The Open Psychology Journal

Content list available at: https://openpsychologyjournal.com

RESEARCH ARTICLE

Tooth Loss, Occlusal Teeth Support, Salivary Flow Rate, and Food Texture Choice in the Elderly with Cognitive Impairment: A Preliminary Study in Indonesia

Kartika I. Sari[1,*], Paulus A. Ong[2], Ambrosius Purba[3] and Sunardhi Widyaputra[1]

[1]*Department of Oral Biology, Faculty of Dentistry, Universitas Padjadjaran, Sumedang, Jawa Barat 45363,, Indonesia*
[2]*Department of Neurology, Hasan Sadikin Hospital, Bandung, Indonesia*
[3]*Department of Physiology, Faculty of Medicine Universitas Padjadjaran, Sumedang, Jawa Barat 45363, Indonesia*

Abstract:

Background:

The elderly are at risk of experiencing oral health problems and chewing due to tooth-loss, decreased occlusal teeth support, and decreased salivary flow rate.

Objective:

This study aimed to compare distribution and comparison tooth loss, the proportion of occlusal teeth support, salivary flow rate, and the choice of food texture between the normal and cognitive impairment groups.

Methods:

Preliminary study and cross-sectional designed method on community-dwelling elderly in Bandung City, Indonesia. The inclusion criteria were no complaint of orofacial pain, not wearing denture prostheses, good communication skills, reading and writing skills, and good physical health. Demographic data include age, gender, education, and occupation. Tooth loss distribution, the proportion of occlusal contact zone, salivary flow rate, and choice of food texture were determined. Cognitive function was measured using the mini mental short examination (MMSE) form. A Mann-Whitney test was used to compare normal and cognitive impairment groups with a significance level of p-value <0.05.

Results:

25 cognitive normals with MMSE score ≥25 and 10 cognitive impairment with MMSE score <25. Mean anterior tooth-loss was 2.16±3.89 vs. 4.90± 4.28 ($p<0.05$) and posterior tooth loss was 7.12± 5.89 vs 10.40± 4.90, $p> 0.05$ under normal condition compared with the cognitive impairment groups. Fewer occlusal support zone was found more frequently in cognitive impairment by groups B2, B3, B4, and C according to the Eichner Index classification. Salivary flow rate was 1.2942± 0.5768 vs 1.2755± 0.9811, $p> 0.05$. The participants in both groups preferred a hard-solid food portion.

Conclusion:

The loss of anterior teeth is significantly different. The loss of posterior teeth appeared to be different between the elderly with cognitive impairment compared with the normal groups. The occlusal support zone, salivary flow rate, and the choice of food texture as a meal served were similar between both groups in this study.

Keywords: Tooth loss, Occlusal support zone, Salivary flow rate, Choice of food texture, Cognitive impairment, Fever.

Article History	Received: September 25, 2020	Revised: February 19, 2021	Accepted: April 1, 2021

1. INTRODUCTION

Poor oral health among the elderly is evident in a high rate of tooth loss and the prevalence of periodontal disease [1 - 3]. Older people are more likely to lose anterior and posterior teeth. Tooth loss has a negative impact on poor oral health-related quality of life (OHRQoL). The inability to chewing is associated with a decrease in the number of natural teeth [4]. Indonesia is preparing for an aging population. The population aged 60 and over is projected to increase to 33.7 million or 11.8% of the total population in 2025, and in 2035, it will reach 48.2 million, or 15.8% [5]. Based on data from the Indonesian

* Address correspondence to this author at the Department of Oral Biology, Faculty of Dentistry, Universitas Padjadjaran, Sumedang, Jawa Barat 45363, Indonesia TeL: +6285263167939; E-mail: kartika.sari@fkg.unpad.ac.id

Basic Health Research 2013 (RISKESDA), it is known that people aged 55-64 years have lost their teeth 10.13, and at the age of 65 years and over have lost their teeth 17.05 [6].

Aging is a risk factor for deteriorating oral function. Toothache is one of the health complaints most frequently reported by the elderly population in Indonesia, which is around 0.8-1.8% [6]. The loss of oral function impacts the quality of life (QoL) [4, 7]. The elderly are also at higher risk of developing xerostomia [8, 9]. These conditions cause poor masticatory performance and chewing ability [4, 10], which impacts the choice of food texture for daily diet and insufficient nutritional intake [11 - 13]. A literature study revealed that decreased masticatory activity can affect cognitive function [14 - 16].

Indonesia is a member of the Association of Alzheimer's Disease International (AADI) in the Asia Pacific region. People with Alzheimer's disease in Indonesia increased as many as people with dementia, in 2015 it reached 1 million people and in 2016 there was an increase of 1.2 million people. As people age, it is estimated that by 2030 people with dementia Alzheimer's disease will reach 1.8 million people and the number of people with dementia Alzheimer's disease in 2050 is estimated to be 4 times higher to 4 million [17].

The link between mastication function and cognition has been explored in human studies, particularly in the elderly [18]. However, there has been no published study for the elderly Indonesian population on this topic. Therefore, this preliminary study aimed to determine the distribution and comparison of tooth loss, the proportion of tooth contact zones, salivary flow rate, and choice of food texture between normal and cognitive impairment in the community-dwelling elderly at Coblong District Bandung, Indonesia.

