having dentures might represent an advantage. The problem is that not all dentures are properly fitted, and many people do not replace them over time, experiencing masticatory disability. Within this cross-sectional study those who wore adequate dentures had masticatory ability and were less likely to present cognitive decline.

Furthermore, the trigeminal nerve stimulus is increased when an individual with adequate denture chews well [17,20,27]. In fact, the sensory information that is sent through mastication to the brain can maintain the learning and memory function of the brain [9]. Therefore, we can deduce that quality of denture can play a role in maintaining cognitive status by providing better mastication and mucous membrane stimulus [9]. However, in none of the previous community-based studies was the quality of denture assessed. To our knowledge, our study is the first that aimed to take into account the role of adequate denture in the assessment of cognitive status in edentate elders by clinical examination and the use of a validated measurement tool. Previous studies reported that the association between tooth loss and cognitive impairment or dementia was stronger in people who didn't use dentures [13,25].

The bivariate analyses of the present study confirmed these results since masticatory disability occurred mostly in edentate individuals with lower functional denture quality, who subsequently had lower scores in cognitive status. Such results show that the masticatory pathway mediates the association between oral health and cognitive status, and it has therefore been used in the regression model among potential predictors.

The present study has several potential limitations. First, the study design was cross-sectional, so caution must be used in the interpretation of the observed associations. However, there is emerging evidence from large-cohort longitudinal studies regarding the role of oral health in cognitive status, which may help to elucidate the mechanism [11,13,14,23–25]. Secondly, cognitive status and mastication performance were ascertained by use of self-reported measures. Thirdly, even though depressive symptoms, age, and education were added to the multivariate model in order to account for their potential as confounders, we were not able to take into account several residual confounders, such as genetic and vascular risk factors. Moreover, we do not to assume that the analyses, even adjusted for confounders, establish the 'causal part' of the association between masticatory ability and cognitive function. Long-term cohort studies that integrate epidemiological and clinical data with neuropathological and neuroimaging information are needed to better understand the underlying mechanisms that link both oral status and mastication performance to neurodegeneration.

Cognitive impairment is a major public health issue, and the development of preventive strategies is needed to decrease substantial risk of morbidity in elders.

5. Conclusion

These results suggest that cognitive status may be influenced by functional denture quality via the mastication pathway. There is a need for large-scale cohort studies with comprehensive assessments of oral health status, masticatory function, and cognitive activity with both objective and subjective measurement tools.

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