Association between Masticatory Function Assessment and Masseter Muscle Thickness in the Elderly

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Association between Masticatory Function Assessment and Masseter Muscle Thickness in the Elderly

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먼저, 본 논문이 완성될 수 있도록 지도해 주신 교수님들께 진심을 담아 감사드립니다. 넓은 안목과 아낌없는 칭찬으로 용기를 북돋아 주시고, 언제나 세심하게 이끌어 주셨던 최종훈 지도교수님께 무한한 감사 인사를 드립니다. 다양한 연구를 접할 수 있도록 기회를 주시고, 끊임없는 관심과 애정으로 격려해 주신 안형준 교수님께 깊은 감사드립니다. 소중한 조언과 질문을 통해 논문의 완성도를 높여 주신 권정승 교수님께 감사드리며, 논문이 잘 진행되고 있는지 관심갖고 조언해 주신 김성택 교수님께도 감사드립니다. 또한, 저의 부족한 논문을 꼼꼼하게 살펴봐 주시고, 연구에 꼭 필요한 피드백을 주셨던 김백일 교수님, 김지환 교수님께 감사드립니다.

학위 과정 중 함께 한 분들 덕분에 힘든 순간이 있어도 마음이 넉넉하고, 웃으며 지낼 수 있었습니다. 마음 터 놓고 나누며 둘도 없는 찐 친구가 되어준 박연정 선생님에게 감사합니다. 모든 것이 낯설고 어렵던 시간에

따뜻하게 감싸주신 신광수 선생님, 감사하고 그립습니다. 같은 교실은 아니지만 저의 삶을 응원해주시고 고민이 있을 때 마다 깨달음을 주시는 이선경 선생님과 언제나 밝고 명랑한 모습으로 비타민같은 존재가 되어준 이태양 선생님에게 감사합니다. 아울러 우리 구강내과의 모든 식구들에게 진심으로 감사한 마음을 전합니다.

늦은 나이에 시작한 시집간 딸의 새로운 도전을 기특하게 여겨 주시고, 무한한 신뢰를 보내주신 친정 부모님과 끝까지 공부에 전념할 수 있도록 사랑을 담아 응원해주신 시아버님과 시어머님께 깊은 감사드립니다. 그리고 나의 가장 좋은 친구이자 사랑하는 동생 정효이에게도 감사합니다.

생각만으로도 벅차고 빈틈없이 고마운 사람, 남편 권병훈에게 더 없는 감사와 사랑의 마음을 전합니다. 당신이 나에게 늘 그랬던 것처럼 나 역시 앞으로도 당신을 축복하고, 당신 곁을 지키겠습니다. 마지막으로 이 모든 결실을 맺을 수 있도록 이끌어 주시고, 은혜와 능력을 부어 주신 주님께 감사와 영광을 돌립니다. 배움을 통해 앞으로 더 성장하고, 발전하여 어디서든 쓰임 받는 겸손한 사람이 되겠습니다.

2020 년 8 월

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Purpose: This study investigated the association between the objective indicator of masticatory function assessment and the masseter muscle thickness (MMT) using ultrasound imaging in the elderly.

Methods: A total of 99 subjects (males: 24, females: 75, mean age: 76 years) were analyzed. The maximum bite force (MBF) was measured using a pressure-sensitive sheet and an image scanner. The mixing ability index (MAI) was calculated by image analysis after asking the subjects to chew upon a wax specimen. The MMT during rest and clenching was

obtained with a diagnostic ultrasound system, and the difference in MMT during rest and during clenching was defined as the difference in masseter muscle thickness (DMMT). Multiple regression analysis was performed to investigate the relationship between masticatory function assessment and MMT.

Results: The MBF showed positive correlation with the number of remaining teeth (β=0.350, *P*=0.002) and DMMT (β=0.239, *P*=0.016), while the MAI correlated only with the number of remaining teeth (β=0.478, *P*<0.001).

Conclusions: The DMMT reflects the state of masseter muscle contraction, and can be used as a predictor of the number of teeth as well hen assessing masticatory function in the elderly.

Keywords : Elderly, Masticatory function, Bite force, Masticatory efficiency, Masseter muscle thickness

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I. INTRODUCTION

Mastication is a primary oral function, which not only helps with food intake, but is also closely related to physical and mental functions (Nakata et al., 1998). Peyron et al., (2004) showed that the chewing cycle and the time required for food intake increased with age. The elderly with a reduced masticatory function had a higher prevalence of indigestion, malnutrition, aspiration pneumonia, and cognitive impairment, and a subsequent decrease in the quality of life (Petersen et al., 2005; Kwon et al., 2017; Muller et al., 2017;

Kandelman et al., 2008). The eventual goal of dental treatment is to maintain and restore healthy masticatory function throughout life, and appropriate evaluation and management is essential to improve mastication in the elderly.

Various methods of assessing masticatory functions have been proposed, and maximum bite force (MBF) and mixing ability index (MAI) are proven indicators for assessing masticatory function objectively (Ikebe et al., 2011; Jeong et al., 2010). Tooth loss is a representative cause of reduced MBF and MAI, and it has been reported that it decreases the masticatory function in the elderly, induces alveolar bone resorption, and reduces masseter muscle mass (Newton et al., 1993).

