The relationship between masseter muscle thickness measured by ultrasonography and facial profile in young Korean adults

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ABSTRACT

Purpose: The purpose of this study was to evaluate the relationship between masseter muscle thickness, facial morphology, and mandibular morphology in Korean adults using ultrasonography.
Materials and Methods: Ultrasonography was used to measure the masseter muscle thickness bilaterally of 40 adults (20 males, 20 females) and was performed in the relaxed and contracted states. Facial photos and panoramic radiography were used for morphological analyses and evaluated for correlations with masseter muscle thickness. We also evaluated the correlations of age, body weight, stature, and body constitution with masseter muscle thickness.
Results: In the relaxing, the masseter was 9.8 ± 1.3 mm in females and 11.3 ± 1.2 mm in males. In the contracted state, it was 12.4 ± 1.4 mm in females and 14.7 ± 1.4 mm in males. Facial photography showed that bizygomatic facial width over facial height was correlated with masseter muscle thickness in both sexes in the relaxed state, and was statistically significantly correlated with masseter muscle thickness in males in the contracted state. In panoramic radiography, correlations were found between anterior angle length and posterior angle length and masseter muscle thickness in females, and between body length and posterior angle length, between anterior angle length and body length, between ramal length and body length, and between body length and condyle length in males.
Conclusion: Masseter muscle thickness was associated with facial and mandibular morphology in both sexes, and with age in males. Ultrasonography can be used effectively to measure masseter muscle thickness.
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KEY WORDS: Ultrasonography; Masseter Muscle; Young Adult; Radiography, Panoramic

Introduction

Facial morphology is influenced by hard tissues such as bones and soft tissues such as muscles. Aside from tooth, bone is the hardest tissue in the body, but it has been reported that its form and image continuously change through the process of modeling and remodeling. Fac-

tors that can lead to a change in bone tissue form include electric stimulation, mechanical stimulation, hormones, and general diseases, and it is understood that bone tissue form is most affected by nearby soft tissues such as muscles.[1,2] In his functional matrix theory, Moss claimed that the growth of bone tissues is affected by nearby soft tissues that work as a functional matrix.[3] He claimed that muscles attached to the mandible affect the growth of the mandible and that the orbit affects the growth and development of the orbital bone.[3-6] Muscle function has a major impact on bone tissues, not only in the growth phase, but also in adulthood.[4] For example, patients with

sarcopenia have a higher risk of contracting osteoporosis and, likewise, after mandibular osteotomy the bone tissue in the mandible experiences re-deposition. Therefore, the evaluation of muscular shape and function is important in analyzing facial features as well as in analyzing related bone tissues.

However, the evaluation of facial soft tissues—in particular, muscles—has presented more technical difficulties than the evaluation of hard tissues. In other words, hard tissues can be analyzed for the morphology of facial bone through lateral radiography,[7,8] and recently, it became easier to analyze the 3-dimensional skeletal morphology and features of the jaw due to the development of cone-beam computed tomography (CBCT).[9] However, it is more difficult to assess soft tissues using radiography. While it is possible to measure the thickness and other characteristics of masticatory muscles through soft tissue imaging by computed tomography (CT), patient exposure to radiation is an added risk. Thus, CT is of limited value in performing common examinations. It is also possible to evaluate soft tissues through magnetic resonance imaging (MRI), but it is expensive and time-consuming; furthermore, the fact that MRI is a static imaging modality, not a dynamic one, makes it difficult to analyze the shape during muscle contraction and relaxation.[10]