2. MATERIALS AND METHODS

This cross-sectional study obtained the approval of the Ethics Committee of the Faculty of Medicine, Universitas Padjadjaran Indonesia with registration number 0519010096. Data collection was carried out selectively from two Integrated Services Centre (Posyandu) in Coblong District, Bandung City, Indonesia. There were 35 elderly people aged ≥ 60 years. The inclusion criteria were no complaints of orofacial pain, not wearing denture prostheses, good communication skills, reading and writing skills, and good physical health. The characteristics of the elderly include sex, age, education, and occupation were observed. This study measured and compared the distribution of tooth loss, the proportion of occlusal contact zones, salivary flowrate, choice of food texture, and cognitive score.

2.1. Distribution of Tooth Loss and Occlusal Supporting Zone

The number of tooth loss was recorded. The tooth loss was considered as missing teeth, radix, or the teeth, which were indicated for extraction. Third molars were excluded from the counted tooth. The distribution of tooth loss was divided into two categories; anterior and posterior tooth loss. There are two groups of anterior tooth loss, namely loss of anterior teeth ≤ 3 and 4-12 anterior tooth loss. Likewise, the posterior tooth loss was divided into two groups as well, namely loss of posterior teeth ≤9 and 10-16 posterior tooth loss.

The occlusal contact zone was determined from a dental status recording and assessed by Eichner Index (EI) classification. The Eichner index is based on the presence or absence of an occlusal contact zone in each premolar and molar region. A maximum of four contact zone and at least one tooth in contact with the antagonist were counted [19]. EI classification as followed; the classification was divided into categories groups A, B1-4, and C, as shown in Fig. (**1**).

2.2. Salivary Flow Rate Assessment

One of the simpler, reproducible, and low-cost tests for salivary flow rate measurement is the Saxon test protocol by Peter [20, 21]. This method is implementable for the elderly. Participants were seated and asked to chew cotton wrapped in sterile gauze for 2 minutes. The specific instructions given were: "Place the pieces of gauze into your mouth and begin chewing as if you were chewing gum. Chew as natural as usual. Do not swallow saliva. After 2 minutes, the gauze and the whole saliva spit it out into a plastic cup." The production of saliva was calculated by weighing the plastic cup with gauze before and after chewing.

The sample volume of saliva was determined gravimetrically, assuming a specific gravity of 1.0, the weighing (gm/ml) converted into ml/ minute (1gm = 0,001liter =1 ml). Saliva was collected between 10:00 - 15.00 am. Measurement of saliva scale used AEG-80 SM electric analytical balance, which is accurate to 10^{-4} gm. The flow rates of all saliva were expressed in ml/min.

2.3. Choice of Food Texture for Daily Serving

The choice of food texture was taken from the data collected (using a modification of the semi-Quantitative FFQ list) based on the physical appearance of food in a daily serving. The lists of types of food served daily, namely regular dishes and special dishes. The participants were asked to choose one type of dish they prefer to serve. Daily serving variations based on how they prepared the food for the meal. These were divided into soft solid food (stimmed or boiled) and hard solid food (fried or baked). Food texture was categorized as hard solid if it requires high masticatory activity and food texture was categorized as soft solid if it requires low masticatory activity [22]. In the present study, the regular dish meant hard solid food and the special diet meant soft solid food, respectively.

2.4. A Screening Tool for Cognitive Function

MMSE is a global screening tool for cognitive function and has been used in the previous study elsewhere on the topic of mastication and cognitive function [23 - 26]. We used MMSE as screening tools in this study. The cognitive function category was divided into two based on the cutoff > 25 normal and ≤ 25 was cognitive impairment, respectively.