The masseter, temporalis, medial pterygoid, and lateral pterygoid muscles are collectively called the masticatory muscles. Among them, the masseter is the main elevator muscle of the mandible and is involved in mastication. In a study by Murakami et al. (2015) it was found that the chewing ability of the elderly was associated with sarcopenia. The loss of muscle mass and muscle strength due to aging occurs not only in skeletal muscles, but also in masticatory muscles (Iinuma et al., 2012). Additionally, the edentulous group has been reported to have a masseter muscle thickness (MMT) less than that of the dentulous group (Bhoyar et al., 2012). Therefore, there is a need to measure the masseter muscle size in the evaluation of masticatory function in the elderly.

Ultrasound imaging has been used to measure MMT as an indicator of muscle size. It is also considered useful for clinical evaluation with considerable cost savings and convenience compared to CT or MRI (Reis et al., 2017; Emshoff et al., 2003).

In previous studies, changes in the MMT according to tooth loss (Yarmaguchi et al., 2018), the relationship between masseter muscle tension and chewing ability (Ohara et al., 2013), and the role of the masseter muscle size and oral function according to age and sex have been reported (Lin et al., 2017). However, only a few studies have examined the relationship between MBF, MAI, and MMT, and the effect of MMT on objective masticatory function is unclear. Therefore, the purpose of this study was to investigate the association between the objective indicator of masticatory function assessment and the MMT using ultrasound imaging.

Ⅱ. MATERIALS AND METHODS

1. Subjects

This study approved by the Institutional Review Board of Yonsei University Dental Hospital (IRB. 2-2016-0034). From April 18, 2017 to September 21, 2018, a total of 132 subjects were recruited after visiting the elderly welfare facilities in Seodaemun-gu, Seoul, and Seongnam-si, Gyeonggi-do, and performing oral examinations. The inclusion criteria were: i) Subjects who participated voluntarily, ii) subjects more than 65 years old, iii) subjects able to move on their own, and iv) subjects without unusual systemic diseases. The following subjects were excluded to reduce the disturbance factors in data collection: i) Subjects with painful caries, ii) Subjects with a more than 6 mm periodontal pocket, iii) Subjects with pain and symptoms of temporomandibular joint disorder, ⅳ) Subjects with masticatory dysfunction, v) Subjects with planned dental treatment (resin filling, prosthetic treatment, extraction, implant placement, etc.) during the study period. A total of 99 subjects were analyzed, not counting those who either were excluded or withdrew consent.

2. Number of Remaining Teeth

The number of existing erupted teeth, excluding the residual roots and third molar, were counted, and denture wear was investigated. Considering that the role of the posterior teeth was more important than the anterior teeth in the masticatory function, divide into four groups according to the number of posterior teeth (premolar, molar) lost (no loss, 1–2 lost, 3–5 lost, denture group) (Table 1). In particular, the denture group was consisted as follows: i) 7 cases with complete denture (CD) in both the maxilla and mandible, ii) 5 cases with maxillary CD and mandibular partial denture (PD), iii) 2 cases with maxillary PD and mandibular CD, iv) 9 cases with PD in both the maxilla and mandible, v) 12 cases with maxillary or mandibular PD and opposite natural teeth.

Table 1. Classification of subjects according to tooth loss in posterior teeth

Group	N (%)
No loss	30 (30.3)
1-2 loss	25 (25.2)
3-5 loss	9 (9.1)
Denture	35 (35.4)
Total	99 (100)

3. Functional Tooth Units (FTUs)

The total number of FTUs were defined as pairs of opposing natural teeth and artificial teeth on implant-supported, fixed (bridge pontic) and removable prostheses (Ueno et al., 2008). Two opposing premolars were defined as one FTU and two opposing molars were defined as two FTUs (Fig. 1). Therefore, a person with a complete dentition had 12 FTUs.

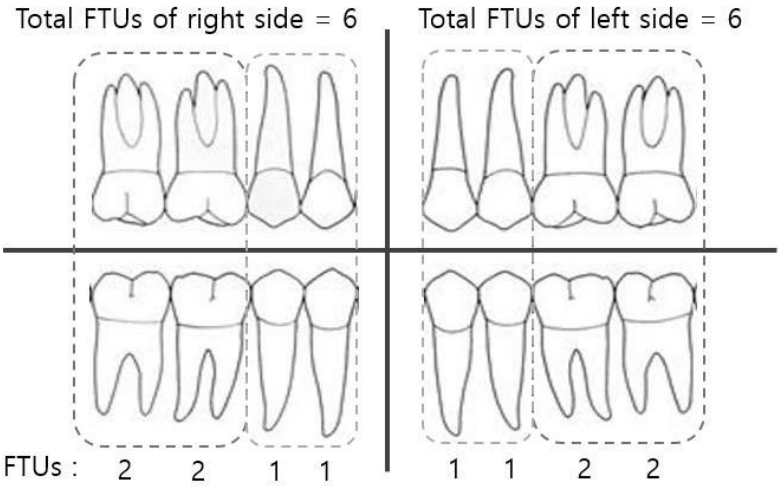


Figure 1. Definition of functional tooth units

4. Measurement of Maximun Bite Force (MBF)

The MBF was measured using 98 mm thick pressure-sensitive sheets (Dental Prescale, 50H type, Fuji Film, Tokyo, Japan) which were analyzed by an image scanner (Occluzer, FPD-707, Fuji Film) (Shinogaya and Matsumoto, 1998). The subjects sat comfortably with their eyes towards the front and clenched maximally in the intercuspal position, with the pressure-sensitive film placed between the maxillary and mandibular dental arches (Fig. 2). Subjects with removable partial dentures kept their dentures in place during the measurement of the MBF. The bite force was calculated after scanning the sheet with an image scanner (Occluzer), taking into consideration the occlusal contact area and the different densities of color (Fig. 3). The bite force (N) was determined as the sum of the degree of coloration and the area at each contact point.

