

Comparative data on facial morphology and muscle thickness using ultrasonography

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SUMMARY The purpose of this investigation was to measure the thickness of the masseter, levator labii superioris, and zygomaticus major muscles; to examine the reproducibility of ultrasonographically measured muscle thickness; to evaluate the association between facial and masticatory muscle thickness and vertical facial pattern; and to test whether the variation in muscle thickness is related to the variation in the body mass index (BMI) of different individuals.

The thickness of the masseter, levator labii superioris and zygomaticus major muscles was measured bilaterally by ultrasonography in 47 (23 females, 24 males) healthy, fully-dentate young adults who volunteered for the study. The measurements for each individual were performed twice for the masseter muscle: during relaxation and during maximal clenching. Standardized lateral cephalograms of the subjects were traced to determine their facial morphology. The data obtained from the lateral cephalograms were used to divide the subjects into three groups according to their vertical facial pattern: low angle ($n = 14$), high angle ($n = 17$) and normal ($n = 16$).

In the low angle group, the mean masseter muscle thickness was 15.20 (± 1.90) mm under relaxed conditions and 16.31 (± 2.18) mm during maximal clenching. In the high angle group, the respective measurements were 13.29 (± 2.52) mm and 14.72 (± 2.63) mm. In the vertically normal group, they were 13.56 (± 1.95) mm and 14.57 (± 1.83) mm. There was no relationship between vertical growth of the face and the thickness of the investigated muscles of facial expression.

Masseter muscle thickness was found to be significantly correlated to vertical facial pattern and BMI, showing that individuals with a thick masseter had a vertically shorter facial pattern, whereas the muscles of facial expression showed no relationship with vertical facial pattern.

Introduction

The effects of muscle thickness on bone morphology can be explained by a theory which is recognized in the field of biodynamics as Wolff's law (Dibbets, 1992). This law points out that the internal structure and the shape of the bone is closely related to function, and defines a relationship between bone shape and muscle function (Wolff, 1870). In order to describe facial morphology, the structure of the facial muscles should be investigated thoroughly to determine the pattern of interaction of the skeleton and muscles. The association between masseter muscle thickness and vertical craniofacial morphology seems to be a negative relationship but, in contrast, the association between masseter muscle thickness and craniofacial width appears to be positive (Weijs and Hillen, 1986; Hannam and Wood, 1989; Kiliaridis and Kålebo, 1991; Raadsheer *et al.*, 1996).

Masseter muscle thickness has been measured by various imaging techniques including ultrasound scanning, computerized tomography (CT) and magnetic resonance imaging (MRI). CT was used by Weijs and Hillen (1984) to measure masticatory muscle thickness in adults. The imaging technique used in that study produced reliable data but, for ethical reasons, radiographic exposure for experimental purposes is now restricted. Hannam and Wood (1989) published results on masseter thickness of adults,

as measured by MRI, a technique which was also found to be accurate.

Increases in lower anterior face height are reported to be independent of other skeletal units but dependent on neuromuscular factors (Woodside and Linder-Aronson, 1979). Furthermore, high palatal vaults have been observed in children with lip incompetence (Galvez and Methenitou, 1989). As the muscles primarily responsible for elevating the upper lip are the levator labii superioris and the zygomaticus major (Rubin, 1989; Nairn, 1975), it can be hypothesized that there might be a relationship between vertical facial morphology and the muscles of facial expression.

Ultrasonography has been used in recent years in different areas of medicine. It has several advantages over CT and MRI, which makes it suitable for larger scale studies (Raadsheer *et al.*, 1994). In contrast to CT, ultrasonography has no known cumulative biological effects. It is proven to be a reproducible, simple and inexpensive method for accurately measuring muscle thickness, provided the operator adheres to a strict imaging protocol (Kiliaridis and Kålebo, 1991; Esformes *et al.*, 2002; Emshoff *et al.*, 2002).

The aim of this study was to (1) measure the thickness of the masseter, levator labii superioris and zygomaticus major muscles, (2) determine the reproducibility of ultrasonographically measured muscle thickness, (3)

evaluate the association between mimical and masticatory muscle thickness and vertical facial pattern and (4) to test whether the variation in muscle thickness is related to the variation in the body mass index (BMI) of different individuals.

