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Effect of Molar Occlusal Balance on Cognitive Function in the Elderly

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ABSTRACT

Background: Elderly people with dementia, who are increasing at a rate comparable to the rate at which the elderly population is growing, are becoming a serious social problem in Korea. Therefore, the purpose of this study was to investigate the association between molar occlusal balance and cognitive function among Koreans aged 65 years and older.

Methods: A total of 308 participants aged 65 years and older who attended a senior center were recruited for the study with their consent. The Korean version of the Mini-Mental State Examination (MMSE-DS) was used to assess cognitive function, and masticatory ability was measured according to the ability to chew food, the number of remaining teeth, and the self-perceived masticatory function. Relative molar occlusal balance was measured using the T-scan III system. All collected data were analysed using SPSS version 23.0.

Results: There was a significant association between cognitive function and molar masticatory ability ($P < .05$). The participants with relative molar occlusal balance had a higher MMSE-DS score when compared to those with relative incision occlusal balance, adjusted for sociodemographic factors and number of remaining teeth, subjective masticatory ability, chewing ability, occlusion time, and denture use. Cognitive function was higher when relative molar occlusion was greater compared to anterior occlusion in anterior-posterior teeth balance.

Conclusions: Cognitive function in elderly people was higher when the relative molar occlusal balance was greater. Mastication with posterior teeth may have a more important effect on stimulation of cognitive function. Therefore, oral health care focusing on maintenance of molar teeth may be crucial for elderly persons.

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Introduction

With an increase in mean life span and a drop in the birth rate, an aging population has become a reality in countries worldwide.¹ The aging rate in Korea is quite high when

compared to those in advanced countries,² and consequently, senile disorders, such as dementia (including Alzheimer's disease) have emerged as serious social problems.³

Dementia is a degenerative neurologic disorder characterised by irreversible and continuous deterioration of brain function, for which patients eventually lose the ability to perform activities of daily living.⁴ In the United States, about 10% of adults aged 65 years or older—that is, about 2 million people—are living with dementia.⁵ In Korea, about 9.2% of the elderly population aged 65 years or older are living with dementia, and the prevalence of dementia is estimated to double every 20 years.⁶ However, the exact cause of dementia remains

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unclear, and adequate methods of treatment are currently lacking. Thus, treatment for dementia is primarily focused on alleviating symptoms and preventing further progression of the disease.⁷ Therefore, identifying risk factors for dementia and focusing on disease prevention is optimal.

Oral health has shared risk factors with many systemic diseases, and there are ongoing studies investigating these associations.⁸ Chewing is directly related to food intake, and nutritionally, it is closely related to general health.^{9,10} Tooth loss is a risk factor for reducing cognitive function by causing a reduction in occlusal balance and masticatory ability.¹¹ Recently, studies have investigated the association between cognitive function and oral health, including the effects of tooth loss and masticatory muscles on cognitive function.^{12,13}

This study was to investigate the association between molar occlusal balance and cognitive function among Korean adults aged 65 years or older.

Methods

A total of 308 participants aged 65 and older who attended a senior citizen center were included in this study. Cognitive function was assessed using the Korean version of the Mini-Mental State Examination (MMSE-DS), and masticatory ability was measured based on the patient's ability to chew food, the number of remaining teeth, and their perceived masticatory function. The relative molar occlusal balance was measured using the T-scan III system. This study was approved by the institutional review board at Kyungpook National University Hospital (IRB No.: KNUH 2015-07-007-001), and written informed consent was obtained from all the study participants.

Study participants

The study participants were recruited from 14 different senior citizen centers located within a single metropolitan city from July 2015 to August 2015. One trained examiner performed oral examinations to assess the number of remaining teeth, denture use, and occlusion, and the cognitive function tests were administered by one nurse in charge. Additionally, a dental hygienist conducted an oral-related survey via a face-to-face interview and collected general information regarding patient characteristics. Of the 642 candidates, those who could not participate in the survey due to hearing problems, when the occlusion could not be measured due to a lack of functional antagonists (natural teeth, fixed prosthesis, removable prosthesis), and who did not wish to participate in the study were excluded, resulting in a total of 308 participants (62%).

General variables

The sample was divided into 2 age groups (<80 and ≥80 years old), and the education level was divided into 2 groups (≤ elementary school and ≥ middle school). The type of living arrangement was divided into 2 groups (alone and with a spouse or other family). The history of hypertension and diabetes diagnosed by physician were obtained through the questionnaire (yes or no).

