JKAOH
Journal of Korean Academy of Oral Health 2021 June 45(2):57-63
https://doi.org/10.11149/jkaoh.2021.45.2.57
Original Article

노인의 저작기능과 인지장애의 관련성

박태준[1†], 허효진[1†], 조민정[1,2], 김현창[3], 염유식[4], 송근배[1], 최연희[1,5]

[1]경북대학교 치의학전문대학원 예방치과학교실, [2]경북대학교 과학기술대학 치위생학과, [3]연세대학교 의과대학 예방의학교실, [4]연세대학교 사회과학대학 사회학과, [5]경북대학교 치의학중개연구소

Association between masticatory function and cognitive impairment in the elderly

Taejun Park[1†], Hyojin Heo[1†], Min-Jeong Cho[1,2], Hyeon Chang Kim[3], Yoosik Youm[4], Keun-Bae Song[1], Youn-Hee Choi[1,5]

[1]Department of Preventive Dentistry, Kyungpook National University School of Dentistry, Daegu, [2]Department of Dental Hygiene, College of Science & Technology, Kyungpook National University, Sangju, [3]Department of Preventive Medicine, Yonsei University College of Medicine, [4]Department of Sociology, Yonsei University College of Social Sciences, Seoul, [5]Institutional for Dentistry, Kyungpook National University, Daegu, Korea

Received: February 28, 2021
Revised: March 6, 2021
Accepted: March 6, 2021

Corresponding Author: Youn-Hee Choi
Department of Preventive Dentistry, Kyungpook National University School of Dentistry, 2177 Dalgubeol-daero, Jung-gu, Daegu 41940, Korea
Tel: +82-53-660-6871
Fax: +82-53-423-2947
E-mail: cyh1001@knu.ac.kr
https://orcid.org/0000-0001-5712-8097

*This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017S1A3A2067165).
†These authors contributed equally to this work.

Objectives: With the surge in the elderly population, a growing interest in the prevention and treatment of geriatric diseases has been observed, along with awareness of the severity of problems associated with dementia, a cognitive impairment. The purpose of this study was to investigate the correlation between chewing ability and cognitive function among elderly people residing in a rural area.
Methods: A total of 162 elderly individuals, aged between 65 and 97 years, were surveyed. Trained examiners conducted interviews and assessments of chewing ability, on the basis of the number of remaining teeth, denture status, masticatory performance evaluating gum, ShadeEye-NCC measuring overall change in color of the gum (⊿E), and T-Scan®III analyzing distribution of occlusion patterns. Cognitive function was assessed using the Korean version of the Mini-Mental State Examination-Dementia Screening (MMSE-DS) tool.
Results: Participants with a low score in the MMSE-DS were found to have distinguishably lower denture need, smaller number of remaining teeth, and lesser color change in the masticatory performance evaluating gum. In the cognitive impairment group, a tendency of having unilateral and anterior occlusion led to occlusal discomfort and chewing difficulties.
Conclusions: The study highlights important associations between chewing ability and cognitive function. The finding corroborates that tooth loss may be a predictive risk factor for cognitive impairment.

Key Words: Chewing ability, MMSE-DS, T-Scan® III

Introduction

The United Nations has defined a population in which those aged 65 years or older comprise 7% to 14% of the population as an aging society, 14% to 20% as an aged society, and 20% or higher as a super-aged society[1)]. In 2019, the percentage of Koreans aged 65 years and older was estimated to be 14.9% of the entire population, categorizing Korea as an aged society[2)]. The elderly population is currently 7.68 million, approximately 2.31 million more compared to a decade ago. Due to this surge in the elderly population, there is a growing interest in the prevention and treatment of geriatric diseases and increasing awareness of the severity of problems associated with dementia, a cognitive impairment.

