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The Association Between Masticatory Function Assessment and Masseter Muscle Thickness in the Elderly

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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.

Methods: A total of 99 subjects (males: 24, females: 75, mean age: 76) were analyzed. The maximum bite force (MBF) was measured with a pressure-sensitive sheet and an image scanner. The mixing ability index (MAI) was calculated by image analysis after asking the subjects to chew a wax specimen. The MMT during rest and clenching were obtained with a diagnostic ultrasound system, and the difference in MMT during rest and MMT during clenching was defined as the difference in masseter muscle thickness (DMMT). Multiple regression analysis was performed to determine the independent variables affecting MBF and MAI.

Results: The MBF showed correlation with the number of remaining teeth (β=0.346, p=0.002) and DMMT (β=0.251, p=0.011). The MAI correlated with only the number of remaining teeth (β=0.476, p<0.001).

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

Key Words: Bite force; Masseter muscle; Mastication; Ultrasonography

INTRODUCTION

Mastication is the main function of the oral cavity, and to process of chewing and swallowing food. The mastication is related to physical and mental functions [1]. It is especially important to accurately evaluate the masticatory function in the elderly because the reduced masticatory ability in the elderly is associated with digestion, malnutrition, aspiration pneumonia, cognitive impairment, and low quality of life [2-5].

The masticatory function can be assessed using a variety of methods. Maximum bite force (MBF) and mixing ability index (MAI) are useful indicators of objective masticatory function assessment, there are closely related to tooth loss [6,7]. The loss of teeth not only causes difficulty in chewing, but also induces the absorption of alveolar bone and reduces masseter muscle mass [8]. In addition, it has been reported that the edentulous group has a thinner masseter muscle thickness (MMT) than the dentulous group [9].

The masseter muscle is a representative masticatory muscle and plays a key role in the masticatory process. It has been reported that muscle mass and muscle weakness due to aging occur not only in skeletal muscles, but also in masticatory muscles [10]. Therefore, it is necessary to consider MMT in the evaluation of masticatory function in the elderly.

Ultrasound imaging has been used to measure MMT as an indicator of muscle size, it was reported as a reliable clinical tool [11,12]. In addition, ultrasound is considered a useful method for clinical evaluation with considerable cost savings and convenience compared to computed tomography or magnetic resonance imaging [12,13].

In previous studies, changes in the MMT according to the tooth loss [14], the relationship between the masseter muscle tension and chewing ability [15], and the role of the masseter muscle size and oral function according to age and sex were reported [16]. However, 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.

MATERIALS AND METHODS

Informed consent was obtained from subjects for participation in the study, and the study was approved by the Institutional Review Board of Yonsei University Dental Hospital (IRB no. 2-2016-0034).

1. Subjects

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 criteria for selecting the subjects included those who were more than 65 years old, who had no unusual systemic diseases, were able to move on their own, and wanted to participate voluntarily. The following subjects were excluded to reduce the disturbance factors of data collection. i) Subjects with painful caries, ii) Subjects with more than 6mm periodontal pocket, iii) Subjects with pain and symptoms of temporomandibular joint, iv) Subjects with masticatory dysfunction, v) Subjects who planned dental treatment (resin filling, prosthetic treatment, extraction, implant placement, etc.) during the study period. A total of 99 data were analyzed, excluding those who met the exclusion criteria or withdrew consent.

2. Number of Remaining Teeth

The number of existing erupted teeth, excluding the residual roots and third molar was counted, and the denture wear was investigated.

3. Measurement of Maximum Bite Force

The MBF was measured with pressure-sensitive sheets 98mm in thickness (Dental Prescale, 50H type; Fuji Film, Tokyo, Japan) and analyzed by an image scanner (Occluzer, FPD-707; Fuji Film) [17]. Subjects sat comfortably and one's eyes were toward the front and performed maximal clenching in the intercuspal position with a pressure-sensitive film placed between the maxillary and mandibular dental arches. 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 different densities of color. The bite force (N) was determined as the sum of the degree of coloration and the area at each contact point.