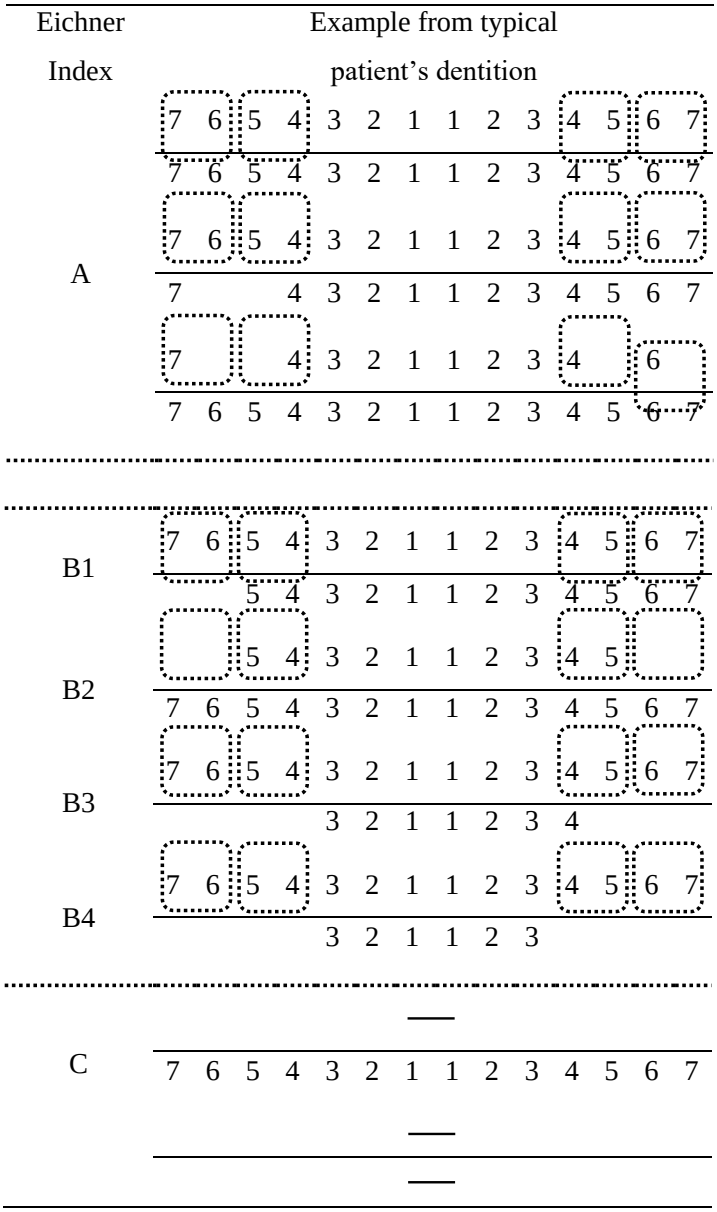

Fig. (1). Table of groups of Eichner Index [19].

3. RESULTS

Based on the MMSE cognitive score in 35 participants, there were 25 subjects normal and 10 subject cognitive impairment. Table **1** showed demographic data of 35 participants. There were no significant differences in participant's characteristics in both groups, the normal and the cognitive impairment, except education ($p=0.006$, $p<0.05$).

Table 1. Characteristic participants based on MMSE score categories.

Demography	Total Sample N = 35	Normal n = 25	Cognitive Impairment n= 10	p-value
Sex†	Male 10 (28,6%)	Male 7 (28%)	Male 3 (30%)	0.906
Age†† **Min–max; mean**	60 – 93; 69.66	60 – 93; 69.16	61 – 83; 70.90	0.410
Edu†† **Min-max; mean**	0 – 16; 8.31	6 – 16; 9.36	0 – 9; 5.70	0.006*

(Table 1) contd.....

Demography	Total Sample N = 35	Normal n = 25	Cognitive Impairment n= 10	p-value
Occupation (%)^ Entrepreneur	(1) 2.9	-	(1) 10.0	0.052
Government Employee	(6) 17.1	(5) 20.0	(1) 10.0	
Laborer	(6) 17.1	(4) 16.0	(2) 20.0	
Retired	(3) 8.6	(3) 12.0	-	
Housewife	(19) 54.3	(13) 52.0	(6) 60.0	

† Chi-Square, †† Mann-Whitney and ^ Kruskal-Wallis, *p< 0.05 was a significant level

Table 2. Description of variables based on the MMSE score categories.

Variable	Total Sample N = 35	Normal cognitive N = 25	Cognitive impairment N = 10	p-value
Tooth loss (mean, SD)†† Anterior Posterior	2.9± 4.1 8.1± 5.8	2.2 ±3.9 7.1±5.9	4.9±4.3* 10.4±4.9	0.009* 0.075
Eichner Index (%) ^ A B1 B2 B3 B4 C	7 (20) 7 (20) 6 (17.1) 3 (8.6) 3 (8.6) 9 (25.7)	6 (24) 6 (24) 4 (16) 2 (8) 2 (8) 5 (20)	1 (10) 1 (10) 2 (20) 1 (10) 1 (10) 4 (40)	0.650
The choice of food texture (%) † Soft solid food Hard solid food	7 (20.59) 27 (79.41)	4 (16.67) 20 (83.33)	3 (30.00) 7 (70.00)	0.381
Salivary flow rate (mean, SD) ††	1.2888± 0.6998	1.2942± 0,5768	1.2755± 0.9811	0.688

† Chi-Square, †† Mann-Whitney,^ Kruskal-Wallis, *p< 0.05 was a significant level

We investigated the distribution of tooth loss according to their position as the anterior and the posterior tooth loss, EI classifications, choice of food texture, and salivary flow rate in the groups were compared. There was a higher significance of anterior tooth loss in the cognitive impairment group compared to the normal cognitive group, p< 0.05. (Table **2**)

We observed the proportion of the choice of food texture and salivary flow rate also in the tooth-loss category without taking into account the cognitive score as presented in Table **3**. The subject preferred the portion of hard solid food (92%) to be served daily in the ≤3 anterior tooth loss group and the portion of soft solid food (55.6%) in the 4-12 anterior tooth loss group. There was a significant difference in daily serving choice between hard solid and soft solid foods in the variability of anterior tooth loss diversity, p= 0.002 (p<0.05). The results were similar for posterior tooth loss with a significant difference, p=0.007 (p<0.05), in choosing daily dishes between hard solid and soft solid foods.