There have been many recent attempts to apply ultrasonography in the dental field. Unlike CT and other imaging modalities that expose the patient to a clinically significant radiation dosage, ultrasonography does not pose the problem of radiation exposure and dynamic analysis is possible. It is also possible to assess the blood vessel flow and speed;[11] this is, therefore, being attempted for a number of anatomical areas including the mastication muscles,[12] salivary glands,[13] and cervical lymph nodes.[14] Applying ultrasonography to these assessments has several limitations. No oral probe suitable for dentists has been developed, the ultrasonographic signal cannot pass through hard tissues, and no method of probe application has been standardized, thus requiring a learning curve period for clinical application. Among measurements using ultrasonography (US), masticatory muscle thickness has been the most common type of analysis. Though masticatory muscle thickness measurement using US does not provide precise evaluations of masticatory force or muscular contractile force, the thickness of muscle displays a proportional relationship with muscular function and hence, several studies have attempted to analyze masticatory force indirectly through measurement of muscle thickness.[8,10,15-18] Masticatory muscles affect masticatory

function and also play a major role in shaping the facial appearance. The masseter originates from the zygomatic arch, attaches to the masseteric tuberosity, and is located closer to the surface than other masticatory muscles, providing the advantage of being easier to assess. Researchers from many countries have published data measuring the masticatory muscle thickness of residents of their respective countries,[8,10,15-18] but few studies have investigated the average thickness of the masticatory muscles of Koreans or the relationship of such values with the facial morphology or the shape of the mandible.

The purpose of this study was to measure masticatory muscle thickness with ultrasonography and to evaluate its correlation with facial morphology and mandible shape to assess the impact of facial muscle thickness on bone tissues and facial morphology.

Materials and Methods

This study was approved by the institutional review board of the Dental Hospital of Yonsei University College of Dentistry (IRB No. 2-2015-0045). Over the period between December 10, 2015 and October 30, 2016, 40 volunteers (20 males, 20 females) were enrolled from among inpatients who visited the Department of Advanced General Dentistry Yonsei University College of Dentistry.

Subjects who met the following selection criteria were enrolled: 1) adults over 20 years of age 2) who did not have dental disease such as temporomandibular joint disorder, myofascial pain syndrome, or the like; 3) who had a Class I molar relationship; and 4) who had not received
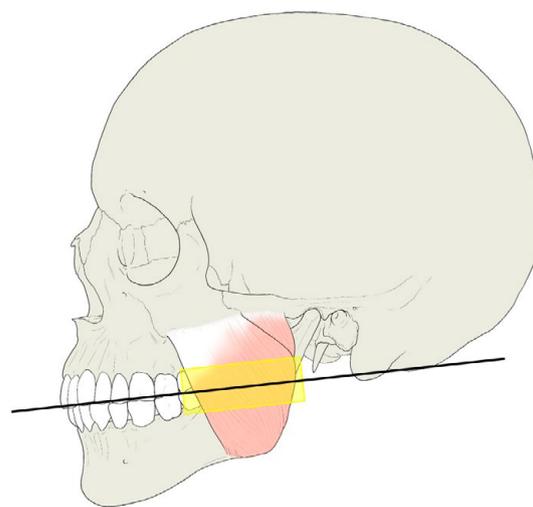

Fig. 1. Scanning level of the masseter muscle in axial imaging (yellow area).

orthodontic treatment. Excluded were those whose masticatory muscles were abnormal or could not be measured due to congenital anomaly, trauma, or tumor. Images taken to measure the masseter muscle were acquired using an ultrasound scanner (E-CUBE 15EX, Alpinion Medical Systems, Seoul, Korea) and a linear probe (L3-12H, Alpinion Medical Systems, Seoul, Korea). The images were acquired in the following sequence: 1) The subjects were taken to a dark and quiet room, guided into an upright position, and examined by palpation to locate the masseter muscle. 2) The transducer was placed at the most promi-

nent area of the masseter muscle at the same angle as the occlusal plane (Fig. 1). 3) During the scan, the masseter muscle was placed in a position where it was perpendicular to the mandible. 4) The mandible was clearly visible as a white (hyperechoic) line, and images were acquired upon adjusting the transducer to present myofascial regions as white lines under the cutaneous and subcutaneous fat layers (Fig. 2). A relaxed state was defined as when both cusps of the upper and lower teeth were gently occluded (Fig. 3A). A contracted state was defined as the maximum contraction of muscles when the upper and lower molars were forcefully occluded (Fig. 3B). Ultrasonographic images were acquired by 2 observers, who each took measurements at intervals of 5 minutes or more and repeated the measurements twice, with the subjects in a relaxed state and in a contracted state. The thickness of the masseter muscle was measured at the thickest points presented in the images (Fig. 3). The images were then displayed on a computer monitor using a computer program installed within the ultrasonographic device.