4. Measurement of Mixing Ability Index

This study used the MAI reported by Jeong et al. [7] 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. Three wax specimens were provided to the subjects, that requested to chew the wax specimen ten times using a normal mastication pattern. Both sides of the collected wax specimens were photographed with a digital camera and saved as image files. Using the digital image analyzer (Image-Pro Plus v6.0; Media Cybernetics Inc., Rockville, MD, USA), the total projection area, projection area >50 μm 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 the variation of data, 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.

5. Measurement of Masseter Muscle Thickness

The MMT was measured using ultrasound system E-cube9 (Alpinion Inc., Seoul, Korea), and linear probe (frequency of 3.0-12.0 MHz) by a dentist. Subjects were instructed to sit with their upper body upright position, scanning was performed at the midpoint between the zygomatic arch and mandibular angle, approximately parallel with the Camper's plane along a line connecting the point under the nasal wing with the tragus of the ear [14]. The MMTs were scanning twice on the right and left during rest and during clenching, the thickest part on the image was measured. The difference in MMT during rest and MMT during clenching was defined as the difference in masseter muscle thickness (DMMT) (Fig. 1). To ensure the reliability of the data, intraclass correlation coefficients for MMT during rest and MMT during clenching were 0.794, 0.815 on the right and 0.832, 0.867 on the left. For the MMT value, the mean of the 4 imaging data (right×2, left×2) was used for analysis.

6. 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. 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) were middle group, 4th quartile (100%, Q4) was defined as High group. To analyze MMT according to MBF and MAI, the Kruskal-Wallis test was performed, post-tested with the Mann-Whitney U-test. The association between MBF, MAI and MMT was investigated by using multiple regression analysis. For all statistical analysis, the IBM SPSS Statistics for Windows, Version 25.0 (IBM Co., Armonk, NY, USA) program was used, and the statistical significance level was set to 5% ($p<0.05$).

RESULTS

Table 1 shows the general characteristics of subjects. There were 99 subjects, 24 males (24.2%) and 75 females (75.8%), and the mean age was 76. The number of remaining teeth was 21.2, and the denture wearers was 34 (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).

Fig. 2 shows the difference of MMT according to MBF. The higher the MBF, the thicker the MMT. The MMT during rest was significantly different in MBF's low and high

Table 1. General characteristics of subjects

Variable	Value (n=99)
Age	76.0±5.8
Sex	
Male	24 (24.2)
Female	75 (75.8)
Number of remaining teeth	21.2±9.2
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

MBF, maximum bite force; MAI, mixing ability index; MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement.
Values are presented as mean±standard deviation or number (%).

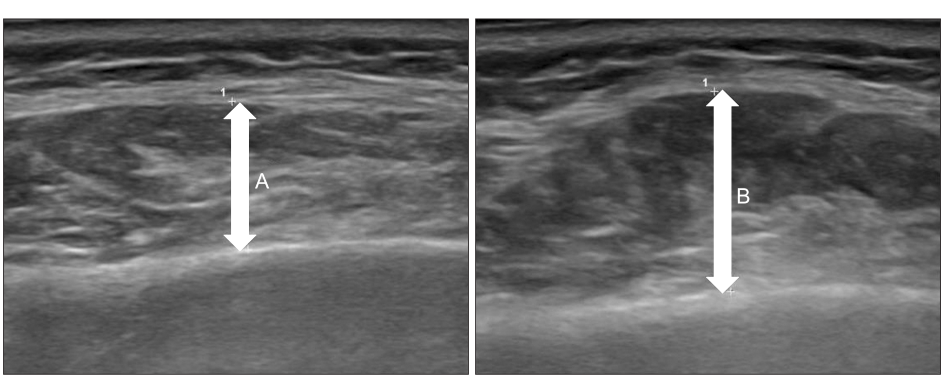

Fig. 1. Masseter muscle imaging with an ultrasonic diagnostic equipment. A, masseter muscle thickness during rest; B, masseter muscle thickness during clenching; B-A, difference in masseter muscle displacement.