Table 3. Description of food texture selection and salivary flowrate in tooth loss category without cognitive score assessment.

Variable	Anterior tooth-loss N=34		p-value	Posterior tooth-loss N=34		p-value
	≤ 3 teeth n=25	4-12 teeth n=9		≤9 teeth n=20	10-16 teeth n=14	
The choice of food texture (%) † Soft solid food Hard solid food	8(2) 92(23)	55.6 (5) 44.4(4)	0.002*	5 (1) 95 (19)	42.9 (6) 57.1(8)	0.007*
Salivary flowrate (mean,SD) ††	1.3340 ± 0.7408	1.1583 ± 0.5831	0.257	1.4711 ± 0.7394	1.0153 ± 0.5525	0.043*

† Chi-Square, †† Mann-Whitney. p< .05 was a significant level

Salivary flow rate in the ≤ 3 groups anterior tooth loss was higher than in the 4-12 groups anterior tooth loss, p> 0.05. In contrast, there was a decrease in salivary flow rate in the posterior 10-16 tooth loss group compared with the ≤ 9 posterior tooth loss group, p< 0.05 as showed in Table **3**.

4. DISCUSSION

This study was the first exploration of the tooth loss distribution, Eichner Index (EI) classification proportion, salivary flow rate, choice of food texture on the two groups based on the MMSE score in the community-dwelling elderly in Indonesia. The result will give important information for continuing the prospective study in the future. There was no significant difference in the characteristics of the participants in age and gender for normal and cognitive impairment groups, p>0.05. We found the level of education was significantly lower in the cognitive impairment group (p=0.006, p<0.05).

There were variations in the level of education in this community from uneducated to university level. The average education level was 8.31 years. Our study shows the cognitive impairment group has a lower level of education, by an average of 5.70 years. We found significantly higher anterior tooth loss in the cognitive impairment groups (p<0,05) and showed a higher tendency of posterior tooth loss compared with the normal groups (10.4±4.9 *vs* 7.1±5.9), p> 0.05. As we mentioned earlier, we investigated the position of tooth loss to determine the distribution of tooth loss occurring in the cognitive impairment group due to an increase in recent studies on tooth status or the number of teeth and cognitive decline [25, 27 - 30]. One study conducted by Takeuchi *et al*. demonstrated an association between posterior tooth occlusion and cognitive function [31]. In our study, we found that the cognitive impairment group had a higher anterior tooth loss and they had a lower education level as well.

A study in Indonesia conducted by Umniyati *et al*. revealed a link between age, anterior tooth loss, and posterior tooth loss, and quality of life. Respondents are mostly women (86%) and have low education (67%). Furthermore, there was no relationship between gender, employment status, and education level with the quality of life [32]. Another study by Kusdhany *et al*. showed that 6.78% of respondents had academic and university degrees, but the results explained that there was no correlation between age and education level with OHR-QoL [33]. These results support our data which shows that most of the respondents still have a low level of education. Low education level will result in a lack of good source income, limited access to oral health information, and delay in visiting dentists. In this community-dwelling elderly, oral health has not become a priority in their life. So, that it will have an impact on low OHR-QoL.

Another similar study in Jordan by A-Omiri *et al*. revealed that tooth loss has an impact on the level of satisfaction with their appearance, pain levels, oral comfort, general performance, and capacity to eat in daily living [34]. Another Brazilian study divided loss of teeth into anterior tooth loss dan posterior tooth loss performed by Batista *et al*. The results showed that tooth loss of up to 12 teeth including the anterior teeth resulted in a higher oral health index profile (OHIP) score compared to those who lost 12 teeth but only the posterior teeth. The position of the tooth loss determines the quality of life rather than the number of teeth alone [35]. A study revealed that oral health-related quality of life (OHR-QoL) did not depend on the number of tooth loss due to a weak correlation (r= -0.133, p= 0.041) [33]. A previous review study by Gerritsen *et al*. stated that tooth loss is associated with impairment of OHR-QoL and distribution of tooth loss affects the severity of impairment [7].

From most of the studies, the proportion of female is higher than men due to the possibility of the female having a long life expectancy. This condition impacts our data which shows a higher proportion of females than males in cognitive impairment compared to the normal groups. The significant correlation between the number of anterior tooth loss and appearance, oral comfort, general performance, and eating dimension indicated that females felt more influence on appearance, comfort, and eating capacity. While on the other hand, females experience partial tooth loss, including loss of anterior teeth, which is higher than males. Factors that influence the perception of a person's quality of life are age, gender, and education [34]. These factors can differ in Indonesia compared to other studies in other countries, possibly due to differences in the way of thinking, education, and social-economic factors [33].

Our data reports the low education of the elderly and most of the respondents were housewives. It may lead to a lack of source of income. This condition impacts a visit to the dentist and is delayed for the treatment of removable or fixed denture treatment (Pontic). Also, a mindset that prioritizes general health with systemic disease often affects the elderly such as hypertension, diabetes, arthritis, etc. Making a denture is still quite expensive. We found that elderly with low education levels have decreased cognitive function and may not care about aesthetic value.