Facial photographs of the subjects were taken to assess facial morphology, using the following indicators: facial height (FH), bizygomatic facial width (BFW), and intergonial facial width (IGW), along with form of the face (FH/BFW, FH/IGW) (Fig. 4, Table 1).[15]

Panoramic radiography was performed to confirm the relationship between the mandibular morphology and the masseter muscle thickness, and the following points were
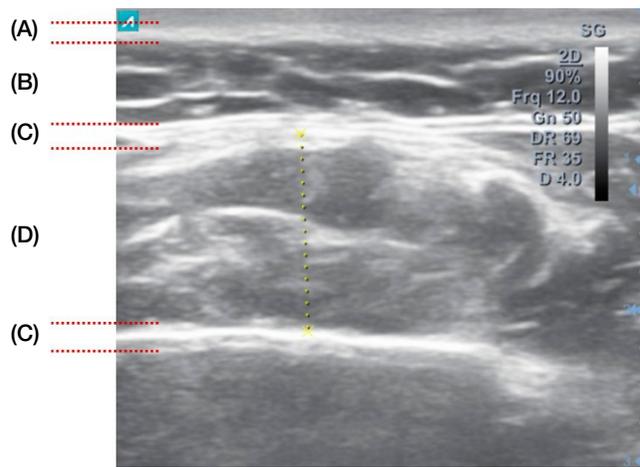

Fig. 2. Anatomical structure of masseter muscle in an ultrasound image. (A) skin layer; (B) fat layer; (C) masseteric fascia; (D) masseter muscle.
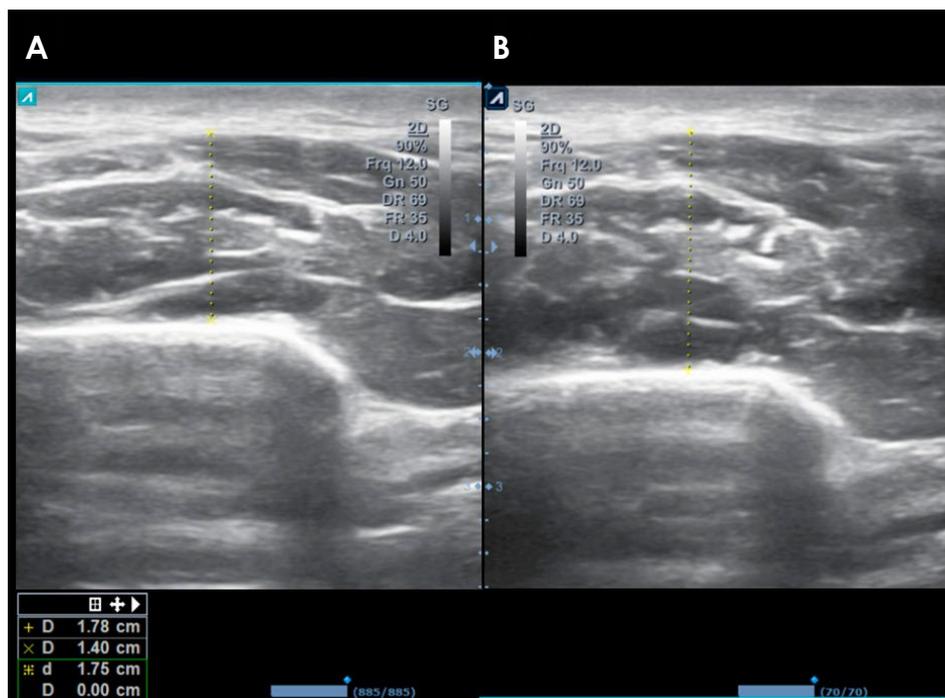

Fig. 3. Cross-sectional view of an ultrasound image. A. Relaxed state. B. Contracted state. The yellow dotted line is the masseter muscle thickness.

identified: center point of the mandibular foramen (C), condyle (Con), coronoid (Cor), posterior gonion (PGo), anterior gonion (AGo), and mental foramen (MF) (Fig. 5, Table 1). However, since panoramic radiography has different magnification ratios in each region, the ratio of the length of each measurement item was used to overcome

this problem (Table 2).[19]

The age, body weight (bw), and stature (s) of the subjects were measured, and body constitution (bw/s) was checked for correlation with masseter muscle thickness.