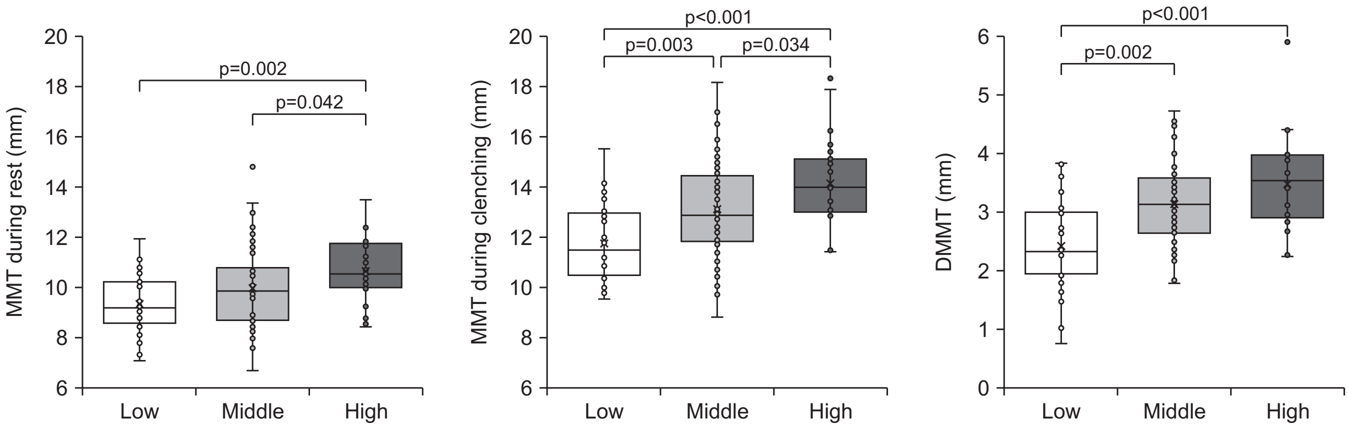

Fig. 2. Difference of masseter muscle thickness according to maximum bite force. MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement. By the Kruskal-Wallis test and Mann-Whitney U-test at α=0.05.

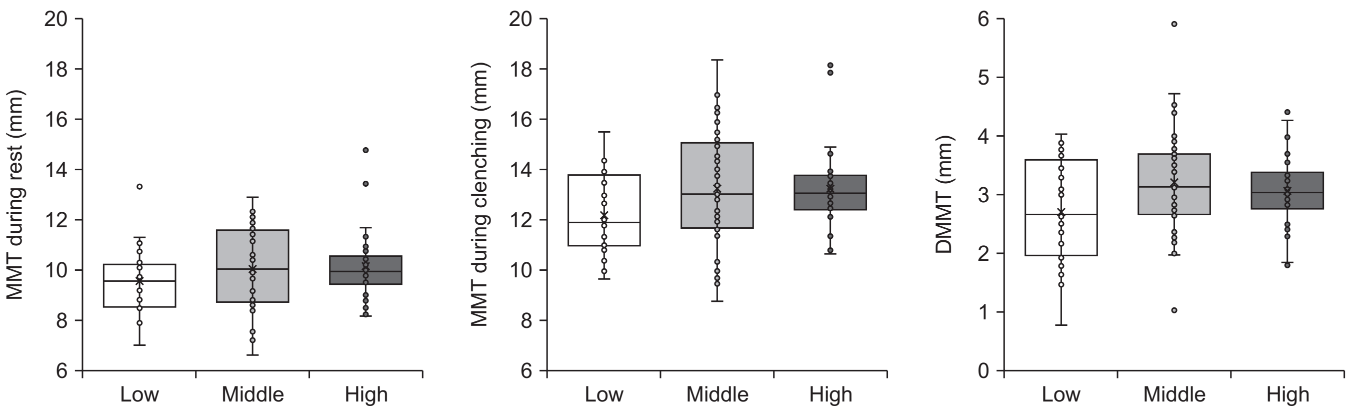

Fig. 3. Difference of masseter muscle thickness according to mixing ability index. MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement. By the Kruskal-Wallis test and Mann-Whitney U-test at α=0.05.

groups (p=0.002), middle and high groups (p=0.042). The MMT during clenching was significantly different in MBF's low and high group (p<0.001), low and middle group (p=0.003), middle and high group (p=0.034). The DMMT was significantly different in MBF's low and high groups (p<0.001), low and middle groups (p=0.002).

Fig. 3 shows the difference of MMT according to MAI. There were no statistically significant differences in MMT during rest, MMT during clenching, and DMMT according to MAI.