Number of remaining teeth

An oral examination was performed to check for the number of teeth remaining (among 28 teeth, with the exception of the third molars). Teeth were excluded if they were nonfunctional or had severe mobility (Miller tooth mobility classification 3). Based on the number of residual teeth, participants were categorized into one of 3 edentulous groups: 1-9 group, 10-19 group, and more than 20 group.

Subjective masticatory ability

Subjective masticatory ability was surveyed using a questionnaire with a 5-point Likert scale.¹⁴ Participants were asked to respond to the question, "Do you have discomfort when chewing?" Responses were 1 for "very true," 2 for "true," 3 for "neutral," 4 for "not true," and 5 for "not at all." Participants who answered "very true" and "true," were classified into the discomfort group. Those who answered "neutral" and "not true" were classified into the regular group, and those who answered "not at all" were classified into the good group, all of which were used for analysis of subjective masticatory ability.

Chewing ability

To measure participants' masticatory ability, subjective food chewing was surveyed.¹⁵ The participants were asked to rate their chewing ability for 5 food items (dried squid, fresh carrot, dried peanuts, radish kimchi, and caramel), the most popular hard food among Korean people using on a 5-point scale as follows: 1, cannot chew at all; 2, cannot chew well; 3, neutral; 4, can chew somewhat; and 5, can chew well. The score for each food item was summed to compute the total score. Based on the total score, participants were classified into the <10 group, 11-20 group, or >21 group. The Cronbach's α value of the reliability was 0.93 (respectively, 0.850, 0.931, 0.925, 0.915, and 0.800).

Molar occlusal balance

Molar occlusal balance was measured using the T-scan III system (Tekscan Inc.) on Microsoft Windows, divided into anterior left, anterior right, posterior left, and posterior right and were recorded in percentages. T-scan III system can be expressed in unilateral or bilateral and anterior or posterior occlusal forces in percentages. T-scan is a method to determine the strength of the contact point through the quantitative analysis of the occlusal contact. This is a method to check occlusion by evaluating the state of contact between the maxilla teeth and the mandible teeth when a tooth is in centric occlusion. Occlusal recording distinguishes the occlusal balance of the graph displayed on the Microsoft Windows screen by color.¹⁶ Occlusal balance I is a comparison of the occlusal balance of the anterior teeth and posterior teeth. The molar occlusal balance of posterior teeth was computed by subtracting the fraction of the anterior occlusion from the fraction of the posterior occlusion, with a higher value indicating a greater molar occlusal balance. Occlusal balance II is

a comparison of bilateral occlusal balance and one-side occlusal balance (left or right).¹⁷

Cognitive function

Cognitive impairment was screened using the MMSE-DS.^{18,19} This was developed for the national dementia screening test in Korea. The MMSE-DS consisted of 30 questions in total, with 0 points for the lowest and 30 points for the highest. The higher the score, the more normal the cognitive function.²⁰ Based on the total score, participants were categorised as either showing non-cognitive impairment (≥ 24) or cognitive impairment (< 24).²¹

Statistical analysis

The collected data were analysed using IBM SPSS (IBM 23.0 for windows, SPSS Inc.) software, and statistical significance was set at 5%. The participants' general characteristics were analysed with frequency analysis, and the comparisons of masticatory ability and cognitive function according to general variables were tested using the Chi-square test, t test, and one-way analysis of variance. Since MMSE-DS scores did not follow a normal distribution, non-parametric tests were performed initially. There were no differences from the results of parametric tests to the significance level ($\alpha = 0.05$). As for analytic consistency and robustness, the parametric approach was used. Linear regression analysis was performed by confirming a normal distribution using the residuals histogram. The association between cognitive function and masticatory ability was evaluated with multiple regression analysis after adjusting for age, sex, educational level, living arrangement, denture use, hypertension, and diabetes.

Results

Table 1 shows that the ages of the 308 participants ranged from 65 to 96 years, with mean ages of 78.69 ± 5.76 years. Most of the participants (249, 80.8%) had an educational level equivalent to an elementary school graduate or below, and 192 (62.3%) were using partial or complete dentures. Forty-six (14.9%) were classified as edentulous, and 57 (18.5%) had 1-9 remaining teeth. Sixty-seven (21.8%) had 10-19 remaining teeth, and 138 (41.6%) had more than 20 remaining teeth. A total of 184 (59.7%) participants had a posterior occlusal balance greater than the anterior occlusal balance, and 109 (35.4%) participants had an MMSE-DS score of 23 or lower.