Figure 2. Maximum bite force measurement procedure

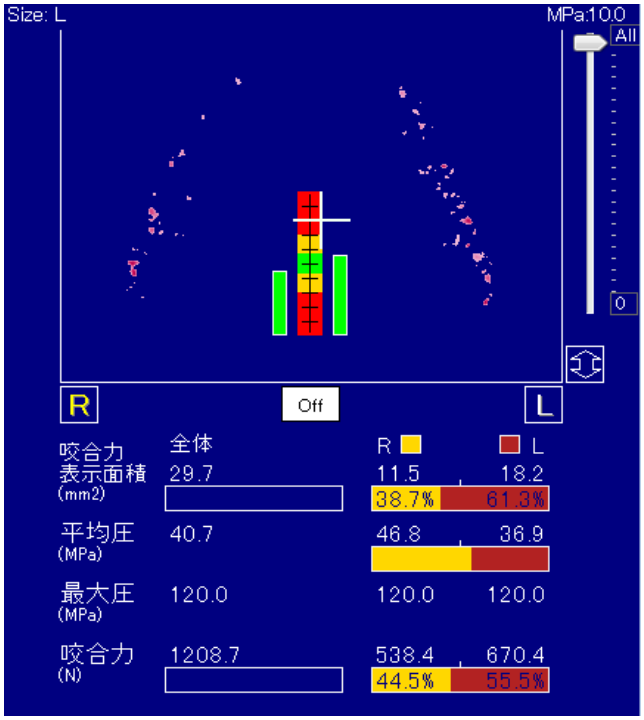


Figure 3. Occluzer's analysis image

5. Measurement of Mixing Ability Index (MAI)

This study used the MAI reported by Jeong et al. (2010) to measure the objective masticatory efficiency. The wax specimens were made to form a 12*12*12 mm cube by arranging red and green utility wax (Fig. 4). Three wax specimens were provided to the subjects and they were requested to chew them ten times using a normal mastication pattern. Both sides of the collected wax specimens were photographed with a digital camera and were saved as image files. Using the digital image analyzer (Imagepro® Plus v 6.0), the total projection area, projection area >50 ㎛ in thickness, maximum length, maximum breadth, red area, and green area of the image data were measured. The MAI value was calculated through the discriminant formula for the measured information. In order to reduce data variation, a single examiner conducted the entire process of image analysis. The average score for the three wax specimens chewed by the subject was determined as the final score (1-100) of MAI, and the higher the score, the higher the masticatory efficiency (Fig. 5).

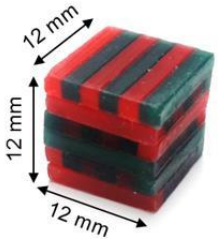


Figure 4. Wax specimens for mixing ability index

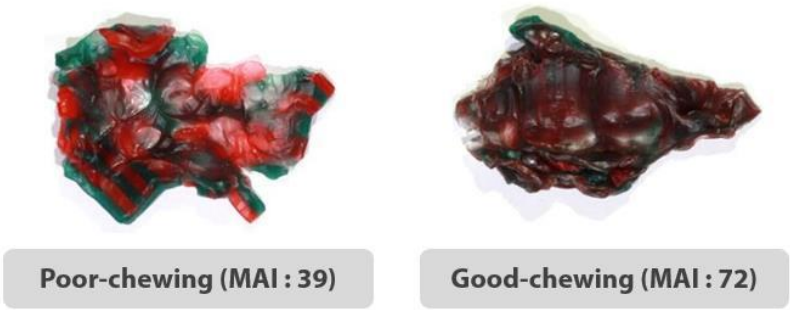


Figure 5. Examples of chewed wax specimens

6. Measurement of Masseter Muscle Thickness (MMT)

The MMT was measured using the ultrasound system E-cube9 (Alpinion Inc., Seoul, Korea), and a linear probe (frequency of 3.0-12.0 MHz) by a dentist. Subjects were instructed to sit with their upper body upright, and scanning was performed at the midpoint between the zygomatic arch and the mandibular angle, approximately parallel to the Camper's plane along a line connecting the point under the nasal wing with the tragus of the ear (Fig. 6) (Yamaguchi et al., 2018). The MMTs were scanned twice on the right and the left, during rest and during clenching, and the thickest part on the image was measured. The difference in MMT during rest and clenching was defined as the difference in masseter muscle thickness (DMMT) (Fig. 7). To ensure the reliability of the data, Intra-class correlation coefficients (ICCs) was performed on the MMT measurement (Table 2), for MMT the mean of the four scanning values in contracted muscle condition (right x 2, left x 2) was used for analysis.