The observation of posterior tooth loss was constrained by the number of samples. However, observing contact occlusion with EI classification revealed that there was more tooth loss and less occlusal support zone in the cognitive impairment group, p>0.05. The elderly who experiences more tooth loss will have an impact on masticatory force decline. The occlusal force can change to be lower in people who have lost occlusal contact. Furthermore, a decrease in occlusal force causes a change in masticatory force. The sequence of masticatory movement and decreased masticatory force may lead to improper cerebral blood circulation. The cerebral blood circulation is influenced by the input of sensory neuron that comes to generate motor commands that control biting force and masticatory movement patterns [36]. The occlusal force will provide feedback control due to changes in the physical properties of food changes [37]. This condition can cause severe cognitive impairment that already exists or can increase the risk of cognitive decline in later life [38 - 40].

Based on the cognitive scores obtained through the MMSE measurement, there was no significant difference in the choice of hard-solid or soft-solid foods between the normal and impaired groups, p>0.05, as well as results of salivary flow rates according to the cognitive test explaining that there was

no significant difference between the two groups, p> 0.05. The results showed that the elderly preferred hard-solid food for daily serving. In general, the elderly had a lower stimulated salivary flow rate than younger ones (p<0.001) [9]. The rate of stimulated saliva flow tended to decrease in the cognitive impairment than in the normal cognitive groups, (p>0,05). The rate of stimulated saliva flow in healthy participants was found to be about 1.60 ml/min [21]. Another study revealed that the stimulated salivary flow rate in the elderly was 1.52 ± 0.73 ml/min [41] and other studies said 1.36 ± 0.97 ml/min [42].

Furthermore, we also looked at the proportion of choice of food texture and salivary flow rate in the tooth loss category regardless of cognitive scores. There was a significant difference in the choice of food texture according to the distribution of tooth loss, as shown in Table **3**. There was a significant difference in the selection of daily meals for the category of anterior tooth loss, p= 0.002 (p<0.05) and category of posterior tooth loss, p=0.007 (p<0.05). The Elderly preferred to serve a portion of hard-solid food for daily meals when they lose fewer anterior teeth and the pattern will change into a portion of soft solid food when more anterior teeth have lost. However, the elderly preferred only one portion of hard-solid food to be served daily regardless of the conditions of posterior tooth loss appearing in the oral cavity.

As we all know, the posterior teeth provide the function for grinding the food. The saliva will moisten the food as it chews it into a bolus [22]. In our study, we showed a significant reduction in salivary flow rate in the group with more posterior tooth loss compared to the group with less posterior tooth loss, p< 0.05 as shown in Table **3**. We have found an association between masticatory activity and salivary secretion called masticatory-salivary reflex in most studies [9, 20, 42 - 44]. Our study is in line with a previous study in Japan which revealed a decrease in salivary flow rate associated with an occlusal decline [43]. Similar results were carried out by Ikebe *et al*. in another study that described a lower salivary flow rate in posterior tooth-loss [45].

The number of natural teeth in the oral cavity has an important role in the mastication process and masticatory force. The masticatory force will lead a signal to stimuli oxygen blood flow in selective brain areas. Stimulation of jaw movement and muscle contraction while chewing gum leads to increased blood oxygenation level-dependent (BOLD) in some of the brain regions. Chewing resulted in a bilateral increase of signal in the sensorimotor cortex, supplementary motor area, insula, thalamus, and cerebellum [37, 46 - 48]. Chewing maintenance hippocampus and alternated to prevent cognitive decline in humans.

Mastication function decline can be compensated by a longer duration of mastication and a softer diet [45, 49 - 52]. Reduced number of teeth and the occlusal supported zone will cause a decrease in the function of mastication due to reduced masticatory force [43, 45, 53]. The masticatory force is involved in masticatory process and is related to the level of food texture [53, 54]. Unfortunately, this study did not assess the masticatory force. The elderly chose a hard solid foods portion in both the normal and cognitive impairment groups. The previous studies showed differences in masticatory pattern semi-solid, soft-solid, and hard-solid foods in the elderly [53, 55].

The limited number of subjects has not provided a comprehensive feature of the oral health condition in the elderly. We found that the condition of resignation due to old age causes a less problematic response with tooth loss and even anterior tooth loss. The elderly did not mind appearance and function when it involves loss of posterior teeth. The elderly's knowledge in this study was low level, possibly having an impact on awareness of behavior in maintaining oral health, treatment, and rehabilitation effort, and so on. Without realizing it, they will experience chewing problems, decreased cognitive function, and lower quality of life.

Further study is needed to explain the findings that elderly with low education experience impaired cognition and do not pay attention to their oral health performance.

CONCLUSION

The loss of anterior teeth is significantly different. The loss of posterior teeth appeared to be different between the elderly with cognitive impairment compared with the normal groups. The occlusal support zone, salivary flow rate, and the choice of food texture as a meal served were similar between both groups in this study.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The protocol of the study was approved by the Institutional Ethics Committee of Universitas Padjadjaran, Indonesia, under approval number 302/ UN6.KEP/EC/2019.

HUMAN AND ANIMAL RIGHTS

No animals were used in this study. All human study procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PARTICIPATION

Written informed consent was obtained prior to participation in this study.