Dementia is a condition associated with multiple cognitive impairments including aphasia, apraxia, agnosia, and loss of executive function, in addition to the memory impairment due to an acquired brain disease, which seriously interferes with the social and occupational functions[3]. Dementia is a serious social problem since severe deterioration in the cognitive function undermines independent physical functioning and results in a high dependence on support systems such as family and the community[4]. According to the 2018 Korean statistics of the cause of death, the number of deaths increased significantly compared to the previous year, citing an increase in the elderly population due to aging. Alzheimer's related deaths increased by 22.5 percent to 12.0 per 100,000 people in 2018.

Previous studies have suggested a variety of factors that are associated with cognitive function[5,6]. The demographic characteristics include age, sex, education, and living arrangements; and the health characteristics include the chewing ability, the number of remaining teeth, denture status, nutrition, exercise, and depression. Chewing ability is the ability to grind food to help in swallowing; however, recent studies suggest that chewing ability can affect brain function[7]. A systematic literature review also reported a relationship between chewing ability and cognitive functions such as memory, retention, and attention[8]. Among the various cognitive functions, the chewing ability was found to have a positive effect on attention, especially sustained attention[9]. The review demonstrated that certain areas of the brain were activated during chewing based on the measurement of local cerebral blood flow[10]. Moreover, the increased chewing ability was found to increase the blood oxygen concentration in the frontal cortex and hippocampus, which carry out cognitive functions, and influence the organs responsible for learning and memory. Evaluation of the effects of the chewing ability on neural activity in the brain showed that chewing can affect the right hippocampus and thalamus, resulting in arousal and enhanced memory to improve the overall cognitive function. Another systematic review of various cross-sectional and cohort studies conducted in the elderly populations also found an association between decreased chewing ability and cognitive function[11].

There is extensive research in the literature reporting the relationship between chewing ability and cognitive function[12]. However, few studies have examined the relationship between oral health, chewing ability, and cognitive function. The present study aimed to evaluate the elderly population in a rural community regarding their denture status, the remaining teeth, the chewing ability by visual inspection and colour-changeable chewing gum, as well as the occlusion patterns, and investigate the relationship with cognitive function.

Materials and Methods

1. Study participants

This cross-sectional study was conducted in the elderly population aged 65 to 97 years, residing in Village K, located in Ganghwa County of Incheon, Korea, over a duration of 10 days in February 2018. The study population was in the Korean Social Life, Health, and Aging Project (KSHAP) which is a precursor to the National Social Life, Health, and Aging Project (NSHAP) conducted in the United States, designed to understand how social networks relate to a wide variety of health conditions in the elderly[13,14]. A trained dentist conducted the oral examination to evaluate the number of remaining teeth, denture status, and occlusion patterns. Trained dental hygienists conducted interviews to obtain information regarding the general characteristics, oral health, and cognitive function measured using Mini-Mental State Examination-Dementia Screening (MMSE-DS). A skilled investigator performed the visual shade-matching of the colour-changeable chewing gum to evaluate the chewing ability and the colour changes were measured using a digital shade analysis system. A total of 162 participants, 53 men and 109 women, who completed the survey questionnaires and the oral health examinations, were included in the data analysis. All participants were informed of the nature of the study and informed consent was obtained. This study was approved by the Institutional Review Board (IRB) of the Kyungpook National University Hospital (KNUH 2015-07-007-001).

2. Assessment of the chewing ability

2.1. Denture status

Regarding the status of the maxillary and mandibular dentures, the participants were classified into three groups: natural teeth, partial/complete denture wearers, and requiring dentures. The criteria for requiring dentures were either the absence of both premolars and molars or the absence of molars in at least one quadrant.

2.2. Number of remaining teeth

An oral examination involved the inspection of all teeth including the third molars. The number of remaining teeth excluded the teeth that allow ≥1 mm horizontal and vertical mobility based on Miller's[15] classification in consideration of the functional chewing aspects, and implants or teeth with only remaining root. The study participants were classified into four groups depending on the number of remaining teeth as edentulous, 1-9, 10-19, or ≥20[16].