Measurement data were statistically analyzed using IBM SPSS 23.0 (IBM Corp., Armonk, NY, USA). Inter-
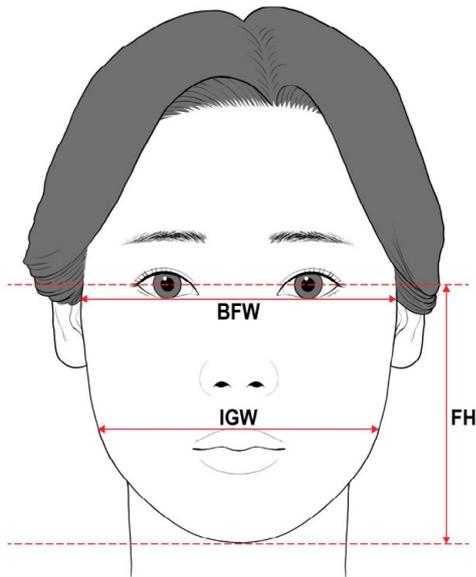

Fig. 4. Schematic diagram of reference points and measurements of length on a facial photograph. Bizygomatic facial width (BFW); intergonial facial width (IGW); facial height (FH).
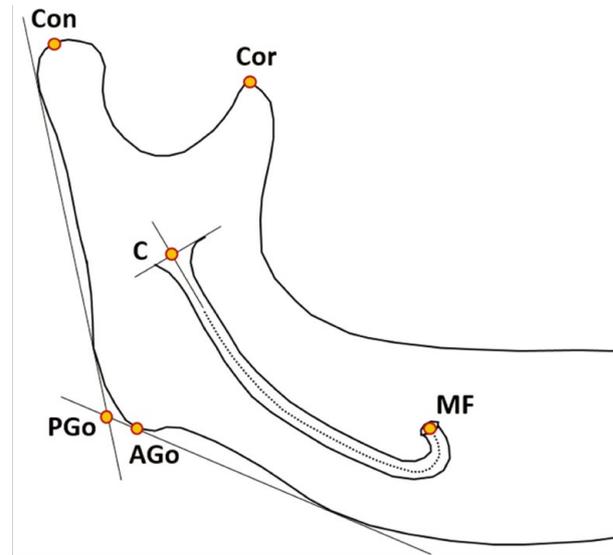

Fig. 5. Schematic diagram of reference points and measurements of length on a panoramic radiograph. Center point of mandibular foramen (C); condyle (Con); coronoid (Cor); posterior gonion (PGo); anterior gonion (AGo); mental foramen (MF).

Table 1. Definition of facial photograph and panoramic radiography measurements using the reference points

Abbreviations	Variable	Definition
C	Center point of mandibular foramen	The imaginary center of the entrance of the mandibular foramen
Con	Condyle	The most superior point of the mandibular condyle
Cor	Coronoid	The most superior point of the mandibular coronoid
PGo	Posterior gonion	The point at which the 2 tangent lines of the mandibular body and ramus intersect
AGo	Anterior gonion	The point at which the tangent to the mandibular angle from the mandibular body
MF	Mental foramen	The entrance of the mental foramen
Con-C	Condyle-Center point of mandibular foramen	Condyle length
Cor-C	Coronoid-Center point of mandibular foramen	Coronoid length
AGo-C	Anterior gonion-Center point of mandibular foramen	Anterior angle length
PGo-C	Posterior gonion-Center point of mandibular foramen	Posterior angle length
MF-C	Mental foramen-Center point of mandibular foramen	Body length
Con-AGo	Condyle-Anterior gonion	Ramal length
BFW	Zygion-Zygion	Bizygomatic facial width
IGW	Gonion-Gonion	Intergonial facial width
FH	Distance between gnathion and the line between the temporal canthus of the eye	Facial height