Table 2 shows the factors related to the masticatory function assessment. In multiple regression analysis, MMT during rest and MMT during clenching have a high correlation, so when both variables are input as independent variables, multicollinearity occurs and MMT during clenching is excluded. The regression model using MBF as a dependent variable was statistically significant (p<0.001). The regression model determination coefficient was R=0.298 and the adjusted coefficient was R^2=0.261. The MBF increased significantly as the number of remaining teeth (β=0.346, p=0.002) and DMMT (β=0.251, p=0.011) increased. The regression model using MAI as a dependent variable was statistically significant (p<0.001). The regression model determination coefficient was R=0.288 and the adjusted coefficient was R^2=0.250. The MAI increased significantly as the number of remaining teeth (β=0.476, p<0.001) increased.

DISCUSSION

The masseter muscle, temporalis muscle, medial pterygoid muscle, and lateral pterygoid muscle are called masticatory muscles. Among them, the masseter muscle is the main

Table 2. The factors related to the masticatory function assessment

Variable	B	Standard B	t	p-value	VIF
MBF					
Age	−0.785	−0.024	−0.274	0.785	1.037
Sex (female)	51.682	0.118	1.133	0.260	1.447
Number of remaining teeth	7.068	0.346	3.122	0.002	1.631
MMT during rest	9.471	0.077	0.752	0.454	1.375
DMMT	56.347	0.251	2.584	0.011	1.254
F=7.914, p<0.001, R=0.298, adjusted R^2=0.261					
MAI					
Age	−0.018	−0.015	−0.164	0.870	1.037
Sex (female)	−0.454	−0.027	−0.261	0.795	1.447
Number of remaining teeth	0.368	0.476	4.260	<0.001	1.631
MMT during rest	−0.024	−0.005	0.049	0.961	1.376
DMMT	1.493	0.176	1.792	0.076	1.254
F=7.539, p<0.001, R=0.288, adjusted R^2=0.250					

VIF, variance inflation factor; MBF, maximum bite force; MMT, masseter muscle thickness; DMMT, difference in masseter muscle displacement; MAI, mixing ability index.
The data was analyzed by multiple regression analysis.

elevator muscle of the mandible, it is involved to the masticatory function. Deterioration in muscle strength due to aging may be caused not only in skeletal muscles, but also in facial muscles. In particular, it is thought that changes in masseter muscle will affect mastication. Therefore, the purpose of this study was to investigate the association between the objective indicator of masticatory function assessment and the MMT sing ultrasound imaging.

In this study, the mean MMT during rest of the elderly was 9.3 mm and MMT during clenching 12.4 mm. In a study by Park et al. [18] the mean MMT during rest of healthy adults aged 20 to 40 years was 14.8 mm and MMT during clenching 17.0 mm. In addition, Radsheer et al. [19] reported that MMT decreases with age in both men and women, confirming that aging can cause a decrease in MMT (Table 1).

The difference of MMT according to MBF and MAI showed that the higher the MBF, the thicker the MMT (Fig. 2), and there was no statistically significant difference in MMT according to MAI (Fig. 3). In addition, as a result analyzing factors related MBF and MAI using multiple regression analysis, MBF showed the number of remaining and DMMT as predictors, but MAI had an effect only on the number of remaining teeth (Table 2). In a study by Bakke et al. [20] observed that in healthy adults, MMT in contraction was strongly correlated with the number of teeth in contact. In general, the MMT during rest is measured lower than MMT during clenching. This is because when muscle contracts, muscle fiber filaments slide into each other and become thicker as the fiber diameter increases [21]. 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 MTT during rest.

However, MAI is a dynamic masticatory state caused by rhythmic movements, and various factors such as movement of the mandible, muscle activity, chewing rate, occlusion and tooth interference caused by lateral movements are complexly involved [22]. Therefore, the effect of MMT on MAI was weak and limited as a predictor.

One of the main goals of dental treatment is to maintain a lifelong healthy masticatory function. In a study by Bhoyar et al. [3] MMT of the edentulous patients was increased after 3 month of denture wear than the thickness at the denture insertion. It has also been shown that implant-supported over-denture were reported to help maintain MMT, bite force and masticatory efficiency rather than general conventional full denture dentures [23]. Therefore, proper prosthetic restoration is considered to increase the MMT and strengthen the 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 can 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.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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