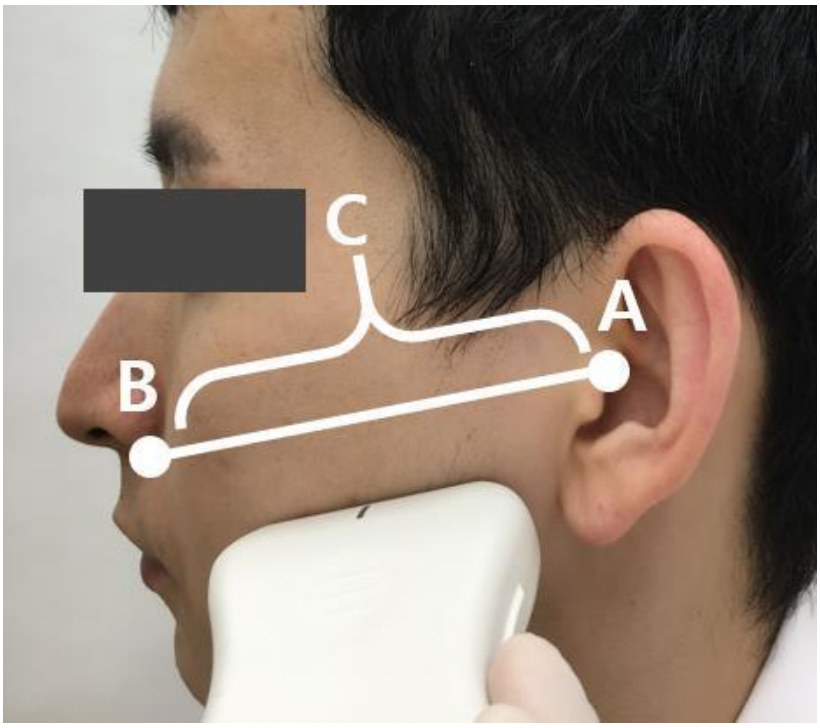


Figure 6. Position of the probe during measurement

A. Upper edge of the tragus

B. Point under the nasal wing

C. Camper's plane

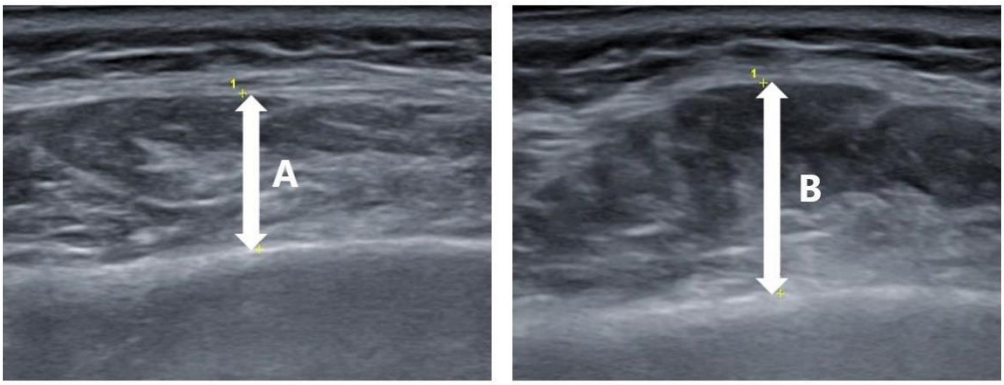


Figure 7. Masseter muscle images with ultrasonic diagnostic equipment

A. Masseter muscle thickness during rest

B. Masseter muscle thickness during clenching

B – A. Difference in masseter muscle thickness displacement

Table 2. Intra-rater reliability of ultrasound measurements of the masseter muscle (N=99)

	MMT during rest		MMT during clenching	
	ICC (1,2)	95% CI	ICC (1,2)	95% CI
Right	0.794	0.694-0.862	0.815	0.724-0.876
Left	0.832	0.750-0.887	0.867	0.801-0.910

ICC, intra-class correlation coefficient; CI, confidence interval; MMT, masseter muscle thickness.

7. Statistical Analysis

As a result of performing the normality test using the Shapiro-Wilk test, the data were not satisfied with the normal distribution and analyzed in a nonparametric test. The characteristics of the subjects according to sex analyzed using the Chi-square test and the Mann-Whitney *U* test. Kruskal-Wallis test was performed to compare the differences in variables according to the number of loss in posterior teeth, and was verified with Mann-Whitney *U* test. MBF and MAI were divided into 3 groups based on quartiles, 1st quartile (25%, Q1) was low group, 2-3 quartiles (50~75%, Q2-Q3) was middle group, 4th quartile (100%, Q4) was defined as high group. To analyze MMT according to MBF and MAI, Kruskal-Wallis test was performed, and post-tested with Mann-Whitney *U* test. The association between MBF, MAI, and MMT was investigated by using the multiple regression analysis. For all statistical analysis, the SPSS statistics Ver.25.0 (SPSS Inc., Chicago, IL, USA) program was used, and the statistical significance level was set to 5% ($P<0.05$).

Ⅲ. RESULTS

1. General characteristics of the subjects

There were 99 subjects, 24 males (24.2%) and 75 females (75.8%), and the mean age was 76. The mean number of remaining teeth were 21.2, the mean FTUs were 10.5 and there were 34 denture wearers (34.3%). The mean values of the variables were: MBF 272.6 (N), MAI 67.6 (score), MMT during rest 9.3 (mm), MMT during clenching 12.4 (mm), and DMMT 3.1 (mm) (Table 3).

Table 3. General characteristics of the subjects

Variable	Value
Age	76.0 ± 5.8
Sex	
Male	24 (24.2)
Female	75 (75.8)
Number of tooth	21.2 ± 9.2
FTUs	10.5 ± 2.0
Denture wear	
Yes	34 (34.3)
No	65 (65.7)
MBF (N)	272.6 ± 188.1
MAI (score)	67.6 ± 7.1
MMT during rest (mm)	9.3 ± 1.6
MMT during clenching (mm)	12.4 ± 7.1
DMMT (mm)	3.1 ± 1.1

Values are presented as n (%) or mean ± standard deviation.

FTUs, functional tooth units; MBF, maximum bite force; MAI, mixing ability index; MMT, masseter muscle thickness; DMMT, difference in masseter muscle thickness displacement.