2.3. Evaluation of the chewing ability with colour-changeable gum

The colour-changeable chewing gum (Masticatory Performance Evaluating Gum XYLITOL, Lotte Co., Ltd., Tokyo, Japan) was used to evaluate the chewing ability both subjectively and objectively. The red dye is pH-sensitive and it changes colour under neutral or alkaline conditions. Citric acid maintains a low internal pH in the green-yellowish coloured gum before chewing. As chewing progresses, the gum changes to a pink colour since the yellow and blue dyes seep into the saliva and the pink colour appears due to elution of the citric acid[17]. After the gum was chewed naturally by the participants for two minutes, a visual shade matching was performed using a five-point scale: 1=green, 2=yellow, 3=light pink, 4=pink, 5=hot pink. The participants were classified into two levels of chewing ability: 1 to 3 points were classified as poor chewers and 4 to 5 points were classified as good chewers.

2.4. Colourimeter (ShadeEye-NCC) digital shade analysis system

For the objective numerical representation of the colour-changeable chewing gum, measurements were obtained using ShadeEye-NCC (Dental Chroma Meter, SHOFU Inc., Kyoto, Japan), a digital shade analysis system. ShadeEye-NCC employs the CIELAB colour system to offer values of L* (brightness of colour), a* (red-green hue), and b* (yellow-blue hue) for calculation of the ΔE (overall change in colour)[18]. To obtain ΔE, five areas of the gum were randomly measured and the measurements were averaged[19].

$$\Delta E = \sqrt{(L^* - 72.3)^2 + (a^* + 14.9)^2 + (b^* - 33.0)^2}$$

2.5. Examination of occlusion pattern

The T-scan III® system (Tekscan, Inc., Boston, MA, USA) is a diagnostic device that provides dynamic occlusal measurement revealing the level and timing of force on individual teeth and the occlusal stability of the overall bite[20]. The participants were asked to sit in chairs, slightly lift their heads, and clench their teeth in centric occlusion position. Then the dentist measured the occlusal pattern by setting the occlusal sensor's pointer of the T-scan III® system between the maxillary central teeth to maintain the correct position. The occlusion recordings were obtained by adjusting the sensitivity until 1-3 red dots appeared, having the participants clench their teeth in the centric occlusion position for two seconds, and repeating the process 2-3 times to determine the colour variations in the occlusion forces on a graph. The measurements were classified into four categories for analysis—unilateral, bilateral, anterior, and posterior[21].

3. Assessment of the cognitive function

The cognitive function of the participants was assessed using the Korean version of the Mini-Mental State Examination for Dementia Screening (MMSE-DS) developed by Kim et al.[22] for the standardization of dementia screening tools at the Ministry of Health and Welfare. The assessment included 19 items with scores ranging between 0 to maximum 30 points (10 points for orientation, 6 points for verbal memory, 5 points for concentration and calculation, 5 points for language, 3 points for praxis, 1 point for visuospatial construction, and 2 points for judgment and common sense). The total score of each participant was evaluated according to age, gender, education level, and the type of residence based on the test manual[23]. An MMSE-DS score ≤23 was considered to indicate cognitive impairment, while a score of >23 was considered as normal cognitive function[24].

4. Statistical analysis

Data analysis was performed using IBM SPSS version 23.0 for Windows (SPSS Inc., Chicago, IL, USA) at a 5% significance level. Frequency analysis was used to determine the participants' general characteristics, while the Chi-square test, t-test, and one-way ANOVA were used to determine the relationship between the general characteristics, chewing ability, and cognitive function. If the results of the one-way ANOVA suggested a mean difference, we further conducted the Scheffe's post hoc test. We also conducted a multiple regression analysis to evaluate the relationship between chewing ability and cognitive function, adjusting for age, gender, education level, and living arrangements.