AVAILABILITY OF DATA AND MATERIALS

Not applicable

FUNDING

This study is supported by the Academic leadership Grant (ALG) of Universitas Padjadjaran number 1427/ UN6.3.1/ LT/ 2020.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

All authors are grateful to the participants who participated in this study.

REFERENCES

[1] Gil-Montoya JA, de Mello AL, Barrios R, Gonzalez-Moles MA, Bravo M. Oral health in the elderly patient and its impact on general well-being: A nonsystematic review. Clin Interv Aging 2015; 10: 461-7.
[http://dx.doi.org/10.2147/CIA.S54630] [PMID: 25709420]

[2] Razak PA, Richard KM, Thankachan RP, Hafiz KA, Kumar KN, Sameer KM. Geriatric oral health: A review article. J Int Oral Health 2014; 6(6): 110-6.
[PMID: 25628498]

[3] Okamoto N, Amano N, Nakamura T, Yanagi M. Relationship between tooth loss, low masticatory ability, and nutritional indices in the elderly : A cross-sectional study 2019; 1-10.
[http://dx.doi.org/10.1186/s12903-019-0778-5]

[4] Bortoluzzi MC, Traebert J, Lasta R, Da Rosa TN, Capella DL, Presta AA. Tooth loss, chewing ability and quality of life. Contemp Clin Dent 2012; 3(4): 393-7.
[http://dx.doi.org/10.4103/0976-237X.107424] [PMID: 23633796]

[5] Republik Indonesia KK. Indonesia memasuki periode aging [Internet] 2016.
https://www.kemkes.go.id/article/view/16031000003/indonesia-masuki-periode-aging-population.html/

[6] Kemenkes RI. Riset kesehatan dasar 2013 [Internet] Jakarta: Badan penelitian dan pengembangan kesehatan 2013. http://kesga.kemkes.go.id/images/pedoman/Data Riskesdas 2013.pdf

[7] Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NHJ. Tooth loss and oral health-related quality of life: A systematic review and meta-analysis. Health Qual Life Outcomes 2010; 8(1): 126. http://www.hqlo.com/content/8/1/126 [Internet].
[http://dx.doi.org/10.1186/1477-7525-8-126] [PMID: 21050499]

[8] Sørensen CE, Hansen NL, Mortensen EL, Lauritzen M, Osler M, Pedersen AML. Hyposalivation and poor dental health status are potential correlates of age-related cognitive decline in late midlife in danish men. Front Aging Neurosci 2018; 10
[http://dx.doi.org/10.3389/fnagi.2018.00010]

[9] Smith CH, Boland B, Daureeawoo Y, Donaldson E, Small K, Tuomainen J. Effect of aging on stimulated salivary flow in adults. J Am Geriatr Soc 2013; 61(5): 805-8.
[http://dx.doi.org/10.1111/jgs.12219] [PMID: 23617733]

[10] Lexomboon D, Trulsson M, Wårdh I, Parker MG. Chewing ability and tooth loss: association with cognitive impairment in an elderly population study. J Am Geriatr Soc 2012; 60(10): 1951-6.
[http://dx.doi.org/10.1111/j.1532-5415.2012.04154.x] [PMID: 23035667]

[11] Mioche L, Bourdiol P, Peyron MA. Influence of age on mastication: Effects on eating behaviour. Nutr Res Rev 2004; 17(1): 43-54.
[http://dx.doi.org/10.1079/NRR200375] [PMID: 19079914]

[12] Whitelock E, Ensaff H. On your own: Older adults' food choice and dietary habits. Nutrients 2018; 10(4): 413.

[13] Azzolino D, Passarelli PC, De Angelis P, Piccirillo GB, D'Addona A, Cesari M. Poor oral health as a determinant of malnutrition and sarcopenia. Nutrients 2019; 11(12): 2898.
[http://dx.doi.org/10.3390/nu11122898] [PMID: 31795351]

[14] Teixeira FB, Pereira Fernandes LdeM, Noronha PA, *et al.* Masticatory deficiency as a risk factor for cognitive dysfunction. Int J Med Sci 2014; 11(2): 209-14.
[http://dx.doi.org/10.7150/ijms.6801] [PMID: 24465167]

[15] Toyoshita Y, Kan Y, Sasaki M, Kawanishi K, Koshino H. Relationship between masticatory function and mild cognitive impairment in elderly people wearing removable dentures. Dent Oral Cranio Fac Tes 2017; 3(7): 1-3. https://www. oatext.com/pdf/DOCR-S2-001.pdf

[16] Shin HE, Chang IJ, Cho MJ, Song KB, Choi YH. Association between masticatory ability, oral health-related quality of life, and cognitive function in the elderly population using structural equation modeling. J Korean Acad Oral Health 2018; 42(4): 159-66.
[http://dx.doi.org/10.11149/jkaoh.2018.42.4.159]

[17] International AD, Australia A. Dementia in the Asia Pasific Region 2014.https://www.alzint.org/u/Dementia-Asia-Pacific-2014.pdf

[18] Tada A, Miura H. Association between mastication and cognitive status: A systematic review. Arch Gerontol Geriatr 2017; 70: 44-53.
[http://dx.doi.org/10.1016/j.archger.2016.12.006] [PMID: 28042986]