2. Difference of variables according to the sex

Females had more remained teeth than males, FTUs were higher in males(P=0.046), and the proportion of denture wearers was higher in males (P=0.007). There were no statistically significant differences in MBF, MAI, MMT during rest, and MMT during clenching, but DMMT in males were higher than females (P=0.046) (Table 4).

Table 4. Difference of variables according to the sex

Variables	Male (N=24)	Female (N=75)	*P*-value
Age	77.5 ± 5.1	75.6 ± 6.0	0.106[b]
Number of remaining teeth	14.7 ± 11.8	23.3 ± 7.1	0.002[b]
FTUs	11.1 ± 1.9	10.3 ± 2.1	0.046[b]
Denture wear	14 (58.3)	20 (26.7)	0.007[a]
MBF (N)	206.5 ± 150.4	293.8 ± 194.8	0.064[b]
MAI (score)	66.0 ± 10.1	68.2 ± 5.9	0.987[b]
MMT during rest (mm)	10.3 ± 1.7	9.8 ± 1.4	0.258[b]
MMT during clenching (mm)	13.7 ± 2.2	12.8 ± 1.9	0.111[b]
DMMT (mm)	3.3 ± 0.9	2.9 ± 0.8	0.046[b]

Values are presented as n (%) or mean ± standard deviation.

MBF, maximum bite force; MAI, mixing ability index; MMT, masseter muscle thickness; DMMT, difference in masseter muscle thickness displacement.

[a]Chi-square test, [b]Mann-Whitney *U* test.

3. Difference in variables according to the number of loss in posterior teeth (Premolars, Molars)

FTUs (P<0.001), MBF (P<0.001), MAI (P=0.037), MMT during rest (P=0.002), and MMT during clenching (P=003) were significantly different according to each group. The FTUs of the No loss group were 12, and the denture group had higher FTUs than the 1-2 loss and 3-5 loss groups. MBF was higher in the no loss group and 1-2 loss group, and MAI was the highest in the no loss group. MMT during rest and MMT during clenching was decreased in the denture group, and DMMT was not statistically significant (Table 5).

Table 5. Difference of variables according to the number of loss in posterior teeth

Variables	No loss (N=30)	1-2 loss (N=25)	3-5 loss (N=9)	Denture (N=35)	*P*-value
FTUs	12.0 ± 0.0[a]	9.52 ± 1.3[b]	6.22 ± 1.5[c]	10.9 ± 1.6[b]	< 0.001
MBF (N)	378.8 ± 215.8[a]	309.6 ± 158.4[a]	220.5 ± 119.2[a,b]	168.7 ± 135.6[b]	< 0.001
MAI (score)	70.7 ± 3.0[a]	68.1 ± 4.3[b]	67.1 ± 7.3[b]	65.0 ± 9.9[b]	0.037
MMT during Rest (mm)	10.4 ± 1.2[a]	10.4 ± 1.7[a]	10.0 ± 2.2[a,b]	9.2 ± 1.2[b]	0.002
MMT during Clenching (mm)	13.6 ± 1.5[a]	13.7 ± 2.1[a]	12.8 ± 2.8[a,b]	12.1 ± 1.7[b]	0.003
DMMT (mm)	3.2 ± 0.6[a]	3.2 ± 0.9[a]	2.8 ± 1.2[a]	2.9 ± 0.8[a]	0.338

Values are presented as mean±standard deviation.

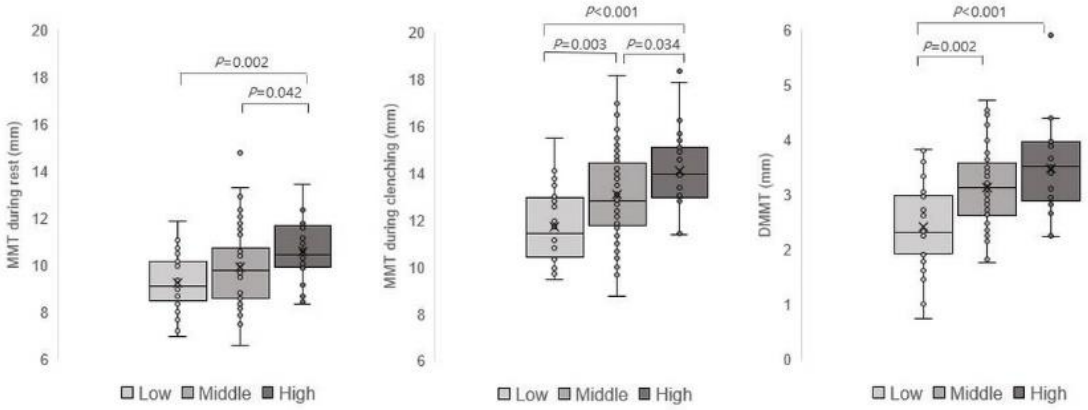
MMT, masseter muscle thickness; DMMT, difference in masseter muscle thickness displacement.

By the Kruskal-Wallis test at α=0.05.

[a,b] The same superscript characters are not significant by Mann-Whitney *U* test at α=0.05.

4. Difference in MMT according to MBF

The higher the MBF, the thicker the MMT. The MMT during rest was significantly different between MBF's low and high groups (*P*=0.002), and between the middle and high groups (*P*=0.042). The MMT during clenching was significantly different between MBF's low and high group (*P*<0.001), low and middle group (*P*=0.003), and middle and high group (*P*=0.034). The DMMT was significantly different between MBF's low and high groups (*P*<0.001), and between the low and middle groups (*P*=0.002) (Fig. 8).