Results

The characteristics of the study participants and the chewing ability factors with cognitive function are shown in Table 1. The participants were divided into two groups according to their MMSE-DS scores (cognitive impairment, MMSE-DS score ≤23, n=52 or MMSE-DS score >23, n=110). The mean MMSE-DS score was lower for participants aged 80 years or older (23.84 ±3.98), women (24.19±3.97), less educated (24.19±3.90) and those living with family other than spouses (22.84±4.67). All the variations were significantly different ($P<0.05$). The variations in cognitive function according to the chewing ability indicate that more the teeth, higher the mean MMSE-DS score ($P<0.05$). The cognitive function between the two groups was classified based

Table 1. Cognitive function with socio-demographic and chewing ability

	N (%)	MMSE-DS score		Cognitive impairment Yes (≤23)	Cognitive impairment No (>23)	*P*-value**
		Mean±SD	*P*-value*	N=52	N=110	
Age			.010			.010**
<80	89 (54.9)	25.36±3.45		21 (40.4)	68 (61.8)	
≥80	73 (45.1)	23.84±3.98		31 (59.6)	42 (38.2)	
Gender			.019*			.031**
Male	53 (32.7)	25.66±3.12		11 (21.2)	42 (38.2)	
Female	109 (67.3)	24.19±3.97		41 (78.8)	68 (61.8)	
Education			.001*			.002**
≤Elementary	129 (79.6)	24.19±3.90		49 (94.2)	80 (72.7)	
>Elementary	33 (20.4)	26.58±2.40		3 (5.8)	30 (27.3)	
Living arrangement			.002*			.014**
Alone	42 (25.9)	23.62±3.78		19 (36.5)	23 (20.9)	
With spouse	101 (62.3)	25.46±3.36		24 (46.2)	77 (70.0)	
With family	9 (11.7)	22.84±4.67		9 (17.3)	10 (9.1)	
Denture status			.284			.053
Need denture	29 (17.9)	23.55±4.15		13 (25.0)	16 (14.5)	
Denture wearer	69 (42.6)	24.87±3.94		18 (34.6)	51 (46.4)	
Natural teeth	64 (39.5)	24.97±3.33		21 (40.4)	43 (39.1)	
Number of remaining teeth			.017*			.276
0	17 (10.5)	22.06±4.53		9 (17.3)	8 (7.3)	
1-9	25 (15.4)	24.40±4.16		7 (13.5)	18 (16.4)	
10-19	35 (21.6)	24.91±3.61		11 (21.1)	24 (21.8)	
≥20	85 (52.5)	25.15±3.37		25 (48.1)	60 (54.5)	
Color-changeable gum			.001*			.044**
Poor (1-3)	40 (24.7)	23.05±4.95		18 (34.6)	22 (20.0)	
Good (4-5)	122 (75.3)	25.20±3.13		34 (65.4)	88 (80.0)	
Occlusion balance I			.206			.078
Unilateral	65 (40.1)	24.22±4.10		26 (50.0)	39 (35.4)	
Bilateral	97 (59.9)	24.98±3.51		26 (50.0)	71 (64.6)	
Occlusion balance II			.284			.053
Anterior	101 (62.3)	24.43±3.59		14 (26.9)	47 (42.7)	
Posterior	61 (37.7)	25.08±4.03		38 (73.1)	63 (57.3)	

Occlusion balance I: Bilateral balanced occlusion.
Occlusion balance II: Anterior and posterior balanced occlusion.
*$P<0.05$ by one-way ANOVA or t-test.
**$P<0.05$ by χ^2-test.

on the colour change in the chewing gum and the MMSE-DS score was significantly lower ($P<0.001$) in the group with poor chewing ability indicated by less colour change.

The relationship between Shade Eye-NCC measuring the chromaticity of the chewing gum and the cognitive function is shown in Table 2. The overall change in colour (ΔE) was strongly correlated with the denture status ($P<0.05$), the number of remaining teeth ($P<0.05$), visual inspection of colour changes in the gum ($P<0.05$), and bilateral occlusion balance ($P<0.05$).

According to the multiple regression analysis results to determine the relationship between chewing ability and the cognitive function is shown in Table 3. The MMSE-DS score was positively correlated with the denture status (β=0.406, $P<0.05$), the number of remaining teeth (β=0.352, $P<0.05$), and age (β=-0.197, $P<0.05$) in Model III, in which the age, gender, education level, and living arrangements were adjusted. No multicollinearity among the variables was found.