class and intraclass correlation coefficients were used to reduce the measurement error of masseter muscle thickness. The Student *t* test was performed to evaluate the gender and analysis of left/right measurements from ultrasonography and panoramic radiography. The Spearman rho test was performed to assess the correlations of facial photography, panoramic radiography, age, body weight, stature, and body constitution with masseter muscle thickness.

Results

Both intraclass and interclass correlation coefficients showed that the masseter muscle thickness data measured twice by 2 observers were reliable (Table 3).[20] The masseter muscle thickness measured by ultrasonography showed a significant difference according to gender (Table 4). No statistically significant differences were found between the left and right sides in mandibular morphology measured by ultrasonography or masseter muscle thickness parameters measured using panoramic radiography (Table 5).

In the facial morphology data, FH/IGW and the thickness of the masseter muscle measured in the relaxed state were found to be correlated in both sexes. In the contracted state, the thickness of the masseter muscle and the value of FH/IGW were also statistically significant in males (Table 6).

In mandibular morphology measured by panoramic radiography, a correlation was found between PGo-C/AGo-C and masseter muscle thickness in the relaxed state in females (Table 7). Con-C/MF-C and MF-C/Con-AGo also showed a significant correlation in the contracted state of the males, while PGo-C/MF-C, MF-C/AGo-C, and MF-C/Con-AGo showed a significant correlation in the relaxed state (Table 7).

In males, the thickness of the masseter muscle in the

Table 2. Definition and description of facial morphology and mandibular morphology using the measurement items

Abbreviations	Definition
Facial morphology	
FH/BFW	Bizygomatic facial width over facial height
FH/IGW	Intergonial facial width over facial height
Mandibular morphology	
Con-C/Cor-C	Coronoid length over condyle length
Con-C/AGo-C	Anterior angle length over condyle length
Con-C/PGo-C	Posterior angle length over condyle length
Con-C/MF-C	Body length over condyle length
Con-C/Con-AGo	Ramal length over condyle length
Cor-C/AGo-C	Anterior angle length over coronoid length
Cor-C/PGo-C	Posterior angle length over coronoid length
Cor-C/MF-C	Body length over coronoid length
Cor-C/Con-AGo	Ramal length over coronoid length
AGo-C/Con-AGo	Ramal length over anterior angle length
PGo-C/AGo-C	Anterior angle length over posterior angle length
PGo-C/MF-C	Body length over posterior angle length
PGo-C/Con-AGo	Ramal length over posterior angle length
MF-C/AGo-C	Anterior angle length over body length
MF-C/Con-AGo	Ramal length over body length

Table 3. Intra and interclass correlation coefficient

		Left		Right	
		Relaxed	Contracted	Relaxed	Contracted
Intraclass Correlation	Measurement 1	0.7	0.8	0.7	0.8
Coefficient	Measurement 2	0.9	0.9	0.8	0.8
Interclass Correlation	Observer 1	0.9	0.8	0.6	0.7
Coefficient	Observer 2	0.9	0.9	0.8	0.8

Table 4. Masseter muscle thickness in ultrasonography (unit: mm)

	Relaxed male	Relaxed female	P	Contracted male	Contracted female	P
Left	11.3 ± 1.1	10.1 ± 1.5	0.013*	14.7 ± 1.5	12.5 ± 1.6	0.000*
Right	11.4 ± 1.5	9.5 ± 1.4	0.000*	14.7 ± 1.6	12.2 ± 1.6	0.000*
Total	11.3 ± 1.2	9.8 ± 1.3	0.001*	14.7 ± 1.4	12.4 ± 1.4	0.000*

*: $P < .05$

Table 5. Left and right comparison of mandibular length ratio and masseter muscle thickness