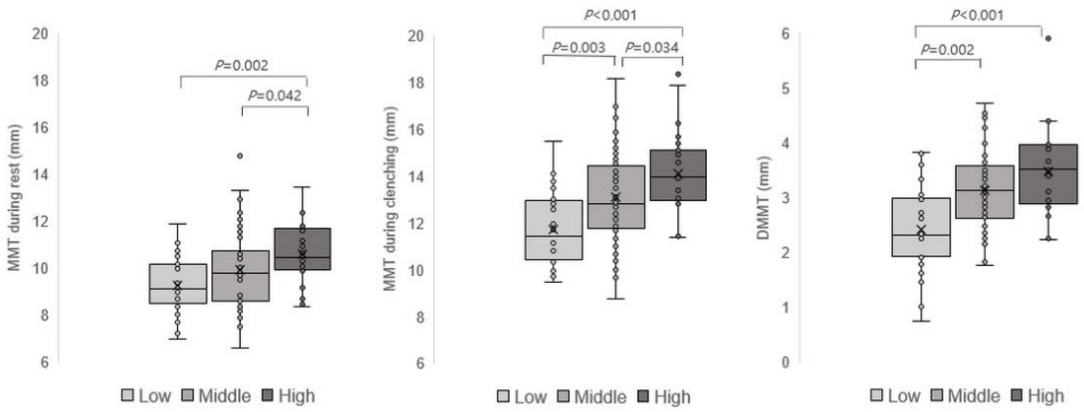


MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement.
By the Kruskal-Wallis test and Mann-Whitney *U* test at α=0.05.

Figure 8. Difference in masseter muscle thickness according to maximum bite force

5. Difference in MMT according to MAI.

There were no statistically significant differences in MMT during rest, MMT during clenching, and DMMT according to MAI (Fig. 9).



MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement.
By the Kruskal-Wallis test and Mann-Whitney *U* test at α=0.05.

Figure 9. Difference in masseter muscle thickness according to mixing ability index

6. The factors related to masticatory function assessment

In multiple regression analysis, MMT during rest and MMT during clenching had a high correlation, so when both variables were entered as independent variables, multicollinearity occurred, and MMT during clenching was excluded. The regression model using MBF as a dependent variable was statistically significant ($P<0.001$). The regression model determination coefficient was R=0.308 and the adjusted coefficient was $R^2=0.263$. The MBF increased significantly as the number of remaining teeth (β=0.350, $P=0.002$) and DMMT (β=0.239, $P=0.016$) increased. The regression model using MAI as a dependent variable was statistically significant ($P<0.001$). The regression model determination coefficient was R=0.292 and the adjusted coefficient was $R^2=0.246$. The MAI increased significantly as the number of remaining teeth (β=0.478, $P<0.001$) increased (Table 6).

Table 6. The factors related to masticatory function assessment

Variables	B	standard B	*t*	*P*-value	VIF
MBF					
Age	-0.392	-0.012	-0.136	0.892	1.053
Sex (Female)	58.913	0.135	1.281	0.203	1.475
Number of remaining teeth	7.151	0.350	3.161	0.002	1.633
FTUs	9.401	0.102	1.132	0.261	1.071
MMT during rest	11.181	0.090	0.882	0.380	1.395
DMMT	53.574	0.239	2.445	0.016	1.270
F=6.829, *P*<0.001, R=0.308, adjusted R^2=0.263					
MAI					
Age	-0.009	-0.007	-0.082	0.935	1.053
Sex (Female)	-0.291	-0.018	-0.165	0.869	1.475
Number of remaining teeth	0.370	0.478	4.267	< 0.001	1.633
FTUs	0.212	0.060	0.666	0.507	1.071
MMT during rest	0.015	0.003	0.031	0.975	1.395
DMMT	1.430	0.168	1.701	0.092	1.270
F=6.319 *P*<0.001, R=0.292, adjusted R^2=0.246					

The data was analyzed by multiple linear regression analysis.

FTUs, functional tooth units; MBF, maximum bite force; MAI, mixing ability index; MMT, masseter muscle thickness; DMMT, difference in masseter muscle thickness displacement.

Ⅳ. DISCUSSION

The purpose of this study was to investigate the association between the objective indicator of masticatory function assessment and the MMT using ultrasound imaging.

In this study, the mean MMT in the elderly during rest was 9.3 mm and during clenching was 12.4 mm (Table 3). In a study by Park et al. (2018), the mean MMT during rest in healthy adults aged 20 to 40 years was 14.8 mm and during clenching it was 17.0 mm. In addition, Raadsheer et al. (1996) reported that MMT decreases with age in both men and women, confirming that aging can cause a decrease in MMT.

In this study, the number of remaining teeth in female was high, and the proportion of denture wearers was higher in males, but there was no significant difference in masticatory function-related variables (Table 4). The mean number of remaining teeth was 15 in males and 23 in females, but the mean FTUs was 11 in males and 10 in females. In a study by Naka et al., subjects with fewer teeth tended to have their missing teeth replaced with an removable partial denture (RPD), and thus, they had many artificial functional tooth units, and subjects with fewer teeth mentioned more impaired chewing ability than those wearing RPDs. In addition, DMMT of male was thicker than that of female. Ohara et al. (2013) also found that males have thicker DMMT than females, which is consistent with this study, and the thicker the DMMT, the higher the occlusal force. Therefore, although the number of teeth remaining in male was decrease, it was considered that there was no significant difference in masticatory function by sex due to the influence of other factors.