[19] Yoshino K, Kikukawa I, Yoda Y, *et al.* Relationship between Eichner Index and number of present teeth. Bull Tokyo Dent Coll 2012; 53(1): 37-40.
[http://dx.doi.org/10.2209/tdcpublication.53.37] [PMID: 22452891]

[20] Kubota C, Kanazawa M, Hama Y, Komagamine Y, Minakuchi S. Association between chewing-stimulated salivary flow under the effects of atropine and mixing ability assessed using a color-changeable chewing gum. J Prosthodont Res 2017; 61(4): 387-92. [Internet].
[http://dx.doi.org/10.1016/j.jpor.2016.12.009] [PMID: 28126244]

[21] Kohler PF, Winter ME. A quantitative test for xerostomia. The Saxon test, an oral equivalent of the Schirmer test. Arthritis Rheum 1985; 28(10): 1128-32.
[http://dx.doi.org/10.1002/art.1780281008] [PMID: 4052124]

[22] Bilt A, Van Der , Abbink JH. The influence of food consistency on chewing rate and muscular work. Arch Oral Biol 2017; 83: 105-.

[23] Saito S, Ohi T, Murakami T, *et al.* Association between tooth loss and cognitive impairment in community-dwelling older Japanese adults: A 4-year prospective cohort study from the Ohasama study. BMC Oral Health 2018; 18(1): 142.
[http://dx.doi.org/10.1186/s12903-018-0602-7] [PMID: 30126407]

[24] Mummolo S, Ortu E, Necozione S, Monaco A, Marzo G. Relationship between mastication and cognitive function in elderly in L'Aquila. Int J Clin Exp Med 2014; 7(4): 1040-6.
[PMID: 24955179]

[25] Nilsson H, Berglund J, Renvert S. Tooth loss and cognitive functions among older adults. Acta Odontol Scand 2014; 72(8): 639-44.
[http://dx.doi.org/10.3109/00016357.2014.882983] [PMID: 24479559]

[26] Nilsson H, Sanmartin Berglund J, Renvert S. Longitudinal evaluation of periodontitis and development of cognitive decline among older adults. J Clin Periodontol 2018; 45(10): 1142-9.
[http://dx.doi.org/10.1111/jcpe.12992] [PMID: 30076762]

[27] Luo J, Wu B, Zhao Q, *et al.* Association between tooth loss and cognitive function among 3063 Chinese older adults: A community-based study. PLoS One 2015; 10(3)e0120986
[http://dx.doi.org/10.1371/journal.pone.0120986] [PMID: 25803052]

[28] Elsig F, Schimmel M, Duvernay E, *et al.* Tooth loss, chewing efficiency and cognitive impairment in geriatric patients. Gerodontology 2015; 32(2): 149-56.
[http://dx.doi.org/10.1111/ger.12079] [PMID: 24128078]

[29] Takeuchi K, Ohara T, Furuta M, *et al.* Tooth loss and risk of dementia in the community: The hisayama study. J Am Geriatr Soc 2017; 65(5): e95-e100.
[http://dx.doi.org/10.1111/jgs.14791] [PMID: 28272750]

[30] Okamoto N, Morikawa M, Okamoto K, *et al.* Relationship of tooth loss to mild memory impairment and cognitive impairment: Findings from the Fujiwara-kyo study. Behav Brain Funct 2010; 6(1): 77.
[http://dx.doi.org/10.1186/1744-9081-6-77] [PMID: 21194415]

[31] Takeuchi K, Izumi M, Furuta M, *et al.* Posterior teeth occlusion associated with cognitive function in nursing home older residents: A cross-sectional observational study. PloS One 2015; 10(10): e0141737.
[http://dx.doi.org/10.1371/journal.pone.0141737]

[32] Umniyati H, Surachmin A, Ambarsati G. The relationship between anterior tooth loss and quality of life among elderly in Posbindu, Bojongnangka, Kelapa Dua Sub-District, Tangerang, Jakarta-Indonesia. Bali Med J 2018; 7(3): 626-30.
[http://dx.doi.org/10.15562/bmj.v7i3.1192]

[33] Kusdhany LS, Sundjaja Y, Fardaniah S, Ismail RI. Oral health related quality of life in Indonesian middle-aged and elderly women. Med J Indones 2011; 20(1): 62-5.
[http://dx.doi.org/10.13181/mji.v20i1.430]

[34] Al-Omiri MK, Karasneh JA, Lynch E, Lamey PJ, Clifford TJ. Impacts of missing upper anterior teeth on daily living. Int Dent J 2009; 59(3): 127-32.
[PMID: 19637520]

[35] Batista MJ, Lawrence HP, de Sousa MdaL. Impact of tooth loss related to number and position on oral health quality of life among adults. Health Qual Life Outcomes 2014; 12: 165. http://www.hqlo.com/content/12/1/165 [Internet].
[http://dx.doi.org/10.1186/s12955-014-0165-5] [PMID: 25433483]

[36] Bosman F, van der Bilt A, Abbink JH, van der Glas HW. Neuromuscular control mechanisms in human mastication. J Texture Stud 2004; 35: 201-21.
[http://dx.doi.org/10.1111/j.1745-4603.2004.tb00833.x]

[37] Takahashi T, Miyamoto T, Terao A, Yokoyama A. Cerebral activation related to the control of mastication during changes in food hardness. Neuroscience 2006; 145(3): 791-4.