	Left	Right	P
Ultrasonography			
Relaxed	1.1±0.1	1.0±0.2	0.459
Contracted	1.4±0.2	1.3±0.2	0.780
Panoramic radiography			
Con-C/Cor-C	1.1±0.1	1.2±0.2	0.273
Con-C/AGo-C	1.1±0.2	1.1±0.2	0.557
Con-C/PGo-C	1.2±0.2	1.2±0.2	0.773
Con-C/MF-C	0.5±0.1	0.5±0.1	0.172
Con-C/Con-AGo	0.5±0.0	0.5±0.1	0.501
Cor-C/AGo-C	1.0±0.2	1.0±0.2	0.923
Cor-C/PGo-C	1.0±0.2	1.0±0.2	0.954
Cor-C/MF-C	0.4±0.1	0.4±0.1	0.985
Cor-C/Con-AGo	0.5±0.1	0.5±0.1	0.707
AGo-C/Con-AGo	0.5±0.0	0.5±0.0	0.679
PGo-C/AGo-C	0.9±0.0	0.9±0.0	0.570
PGo-C/MF-C	0.4±0.1	0.4±0.1	0.430
PGo-C/Con-AGo	0.5±0.0	0.5±0.0	0.795
MF-C/AGo-C	2.3±0.3	2.3±0.3	0.317
MF-C/Con-AGo	1.2±0.1	1.1±0.1	0.157

Table 6. Correlation analysis between facial characteristics and masseter muscle thickness

	Male			Female		
		r	P		r	P
FH/BFW						
Relaxed	0.8±0.0	−0.433	0.057	0.8±0.0	−0.379	0.099
Contracted		−0.281	0.229		−0.250	0.288
FH/IGW						
Relaxed	0.9±0.1	−0.687	0.001*	0.9±0.1	−0.603	0.005*
Contracted		−0.488	0.029*		−0.437	0.054

r: coefficient of correlation, *: $P < .05$

relaxed state was found to be significantly related to age (Table 8). No statistically significant correlations were found between the masseter muscle thickness and the remaining factors (Table 8).

Discussion

The masseter muscle thickness measured by ultrasonography was 9.8 ±1.3 mm (relaxed state) and 12.4±1.4 mm (contracted state) in females, and 11.3±1.2 mm (relaxed state) and 14.7±1.4 mm (contracted state) in males. The facial width and height tended to become wider and lower as the masseter muscle thickened. Moreover, the values related to the mandibular angle were affected by the thickness of the masseter muscle.

It is known that the thickness of the masseter can be used to indirectly evaluate not only the shape of the face, but also masticatory function.[10,15] Measuring the thickness of the masseter was first attempted with ultrasonography by Kiliaridis and Kälebo (1991)[15], Bakke et al., (1992),[21] and Raadsheer et al. (1994).[10] Masseter thickness values have been reported in patients with temporomandibular disorder,[12] facial asymmetry,[16] bone lesion,[22] and foreign body removal.[23] Because the masseter muscle is located on the surface layer, it can easily be measured by ultrasonography. However, ultrasound is not widely used as a method of measurement in this context. The most important reason for this is that the image quality varies according to the imaging technique applied. Even if an external measurement point and the method to assess it are defined, it is not easy to obtain ultrasonography images without accurate anatomical knowledge. Because the waves used in ultrasonography wave show continuously changing patterns, a great deal of experience performing

Table 7. Correlation analysis between mandibular morphology and masseter muscle thickness