The loss of the posterior teeth is more closely related to changes in MMT and masticatory

function than the anterior teeth (Yamaguchi et al., 2018), and the mastication can be improved by increasing the number of FTUs through prosthetic treatment and denture. However, in this study, the MBF and MAI of the denture group were reduced, and the muscle thickness was also thin, suggesting that there was a limit to recovery of complete masticatory function (Table 5). Therefore, restoration due to tooth loss should be performed as soon as possible, and restoration of a fixed prosthesis rather than a removable prosthesis may help to maintain the muscle thickness and improve the chewing function.

The difference in MMT according to MBF and MAI showed that the higher the MBF, the thicker the MMT (Fig. 8). There was no statistically significant difference in MMT according to MAI (Fig. 9). In addition, as a result of analyzing factors relating to MBF and MAI using multiple regression analysis, MBF showed the number of remaining teeth and DMMT as predictors, but MAI had an effect only on the number of remaining teeth (Table 6). A study by Bakke et al. (1992) observed that in healthy adults, the MMT in contraction strongly correlated with the number of teeth in contact. In general, the MMT during rest is lower than the MMT during clenching. This is because when a muscle contracts, muscle fiber filaments slide into each other and become thicker as the fiber diameter increases (Ariji et al., 2004). DMMT is the difference between MMT during rest and MMT during clenching, and increases with thicker MMT during clenching. It suggests that muscle contraction that occurs in the clenching state is related to MBF, and that DMMT is a more important factor in masticatory function than the MTT during rest.

However, MAI is a dynamic masticatory state caused by rhythmic movements, and

various factors such as the movement of the mandible, muscle activity, chewing rate, occlusion, and tooth interference caused by lateral movements are complexly involved (Fulks et al., 2017). Therefore, the effect of the MMT on MAI was weak and limited.

One of the main goals of dental treatment is to maintain a lifelong healthy masticatory function. In a study by Bhoyar et al., (2012) the MMT of the edentulous patients was found to be more after 3 months of denture wear than that at denture insertion. It has also been shown that implant-supported over-dentures help to maintain MMT, bite force, and masticatory efficiency better than general conventional full dentures (Muller et al., 2012). Therefore, proper prosthetic restoration is considered to increase the MMT and strengthen activity, and the improvement of masticatory function can be expected in healthy elderly people.

Since this study was designed as a cross-sectional study, it was difficult to explain the causal relationship between MMT and masticatory function variables. In addition, it may be limited to generalize the results of research on convenience samples extracted from some regions, and the distribution of subgroups according to gender and tooth loss is uneven. Despite these limitations, this study confirmed that the MMT in the elderly measured by ultrasound imaging could be a predictor of MBF, which is one of the masticatory function assessment indicators. It suggests that occlusal recovery and masseter muscle training in the elderly may help improve mastication ability.

V. CONCLUSION

1. There were 99 subjects, 24 males and 75 females, and the mean age was 76. Females had more remained teeth than males(P=0.002), FTUs were higher in males (P=0.046), and the proportion of denture wearers was higher in males (P=0.007).

2. There were no statistically significant differences in MBF, MAI, MMT during rest, and MMT during clenching according to sex, but DMMT was higher in males than in females (P=0.046).

3. The FTUs of the group without a posterior tooth loss was 12, and the denture group had higher FTUs than the group with a posterior tooth loss (P<0.001).

4. MBF (P<0.001), MAI (P=0.037), MMT during rest (P=0.002), and MMT during clenching (P=0.003) were higher in the group without teeth loss in the posterior teeth.

5. The higher the MBF, the thicker the MMT during rest (P=0.002), MMT during clenching (P<0.001), DMMT (P<0.001).

6. MBF showed the number of remaining (β=0.350, P=0.002) and DMMT (β=0.239, P=0.016) as predictors, but MAI had an effect only on the number of remaining teeth

(β=0.478, P<0.001).

One of the main goals of dental treatment is to maintain a lifelong healthy masticatory function. Therefore, proper prosthetic restoration is considered to increase the MMT and strengthen activity, and the improvement of masticatory function can be expected in healthy elderly people. Despite the limitations of this study, it confirmed that the MMT in the elderly measured by ultrasound imaging could be a predictor of MBF, which is one of the masticatory function assessment indicators. It suggests that occlusal recovery and masseter muscle training in the elderly may help improve mastication ability.

REFERENCES

Ariji Y, Sakuma S, Izumi M, et al. Ultrasonographic features of the masseter muscle in female patients with temporomandibular disorder associated with myofascial pain. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;98(3):337-341.

Bakke M, Tuxen A, Vilmann P, Jensen BR, Vilmann A, Toft M. Ultrasound image of human masseter muscle related to bite force, electromyography, facial morphology, and occlusal factors. Scand J Dent Res. 1992;100(3):164-171.

Bhoyar PS, Godbole SR, Thombare RU, Pakhan AJ. Effect of complete edentulism on masseter muscle thickness and changes after complete denture rehabilitation: an ultrasonographic study. J Investig Clin Dent. 2012;3(1):45-50.

Emshoff R, Emshoff I, Rudisch A, Bertram S. Reliability and temporal variation of masseter muscle thickness measurements utilizing ultrasonography. J Oral Rehabil. 2003;30(12):1168-1172.

Fulks BA, Callaghan KX, Tewksbury CD, Gerstner GE. Relationships between chewing rate, occlusion, cephalometric anatomy, muscle activity, and masticatory performance. Arch Oral Biol. 2017;83:161-168.