Discussion

In this study, we analyzed the effects of chewing ability and cognitive function in 162 elderly people aged 65 or older and residing in a rural area. There were significant differences in the cognitive function according to the age, gender, education level and living arrangements, and in the distribution of cognitive function according to the number of remaining teeth. The mul-

Table 2. Cognitive function and chewing ability according to ShadeEye-NCC L*, a*, b*, ⊿E of colour-changeable gum

	ShadeEye-NCC							
	L*	*P*-value	a*	*P*-value	b*	*P*-value	⊿E	*P*-value
Denture status		.003*		<.001*		.035*		<.001*
Need denture	59.27±3.40		32.05±6.08		16.94±5.26		51.49±7.55	
Denture wearer	58.45±2.19		33.89±4.03		14.23±4.27		54.19±5.16	
Natural teeth	58.24±2.03		36.12±3.11		11.34±3.58		57.29±3.75	
Number of remaining teeth		<.001*		<.001*		.046*		<.001*
0	61.80±4.87		27.48±8.66		21.63±5.71		45.37±10.36	
1-9	59.62±2.94		30.80±5.50		18.35±4.86		49.80±6.76	
10-19	58.79±2.85		33.26±4.61		15.96±4.32		52.98±5.74	
≥20	58.09±2.02		35.90±3.27		11.77±3.51		56.97±3.94	
Color-changeable gum		<.001*		<.001*		.018*		<.001*
Poor (1-3)	61.49±3.98		27.02±6.59		21.88±4.11		44.87±7.74	
Good (4-5)	58.01±1.90		35.84±2.56		12.38±3.30		56.71±3.10	
Occlusion balance I		.183		.002*		.006*		.001*
Unilateral	59.25±3.63		31.84±6.67		15.65±6.34		51.79±8.45	
Bilateral	58.61±2.42		34.88±4.12		14.11±4.60		55.12±5.32	
Occlusion balance II		.311		.540		.484		.767
Anterior	58.68±2.68		33.10±5.04		15.57±5.04		53.01±6.41	
Posterior	59.17±3.39		34.59±6.07		13.32±5.73		55.06±7.58	

Occlusion balance I: Bilateral balanced occlusion.
Occlusion balance II: Anterior and posterior balanced occlusion.
*$P<0.05$ by one-way ANOVA or t-test.

Table 3. Multiple regression analysis of chewing ability and cognitive function

		MMSE-DS score									
	Reference	Model I (crude)			Model II			Model III			
		B	β	*P*-value	B	β	*P*-value	B	β	*P*-value	VIF†
Denture status	Need denture	.128	.420	.000*	.310	.412	.000*	.305	.406	.000*	2.223
Number of remaining teeth	.	.128	.340	.005*	.138	.365	.002*	.133	.352	.003*	2.717
Colour-changeable gum	Poor	.151	.017	.878	.116	.013	.903	.036	.004	.970	4.345
Occlusion balance I	Unilateral	.110	.014	.850	.254	.033	.653	.250	.033	.659	1.115
Occlusion balance II	Anterior	.501	.065	.398	.233	.030	.687	.186	.024	.749	1.152
Total colour change of ShadeEye-NCC (⊿E)	.	.149	.274	.017*	.085	.157	.173	.085	.156	.176	4.495
Age	<80				−.129	−.235	.003*	−.108	−.197	.022*	1.435
Gender	Male				−1.108	−.139	.059	−.770	−.096	.235	1.295
Education	≤Elementary							1.020	.109	.194	1.436
Living arrangement	Alone							−.046	−.007	.920	1.074

*$P<0.05$ by linear regression.
VIF<10, Variance inflation factors.
Model (crude) I: Unadjusted model.
Model II: Model I+age and gender adjusted model.
Model III: Model II+education, and living arrangement adjusted model.

tiple linear regression analysis showed a significant association between the MMSE-DS scores with the number of remaining teeth and denture status. These results suggest the possibility of being dynamically related to the number of remaining teeth and cognitive function.