		Male			Female		
			r	P		r	P
Con-C/Cor-C	Relaxed	1.1±0.3	0.127	0.592	1.1±0.2	−0.020	0.932
	Contracted		0.204	0.389		−0.053	0.825
Con-C/AGo-C	Relaxed	1.1±0.3	−0.161	0.497	1.1±0.2	0.280	0.232
	Contracted		0.005	0.985		0.089	0.710
Con-C/PGo-C	Relaxed	1.2±0.3	−0.194	0.411	1.2±0.2	0.085	0.722
	Contracted		0.059	0.806		−0.048	0.840
Con-C/MF-C	Relaxed	0.4±0.1	0.410	0.073	0.5±0.1	0.272	0.247
	Contracted		0.481	0.032*		0.117	0.622
Con-C/Con-AGo	Relaxed	0.5±0.1	−0.186	0.432	0.5±0.0	0.339	0.144
	Contracted		−0.017	0.942		0.149	0.530
Cor-C/AGo-C	Relaxed	0.9±0.2	−0.152	0.522	1.0±0.1	0.088	0.712
	Contracted		−0.036	0.880		−0.070	0.654
Cor-C/PGo-C	Relaxed	1.0±0.2	−0.259	0.271	1.1±0.1	−0.081	0.736
	Contracted		−0.067	0.779		−0.241	0.306
Cor-C/MF-C	Relaxed	0.4±0.1	0.268	0.254	0.4±0.1	0.330	0.156
	Contracted		0.605	0.191		0.181	0.446
Cor-C/Con-AGo	Relaxed	0.4±0.1	−0.194	0.413	0.5±0.1	0.093	0.696
	Contracted		−0.172	0.470		0.021	0.930
AGo-C/Con-AGo	Relaxed	0.5±0.1	0.133	0.575	0.5±0.0	−0.254	0.279
	Contracted		−0.051	0.830		−0.062	0.796
PGo-C/AGo-C	Relaxed	0.9±0.2	0.261	0.267	0.9±0.0	0.498	0.025*
	Contracted		−0.011	0.962		0.420	0.065
PGo-C/MF-C	Relaxed	0.4±0.1	0.582	0.007*	0.4±0.1	0.346	0.135
	Contracted		0.329	0.157		0.389	0.090
PGo-C/Con-AGo	Relaxed	0.4±0.1	0.200	0.398	0.4±0.0	0.152	0.522
	Contracted		−0.056	0.816		0.241	0.306
MF-C/AGo-C	Relaxed	2.3±0.6	−0.491	0.028*	2.4±0.3	−0.138	0.563
	Contracted		−0.292	0.212		−0.203	0.390
MF-C/Con-AGo	Relaxed	1.1±0.3	−0.619	0.004*	1.2±0.1	−0.207	0.381
	Contracted		−0.574	0.008*		−0.127	0.595

r: coefficient of correlation, *: $P < .05$

Table 8. Correlations of age, body weight, stature, and body constitution with masseter thickness

	Male			Female		
		r	P		r	P
Age						
Relaxed	27.3±5.5	0.459	0.042*	25.5±6.4	−0.324	0.134
Contracted		0.234	0.322		−0.177	0.455
Body weight (bw)						
Relaxed	72.9±8.8	0.217	0.359	51.6±6.1	0.309	0.185
Contracted		0.290	0.215		0.229	0.332
Stature (s)						
Relaxed	176.9±4.3	−0.149	0.530	160.0±4.4	0.107	0.654
Contracted		0.061	0.798		0.223	0.346
Body constitution (bw/s)						
Relaxed	0.4±0.0	0.285	0.223	0.3±0.0	0.307	0.188
Contracted		0.339	0.143		0.172	0.469

ultrasonographic measurements is required. In addition, the image could change according to the force applied to the tissue and the unique anatomical characteristics of each patient. Therefore, assessment by ultrasonography may be more subjective than CT and MRI, both of which can produce a clearer image. For these reasons, ultra-

Table 9. Comparison of the masseter muscle thickness (unit: mm)