Iinuma T, Arai Y, Fukumoto M, et al. Maximum occlusal force and physical performance in the oldest old: the Tokyo oldest old survey on total health. J Am Geriatr Soc. 2012;60(1):68–76.

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):991-996.

Jeong SH, Kang SM, Ryu JH, Kwon HK, Kim BI. Subjective food intake ability in relation to the Mixing Ability Index in Korean adults. J Oral Rehabil. 2010;37(4):242-247.

Kandelman D, Petersen PE, Ueda H. Oral health, general health, and quality of life in older people. Spec Care Dentist 2008; 28: 224– 236.

Kwon SH, Park HR, Lee YM, et al. Difference in food and nutrient intakes in Korean elderly people according to chewing difficulty: using data from the Korea National Health and Nutrition Examination Survey 2013 (6th). Nutr Res Pract. 2017;11(2):139–146.

Lin CS, Wu CY, Wu SY, et al. Age- and sex-related differences in masseter size and its role in oral functions. J Am Dent Assoc. 2017;148(9):644–653.

Müller F, Shimazaki Y, Kahabuka F, Schimmel M. Oral health for an ageing population: the importance of a natural dentition in older adults. Int Dent J. 2017;67 Suppl 2:7–13.

Müller F, Hernandez M, Grütter L, Aracil-Kessler L, Weingart D, Schimmel M. Masseter muscle thickness, chewing efficiency and bite force in edentulous patients with fixed and removable implant-supported prostheses: a cross-sectional multicenter study. Clin Oral Implants Res. 2012;23(2):144-150.

Murakami M, Hirano H, Watanabe Y, Sakai K, Kim H, Katakura A. Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults. *Geriatr Gerontol Int*. 2015;15(8):1007-1012.

Naka O, Anastassiadou V, Pissiotis A. Association between functional tooth units and chewing ability in older adults: a systematic review. *Gerodontology*. 2014;31(3):166-177.

Newton JP, Yemm R, Abel RW, Menhinick S. Changes in human jaw muscles with age and dental state. Gerodontology. 1993;10(1):16–22.

Nakata M. Masticatory function and its effects on general health. Int Dent J. 1998;48(6):540-548.

Ohara Y, Hirano H, Watanabe Y, et al. Masseter muscle tension and chewing ability in older persons. Geriatr Gerontol Int. 2013;13(2):372–377.

Peyron MA, Blanc O, Lund JP, Woda A. Influence of age on adaptability of human mastication. J Neurophysiol. 2004;92(2):773–779.

Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol. 2005;33(2):81–92.

Park G, Choi YC, Bae JH, Kim ST. Does Botulinum Toxin Injection into Masseter Muscles Affect Subcutaneous Thickness?. Aesthet Surg J. 2018;38(2):192-198.

Raadsheer MC, Kiliaridis S, Van Eijden TM, Van Ginkel FC, Prahl-Andersen B. Masseter muscle thickness in growing individuals and its relation to facial morphology. Arch Oral Biol. 1996;41(4):323-332.

Reis Durão AP, Morosolli A, Brown J, Jacobs R. Masseter muscle measurement performed by ultrasound: a systematic review. Dentomaxillofac Radiol. 2017;46(6):20170052.

Ueno M, Yanagisawa T, Shinada K, Ohara S, Kawaguchi Y. Masticatory ability and functional tooth units in Japanese adults. J Oral Rehabil. 2008;35(5):337-344.

Shinogaya T, Matsumoto M. Evaluation of prosthodontic treatment by occlusal force distribution: a methodological study. Eur J Prosthodont Restor Dent. 1998;6(3):121–125.

Yamaguchi K, Tohara H, Hara K, et al. Relationship of aging, skeletal muscle mass, and tooth loss with masseter muscle thickness. BMC Geriatr. 2018;18(1):67.

Abstract (in Korean)

노인의 저작 기능 평가와 교근 두께의 연관성

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정 효 정

연구목적: 본 연구는 노인의 객관적인 저작 기능 평가와 초음파로 촬영된 교근 두께의 연관성을 조사하고자 하였다.

연구대상 및 방법: 65세 이상 노인을 대상자로 모집하였으며, 총 99명(남성: 24명, 여성: 75명)의 데이터를 분석하였다. 최대교합력(Maximum bite force; MBF)은 감압지와 이미지 스캐너를 이용하여 측정하였다. 저작효율(Mixing ability index; MAI)은 대상자에게 왁스 시편을 씹도록 요청한 후, 이미지 분석을 통해 계산되었다. 초음파 장비를 이용하여 이완기와 수축기 상태의 교근 두께(Masseter muscle thickness; MMT)를 측정하였으며, 이완기와 수축기

교근 두께 차이는 DMMT (Difference in masseter muscle thickness)로 정의되었다. 저작 기능 평가와 교근 두께의 연관성을 알아보기 위하여 다중회귀분석을 수행하였다.

연구결과: MBF는 잔존치아 수 (β=0.350, P=0.002)와 DMMT (β=0.239, P=0.016)에서 양의 상관관계가 나타났으며, MAI는 잔존치아 수 (β=0.478, P<0.001)만 연관성이 있었다.

결론: DMMT는 교근의 수축된 상태를 반영하며, 노인의 저작 기능 평가와 잔존치아 수를 예측하는데 활용할 수 있다.

핵심어 : 노인, 저작 기능, 교합력, 저작 효율, 교근 두께