In terms of cognitive function, the mean MMSE-DS score was significantly lower among those aged 80 years or older, among female participants, and among those with low educational levels ($P < .001$). Cross-sectional analysis was performed to examine the distribution of participants, and there were significant differences in cognitive function with respect to age, sex, and educational level ($P < .001$) (Table 2).

The mean MMSE-DS score was higher among those with a posterior occlusal balance greater than the anterior occlusal balance, and there were statistically significant differences in

Table 1 – Characteristics of the study participants.

Variables	No. (%)
Age	
<80	164 (53.2)
≥ 80	144 (46.8)
Sex	
Male	68 (22.1)
Female	240 (77.9)
Education	
\leq Elementary school	249 (80.8)
>Elementary school	59 (19.2)
Living arrangement	
Alone	142 (46.1)
With family	166 (53.9)
Denture use	
Yes	192 (62.3)
No	116 (37.7)
Number of remaining teeth	
0	46 (14.9)
1-9	57 (18.5)
10-19	67 (21.8)
≥ 20	138 (44.8)
Subjective mastication ability	
Discomfort (1-2)	115 (37.3)
Regular (3-4)	105 (34.1)
Good (5)	88 (28.6)
Chewing ability	
Lower (0-10)	89 (28.9)
Middle (11-20)	120 (39.0)
Higher (≥ 21)	99 (32.1)
Occlusion balance I	
Anterior	88 (28.6)
Posterior	103 (33.4)
Occlusion balance II	
Bilateral	117 (38.0)
Left side	184 (59.7)
Right side	124 (40.3)
Occlusion time (s)	
<0.3	214 (69.5)
≥ 0.3	94 (30.5)
MMSE-DS score	
≤ 23	109 (35.4)
>23	199 (64.6)
Hypertension	
Yes	128 (41.6)
No	180 (58.4)
Diabetes	
Yes	56 (18.2)
No	252 (81.8)
Total	308 (100.0)

Occlusion balance I: Anterior and posterior balanced occlusion.

Occlusion balance II: Bilateral, right, left balanced occlusion.

OT (Occlusion time): Description applied to how quickly a patient closes his/her teeth together.

MMSE-DS, Korean version of the Mini-Mental State Examination.

participant distribution according to cognitive function ($P < .005$) (Table 3).

Participants with greater anterior occlusal balance compared to posterior occlusal balance had fewer remaining teeth (Table 4).

Table 5 shows the results of multiple regression analysis regarding the association between masticatory ability and cognitive function. In model II, there was a significant positive association between the relative posterior occlusal balance and MMSE-DS score, in which the MMSE-DS score increased with increasing levels of relative posterior occlusal balance ($= .154$, $P = .009$). In model III, with adjustment for age, sex, living arrangements, educational level, denture use, hypertension, and diabetes, the MMSE-DS score was also significantly positively correlated with posterior occlusal balance ($= .144$, $P = .012$, adjusted $R^2 = .128$), and there was no problem of multicollinearity among the variables (variance inflation factor < 10).

Table 2 – Cognitive function according to general characteristics.

	Cognitive impairment						
	Mean ± SD		P value*	Yes (N = 109)		No (N = 199)	P value**
Age, y			<.001*				.002**
<80	24.89	±4.63		45	(41.3)	119	(59.8)
≥80	22.98	±4.29		64	(58.7)	80	(40.2)
Sex			.002*				.001**
Male	25.53	±4.48		13	(11.9)	55	(27.6)
Female	23.56	±4.50		96	(88.1)	144	(72.4)
Education			<.001*				<.001**
≤ Elementary school	23.37	±4.67		100	(91.7)	149	(74.9)
>Elementary school	26.64	±2.89		9	(8.3)	50	(25.1)
Living arrangement			.376				.340
Alone	24.25	±4.46		63	(57.8)	103	(51.8)
With family	23.78	±4.67		46	(42.2)	96	(48.2)
Denture use			.324				.329
Yes	23.80	±4.64		72	(66.1)	120	(60.3)
No	24.33	±4.45		37	(33.9)	79	(39.7)
Hypertension			.089				.083
Yes	23.47	±4.49		67	(46.9)	61	(37.0)
No	24.37	±4.60		76	(53.1)	104	(63.0)
Diabetes			.918				.882
Yes	24.05	±4.24		25	(17.5)	31	(18.8)
No	23.98	±4.65		118	(82.5)	134	(81.2)

P < .05 shown in bold.