	Male		Female	
	Relaxed	Contracted	Relaxed	Contracted
1991, Kiliaridis et al (Sweden)[15]	9.7±1.5	15.1±1.9	8.7±1.6	13.0±1.8
1998, Kubota et al (Japan)[8]	15.8±3.0	16.7±2.7	–	–
2005, Şatiroglu et al (Turkey)[17]	15.5±2.0	17.2±2.1	12.1±1.9	13.4±1.8
2013, Tircoveluri et al (India)[18]	11.6±0.8	13.5±0.9	12.5±0.5	12.5±0.6
2018, This study	11.3±1.2	14.7±1.4	9.8±1.3	12.4±1.4

sound has not often been used. Recently, the clinical usage of ultrasound has become more common because of its non-ionizing image modality. In dentistry, ultrasound has been used to make simple measurements of the thickness of the masseter muscle, to evaluate the neck nodes[24] and the submandibular[13] and sublingual glands,[25] and to perform follow-up examinations in cancer patients.[26] The development of new intraoral ultrasound probes has made it possible to use ultrasonography for various dental applications including pulpal diagnosis, measuring gingival thickness,[27] and performing vascular measurements.[14]

In this study, 2 observers discussed the anatomical characteristics and external measurement points in order to reduce errors in measurement. A pilot test was used to calibrate the measurement site and the pressure of the ultrasound probe. The reproducibility of the measurements was confirmed through this calibration.

This study examined the relationship between the thickness of the masseter muscle and various parameters of facial and mandibular morphology. Because the ratio of measurement values was assessed, a 1:1 measurement photograph was not necessary. A previous study[9] measuring the length of the condyle, coronoid, and gonion centering on the mandibular foramen reported that they were closely related to deformity of the jaw. In our results, no statistically significant differences were found between the left and right sides on panoramic radiography in adults without a jaw deformity. This observation supports the finding of a previous report that the left and right sides of the mandible were symmetrical in patients without a jaw deformity. In addition, the masseter muscle is known to affect the mandibular angle. In this study, there was a correlation between masseter muscle thickness and gonion length. This result was in agreement with previously reported studies based on computed tomography. Therefore, the measurement of masseter muscle thickness using ultrasound is meaningful and quite accurate.[10,28]

Previous studies have reported a correlation between masseter muscle thickness and facial morphology.[10,15] In our results, regardless of gender, patients with a lower facial height and larger intergonial width tended to have a thicker masseter muscle.

Kiliaridis and Kälebo (1991)[15] and Raadsheer et al. (1996)[10] reported no correlation between masseter muscle thickness and age. However, in the present study, masseter muscle thickness and age in the relaxed state showed a positive correlation in males. This might be related to ethnicity, heredity, and eating habits.

In this study, the masseter muscle thickness of males (relaxed state: 11.3±1.2 mm; contracted state: 14.7±1.4 mm) was thinner than in the studies of Kubota et al. (relaxed state: 15.8±3.0 mm; contracted state: 16.7±2.7 mm)[8] and Satiroğlu et al. (relaxed state: 15.5±2.0 mm; contracted state: 17.2±2.1 mm).[17] Furthermore, in females, the measurements (relaxed state: 9.8±1.3 mm; contracted state: 12.4±1.4 mm) were lower than those of Satiroğlu et al. (relaxed state: 12.1±1.9 mm)[17] and Tircoveluri et al. (12.5±0.5 mm)[18] in the relaxed state (Table 9). These results might originate from variation in eating habits depending on ethnicity and age.

The limitations of this study were the small sample size and lack of comparison among various age groups. The correlation between the masseter muscle thickness and the masticatory force could not be assessed. It should be noted that computerized methods of imaging masticatory force and distribution, such as the T-scan, have only recently been introduced. It would be worthwhile to develop an objective method for measuring the relationship between bite force and masseter muscle characteristics, and to perform a clinical study using that method. In addition, the direction and length of the masseter muscle differ according to the position of the jaw. Therefore, it is necessary to consider the direction and length when we evaluate the thickness of the masseter muscle. That is, in the case of a class II patient with a short ramal height, the muscle length and the force may be the same as those of a patient with a longer ramal height, the masseter muscle thickness may be greater due to its short length. Despite

the limitations of this study, it is meaningful because it provides data on muscle thickness and facial features using ultrasonography.

In conclusion, the thickness of the masseter muscle measured by ultrasound was found to be associated with facial and mandibular morphology in men. Ultrasonography is a simple and accessible technique for measuring masseter muscle thickness.

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