[38] Teixeira FB, Pereira Fernandes L de M, Tavares Noronha PA. Masticatory deficiency as a risk factor for cognitive dysfunction. Int J Med Sci 2014; 11(2): 209-14.

[39] Terasawa H, Hirai T, Ninomiya T, *et al.* Influence of tooth-loss and

concomitant masticatory alterations on cholinergic neurons in rats: Immunohistochemical and biochemical studies. Neurosci Res 2002; 43(4): 373-9.
[http://dx.doi.org/10.1016/S0168-0102(02)00063-9] [PMID: 12135780]

[40] Onozuka M, Watanabe K, Mirbod SM, *et al.* Reduced mastication stimulates impairment of spatial memory and degeneration of hippocampal neurons in aged SAMP8 mice. Brain Res 1999; 826(1): 148-53.
[http://dx.doi.org/10.1016/S0006-8993(99)01255-X] [PMID: 10216208]

[41] Vandenberghe-Descamps M, Laboure H, Prot A, *et al.* Salivary flow decreases in healthy elderly people independently of dental status and drug intake. J Text Stud 2016; 1-8.

[42] Ikebe K, Matsuda KI, Morii K, *et al.* Relationship between bite force and salivary flow in older adults. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 104(4): 510-5.
[http://dx.doi.org/10.1016/j.tripleo.2006.12.006] [PMID: 17448711]

[43] Ikebe K, Matsuda K, Kagawa R, *et al.* Association of masticatory performance with age, gender, number of teeth, occlusal force and salivary flow in Japanese older adults: Is ageing a risk factor for masticatory dysfunction? Arch Oral Biol 2011; 56(10): 991-6. [Internet].
[http://dx.doi.org/10.1016/j.archoralbio.2011.03.019] [PMID: 21529776]

[44] Villa A, Connell CL, Abati S. Diagnosis and management of xerostomia and hyposalivation. Ther Clin Risk Manag 2014; 11: 45-51.
[http://dx.doi.org/10.2147/TCRM.S76282]

[45] Ikebe K, Matsuda K, Kagawa R, *et al.* Masticatory performance in older subjects with varying degrees of tooth loss. J Dent 2012; 40(1): 71-6.
[http://dx.doi.org/10.1016/j.jdent.2011.10.007] [PMID: 22037296]

[46] Chen H, Iinuma M, Onozuka M, Kubo KY. Chewing maintains hippocampus-dependent cognitive function. Int J Med Sci 2015; 12(6): 502-9.
[http://dx.doi.org/10.7150/ijms.11911] [PMID: 26078711]

[47] Onozuka M, Hirano Y, Tachibana A, *et al.* Interaction between chewing and brain activity in human.Novel Trens in Brain Science. Japan: Springer Japan 2008; pp. 99-113.

[48] Onozuka M, Fujita M, Watanabe K, *et al.* Mapping brain region activity during chewing: A functional magnetic resonance imaging study. J Dent Res 2002; 81(11): 743-6.
[http://dx.doi.org/10.1177/0810743] [PMID: 12407087]

[49] Mishellany-Dutour A, Renaud J, Peyron MA, Rimek F, Woda A. Is the goal of mastication reached in young dentates, aged dentates and aged denture wearers? Br J Nutr 2008; 99(1): 121-8.
[http://dx.doi.org/10.1017/S0007114507795284] [PMID: 17666149]

[50] Shiozawa M, Taniguchi H, Hayashi H, *et al.* Differences in chewing behavior during mastication of foods with different textures. J Texture Stud 2013; 44(1): 45-55.
[http://dx.doi.org/10.1111/j.1745-4603.2012.00364.x]

[51] Newton JP, Yemm R, Abel RW, Menhinick S. Changes in human jaw muscles with age and dental state. Gerodontology 1993; 10(1): 16-22.
[http://dx.doi.org/10.1111/j.1741-2358.1993.tb00074.x]

[52] Komino M, Shiga H. Changes in mandibular movement during chewing of different hardness foods. Odontology 2017; 105(4): 418-25.
[http://dx.doi.org/10.1007/s10266-016-0292-z] [PMID: 28150182]

[53] Khamnei S, Zamanlu M, Shakouri SK, Oskoee SS. Mastication patterns in humans: Gender differences. Neurophysiology 2016; 48(5): 375-9.
[http://dx.doi.org/10.1007/s11062-017-9612-3]

[54] Mioche L, Bourdiol P, Peyron M-A. Influence of age on mastication: Effects on eating behaviour. Nutr Res Rev 2004; 17(1): 43-54.
[http://dx.doi.org/10.1079/NRR200375] [PMID: 19079914]

[55] Horio T, Kawamura Y. Effects of texture of food on chewing patterns in the human subject. J Oral Rehabil 1898; 16(2): 177-83.