* t test.

** Chi-square test.

Table 3 – Cognitive function according to masticatory ability.

	Cognitive impairment							
	Mean ± SD		P value*	Yes (N = 109)		No (N = 199)		P value**
Occlusion balance I			.024					.027
Anterior	23.52	±4.75		95	(66.4)	89	(53.9)	
Posterior	24.71	±4.20		48	(33.6)	76	(46.1)	
Occlusion balance II			.181					.941
Bilateral	23.49	±5.18		42	(29.4)	46	(27.9)	
Left side	23.75	±4.89		48	(37.1)	55	(38.8)	
Right side	24.60	±3.68		53	(33.6)	64	(33.3)	
Occlusion time (s)			.558					.215
<0.3	24.10	±4.65		94	(65.7)	120	(72.7)	
≥0.3	23.77	±4.39		49	(34.3)	45	(27.3)	
No. of remaining teeth			.120					.296
0	23.22	±4.93		18	(16.5)	28	(14.1)	
1-9	23.11	±3.86		24	(22.0)	33	(16.6)	
10-19	24.08	±4.70		26	(23.9)	41	(20.6)	
≥20	24.59	±4.59		41	(37.6)	97	(48.7)	
Subjective discomfort during mastication			.698					.402
Discomfort (1-2)	23.76	±4.23		58	(40.6)	57	(34.5)	
Regular (3-4)	24.00	±4.97		49	(34.3)	56	(33.9)	
Good (5)	24.31	±4.52		36	(25.2)	52	(31.5)	
Chewing ability			.461					.354
Lower (0-10)	23.57	±4.94		47	(32.9)	42	(25.5)	
Middle (11-20)	23.96	±4.86		52	(36.4)	68	(41.2)	
Higher (≥21)	24.40	±3.80		44	(30.8)	55	(33.3)	

P < .05 shown in bold.

* One-way analysis of variance or t test.

** Chi-square test.

Table 4 – Number of remaining teeth according to occlusion balance.

	No. of remaining teeth										P value**
	N	Mean ± SD		P value*	0	1-9	10-19	≥20			
Occlusion balance I				<.001							<.001
Anterior	184	13.84	± 9.09		24 (13.0)	42 (22.8)	55 (29.9)	63 (34.2)			
Posterior	124	18.02	±11.22		22 (17.7)	15 (12.1)	12 (9.7)	75 (60.5)			
Occlusion balance II				.253							.392
Bilateral	88	14.42	±10.70		17 (19.3)	18 (20.5)	14 (15.9)	39 (44.3)			
Left side	103	16.10	± 9.89		11 (10.7)	21 (20.4)	22 (21.4)	49 (47.6)			
Right side	117	15.85	±10.09		18 (15.4)	18 (15.4)	31 (26.5)	50 (42.7)			

P < .05 shown in bold.

* One-way analysis of variance or t test.

** Chi-square test.

Table 5 – Multiple regression analysis of masticatory ability and cognitive function.

	MMSE-DS score						VIF
	Model I		Model II		Model III		
	P value		P value		P value		
Occlusion balance I (ref. anterior)	.128	.025*	.154	.009*	.144	.012*	1.057
Occlusion balance II (ref. bilateral)	.012	.834	−.058	.312	−.038	.492	1.039
Number of remaining teeth			.188	.033*	.143	.094	2.421
Subjective masticatory ability			.054	.427	.046	.475	1.489
Chewing ability			−.010	.887	.001	.992	1.617
Occlusion time			−.018	.757	−.016	.774	1.036
Denture use			.133	.124	.163	.052	2.338
Age					−.175	.002*	
Sex					−.060	.350	
Education					.202	.002*	
Living arrangement					−.131	.022*	
Hypertension					.091	.111	
Diabetes					−.038	.513	

P < .05 shown in bold.

Model I: Unadjusted.

Model II: Additionally adjusted for oral function-related factors.

Model III: Additionally adjusted for Socio-demographic factors and hypertension, diabetes.

* P < .05, linear regression. MMSE-DS, Korean version of the Mini-Mental State Examination; VIF, variance inflation factor.