Some studies have evaluated the association between the number of remaining teeth and cognitive functions. According to Van der bilt[25], the number of teeth and the anatomical structure were related to the dentition, and the number of teeth as a single factor can have the most effect. Kalaria et al.[26] reported that the lower the socioeconomic status such as education and income, the higher the risk of developing dementia. Another study by Zahodne et al.[27] also showed that those with lower education levels had a lower cognitive function. Paganini-Hill et al.[28] found that chewing with dentures is more likely to cause dementia than chewing with natural teeth. Consequently, the results of this study can be interpreted on this basis.

This study investigated the elderly population in a rural Village K in Ganghwa County of Incheon, which limits the ability to generalize our findings. In particular, the number of study participants was 162, which is a smaller sample size compared to some studies. In addition, the difficulty in gender analysis due to the gender imbalance among the participants, 53 men (32.7%) and 109 women (67.3%), can be another limitation of this study. Moreover, the association between the sociodemographic dimension and cognitive impairment, and the association between chewing ability and cognitive impairment were investigated separately using correlation analyses. However, the sociodemographic dimension was not applied to the study design to analyze the association between the chewing ability and cognitive function in the study design and needs to be addressed in future research.

The use of the T-scan III® system for determination of the occlusion pattern in the assessment of the chewing ability in this study also has limitations. First of all, as the system was not equipped for absolute assessment of the occlusion patterns due to variations in the sensitivity of its sensors, only the relative occlusal distribution of the participants was examined. Moreover, the study classified the occlusion patterns into unilateral, bilateral, anterior, and posterior patterns by classifying the mouth into four quadrants (anterior, posterior, left and right) and obtaining the relative occlusal distribution of the participants using percentages for the quadrants. However, due to a lack of previous studies reporting the objective criteria for classifying the occlusion, the occlusion patterns used in the present study are relative and arbitrary.

This study reports significant findings including the effects of cognitive impairment measured using MMSE-DS on the chewing ability in elderly participants and verifies the relationship between the decline in cognitive function and low chewing ability. Future studies need to include sociodemographic analysis to examine the relationship between cognitive function and oral health.

Conclusions

The study highlights the importance of association between chewing ability and cognitive function. The finding corroborates that tooth loss may be a predictor of risk factor for cognitive impairment.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017S1A3A2067165).

ORCID

Taejun Park, https://orcid.org/0000-0003-3288-8887
Hyojin Heo, https://orcid.org/0000-0002-5403-7795
Min-Jeong Cho, https://orcid.org/0000-0002-6127-3702
Hyeon Chang Kim, https://orcid.org/0000-0001-7867-1240
Yoosik Youm, https://orcid.org/0000-0003-3822-5777
Keun-Bae Song, https://orcid.org/0000-0002-5416-5500

References

1. Kanasi E, Ayilavarapu S, Jones J. The aging population: demographics and the biology of aging. Periodontol 2000 2016;72:13-18.
2. Kim CB, Yoon SJ, Ko J. Economic activity and health conditions in adults aged 65 years and older: findings of the Korean national longitudinal study on aging. Healthcare (Basel) 2017;5:63.
3. Miura R, Hattori H. Overview and assessment of cognitive function in interpreting postoperative cognitive dysfunction. Masui 2014;63(11):1188-1195.
4. Pitkälä K, Savikko N, Poysti M, Standberg T, Laakkonen M-L. Efficacy of physical exercise intervention on mobility and physical functioning in older people with dementia: a systematic review. Exp Gerontol 2013;43:85-93.
5. Kim M, Park J-H. Factors affecting cognitive function according to gender in community-dwelling elderly individuals. Epidemiol Health 2017;15:e2017054.
6. Chen TY, Chang HY. Developmental patterns of cognitive function and associated factors among the elderly in Taiwan. Sci Rep 2016;16:33486. https://doi:10.1038/srep33486.
7. Kim HJ, Lee JY, Lee ES, Jung HJ, Ahn HJ, Kim B I. Improvements in oral functions of elderly after simple oral exercise. Clin Interv Aging 2019;14:915-924.
8. Delwel S, Scherder EJA, Perez R, Hertogh C, Maier AB, Lobbezoo F. Oral function of older people with mild cognitive impairment or dementia. J Oral Rehabil 2018;45:990-997.
9. Hirano Y, Onazuka M. Chewing and Attention: A Positive Effect on Sustained Attention. Biomed Res Int 2015. https://doi:10.1155.2015.367026.
10. Narita N, Kamiya K, Yamamura K, Kawasaki S, Matsumoto T, Tanaka N. Chewing-related prefrontal cortex activation while wearing partial denture prosthesis: pilot study. J Prosthodont Res 2009;53:126-135.
11. Kim EK, Lee SK, Choi YH, Tanaka M, Hirotsu K, Kim HC, et al. Relationship between chewing ability and cognitive impairment in the rural elderly. Arch Gerontol Geriatr 2017;70:209-913.
12. Cho MJ, Kim JY, Jung YS, Shin HE, Youn HY, Park TJ, et al. Can the