Discussion

Dementia, characterised by cognitive impairment and difficulty in performing activities of daily living, is a disease that lowers the quality of life of not only the individual but also the family.²² Although our understanding of the pathophysiology of dementia is limited, some risk factors have been identified. Kalaria et al.²³ reported that the risk of dementia increases with decreasing socioeconomic status, which includes education level and income. Paganini et al.²⁴ reported that the risk of dementia was higher in those chewing with a denture when compared to those chewing with natural teeth; however, there were no significant differences in cognitive function with respect to the use of a denture in the present study. This is consistent with the findings of Jeon et al.²⁵ that dementia and denture wearing are not related. Previous studies have suggested that the reduction of mastication caused by tooth loss could be a risk factor for cognitive decline.^{26,27} In our study, cognitive function tended to be higher among those with more remaining teeth, but the difference was not statistically significant.

In a study of the association between occlusion and cognitive function, rats and rabbits were fed only soft food that did not

require chewing. And in case the molar teeth were removed to prevent posterior occlusion, the number of neurons in the hippocampus was reduced and spatial memory capacity was impaired.^{28,29} Shin et al.¹⁷ reported that contact at the anterior teeth was greater when divided into occlusion condition of anterior-posterior teeth than left-right occlusion condition in the participants using dentures. In a human study, Okamoto³⁰ confirmed that brain function was improved in the cognitively impaired group when implants were placed to receive occlusal support. Shibuya³¹ reported that occlusal area and occlusal force had a positive correlation with cognitive ability when the brain function of patients with partial dentures was checked according to the use of dentures. In this study, denture status was not significant difference from cognitive function, but Hosoi et al.³² reported that installing complete dentures in edentulous patients improves not only oral health but also brain function. This is thought to be because this study included the use of partial dentures in denture usage. Furthermore, prosthetic teeth as well as natural teeth affect mental health; the posterior occlusion can influence not only nutrient intake but also physical posture and walking ability in elderly people.³³ These results suggest that masticatory ability and occlusion are associated

with cognitive function in the elderly. After classifying participants as having normal or mild cognitive impairment or Alzheimer's dementia and comparing the anterior, premolar, and molar occlusion, Myung³⁴ found that posterior occlusion compared to anterior occlusion is lower in Alzheimer's disease than normal, results that are similar to our findings. In addition, there was a significant difference in the relationship between the posterior occlusal force and the cognitive function after adjusting the number of residual teeth. Even though the number of remaining teeth was the same, the cognitive function was better when the posterior masticatory ability was higher.

This study has a few limitations. First, this was a cross-sectional study, and therefore we could not confirm any casual relationships. Second, convenience sampling was used, and included only older adults attending various senior centers in a metropolitan city during a particular period, and there were fewer male participants than female participants; thus, the findings cannot be generalised to all elderly populations. One reason for the unbalanced sex ratio is that women tend to have a longer life span than men, and elderly men did not tend to visit senior citizen centers in the city as much. Third, most participants had an educational level equivalent to that of an elementary school graduate or lower, and therefore we could not compare results with respect to educational level. Fourth, the occlusal balance was presented as percentages for the anterior left, anterior right, posterior left, and posterior right regions, so it does not reflect the participant's absolute masticatory ability. Finally, elderly people who cannot measure posterior occlusal balance using T-scan were excluded, which may lead to selective bias. Despite these limitations, this study is meaningful in that it examined the subjective masticatory ability and occlusal patterns of an elderly population and identified their associations with cognitive function. In the future, we plan to investigate the oral health and objective masticatory ability of elderly persons to evaluate their associations with cognitive function. Our findings may provide a valuable reference to subsequent studies attempting to identify the association between masticatory ability and cognitive function among the elderly.

This cross-sectional study evaluated the relationship between masticatory ability and cognitive function in the Korean elderly population (aged ≥ 65 years) and found that cognitive function was related to age, sex, education level, and occlusal balance. There was a positive association between cognitive function and the relative molar force measured by the T-scan III. The multiple linear regression model III showed that elderly people chewing more with posterior teeth compared to those with anterior teeth was related to better cognitive function after adjusting for the number of remaining teeth and other confounders.

Author contributions

Study concept and design: Youn-Hee Choi and Hae-Eun Shin.

Analysis and interpretation of data: Hae-Eun Shin, Min-Jeong Cho.

Interpretation of data: Atsuo Amano, Keun-Bae Song.

Critical comments and the final draft of the manuscript: Youn-Hee Choi, Min-Jeong Cho.

Conflict of interest

None disclosed.

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