number of functional teeth potentially affect cognitive function? J Korean Acad Oral Health 2018;42:52-58.
13. Youm Y, Laumann E, Ferraro K, Waite LJ, Kim HC, Park YR, et al. Social network properties and self-rated health in later life: comparisons from the Korean social life, health, and aging project and the national social life, health and aging project. BMC Geriatr 2014;14:102.
14. Lee JM, Lee WJ, Kim HC, Choi W, Lee J, Sung K, et al. The Korean social life, health and aging project-health examination cohort. Epidemiol Health 2014;36:e2014003.
15. Laster L, Laudenbach KW, Stoller NH. An evaluation of clinical tooth mobility measurements. J Periodontol 1975;46:603-607.
16. Cho MJ, Jung EK, Lee SS, Choi YH, Song KB. The relationship between the number of remaining teeth and senile dementia: a pilot study. J Korean Acad Oral Health 2015;39:214-219.
17. Hama Y, Kanazawa M, Minakuchi S, Uchida T, Sasaki Y. Properties of a color-changeable chewing gum used to evaluate masticatory performance. J Prosthodont Res 2014;58:102-106.
18. Li Q, Wang YN. Comparison of shade matching by visual observation and an intraoral dental colorimeter. J Oral Rehabil 2007;34:848-854.
19. Lenhard M. Assessing tooth color change after repeated bleaching in vitro with a 10 percent carbamide peroxide gel. J Am Dent Assoc 1996;127:1618-1624.
20. Luo Q, Ding Q, Zhang L, Xie Q. Analyzing the occlusion variation of single posterior implant-supported fixed prostheses by using the T-scan system: a prospective 3-year follow-up study. J Prosthet Dent 2020;123:79-84.
21. Bowling A, Rowe G, Adams S, Sands P, Samsi K, Crane M, et al. Quality of life in dementia: a systematically conducted narrative review of dementia-specific measurement scales. Aging Ment Health 2015;19:13-31.
22. Kim TH, Jhoo JH, Park JH, Kim JL, Ryu SH, Moon SW, et al. Korean version of mini mental status examination for dementia screening and its' short form. Psychiatry Investig 2010;7:102-108.
23. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189-198.
24. Okuno J, Yanagi H, Tomura S. Is cognitive impairment a risk factor for poor compliance among Japanese elderly in the community? Eur J Clin Pharmacol 2001;57:589-594.
25. Van der bilt A. Assessment of mastication with implications for oral rehabilitation: a review. J Oral Rehabil 2011;38:754-780.
26. Kalaria RN, Maestre GE, Arizaga R, Friedland RP, Galasko D, Hall K, et al. Alzheimer's disease and vascular dementia in developing countries: prevalence, management, and risk factors. Lancet Neurol 2008;7:812-826.
27. Zahodne LB, Stern Y, Manly JJ. Differing effects of education on cognitive decline in diverse elders with low versus high educational attainment. Neuropsychology 2015;29:649-657.
28. Paganini-Hill A, White SC, Atchison KA. Dentition, dental health habits, and dementia: the leisure world cohort study. J Am Geriatr Soc 2012;60:1556-1563.