Subjects and methods

Ethical approval was obtained from the Marmara University Ethics Committee and all subjects gave written consent. The participants in the study were all patients enrolled for orthodontic treatment. The thickness of the masseter, levator labii superioris and zygomaticus major muscles was measured bilaterally in 47 subjects (23 females, 24 males). The mean age of the group was 24.96 ± 3.57 years. The following selection criteria were used:

1. Young adults in the permanent dentition.
2. A range of skeletal jaw discrepancies, both in the antero-posterior and vertical dimensions.
3. No history of orthognathic treatment.
4. No marked jaw asymmetries or craniofacial disorders.
5. No congenital or developmental anomalies of the lips, mouth or face.

Selection criteria were based on examination of the subjects' lateral skull cephalograms, clinical examinations and medical histories.

Ultrasound procedures

All scans were carried out in the Ultrasonography Department, Acibadem Hospital, Istanbul. Each subject was examined by the same operator, using a real-time scanner (Siemens Elegra, Erlangen, Germany) with a 7.5–9.0 MHz broadband transducer. A water-based gel was applied to the probe before the imaging procedure. During imaging, the transducer was held perpendicular to the surface of the skin and special care was taken to avoid excessive pressure. The measurement site was at the thickest part of the masseter, close to the level of the occlusal plane, approximately in the middle of the mediolateral distance of the ramus (Figure 1). The imaging and measurements were performed bilaterally with the subjects in a supine position under two different conditions: when the teeth were occluding gently with the muscle in a relaxed position and during maximal clenching, with the masseter muscle contracted (Figure 2a,b). The levator labii superioris muscle was examined bilaterally between the alar cartilage of the nose and the pupil of the eye, and the measurements were made at the thickest part with the muscle relaxed (Figure 3a). Measurements of the zygomaticus major muscle were also made bilaterally, in the rest position, on a line between the corner of the mouth and the zygomatic process (Figure 3b).

The measurements were made directly from the image at the time of scanning. The imaging and measurements were performed three times, with an interval of five minutes between each measurement.



Figure 1 Measurement method for the masseter muscle.

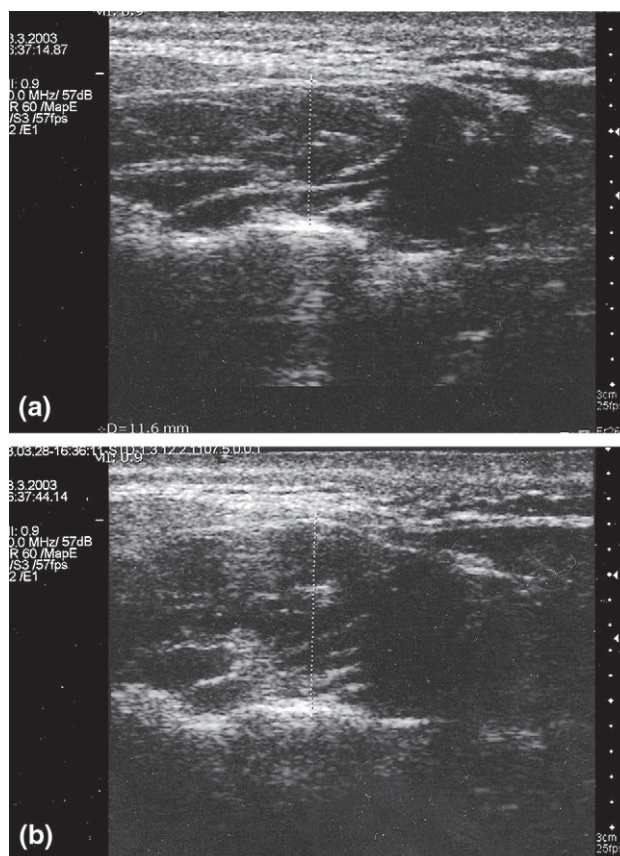


Figure 2 Ultrasonographic image of (a) relaxed and (b) contracted masseter muscle.

Measurements on the lateral cephalometric radiographs

A lateral cephalometric radiograph of each subject was taken in a standardized way. Special care was taken to obtain the radiographs in the natural head position with the teeth in occlusion. Six linear and 11 angular measurements were analysed in order to define the vertical growth pattern

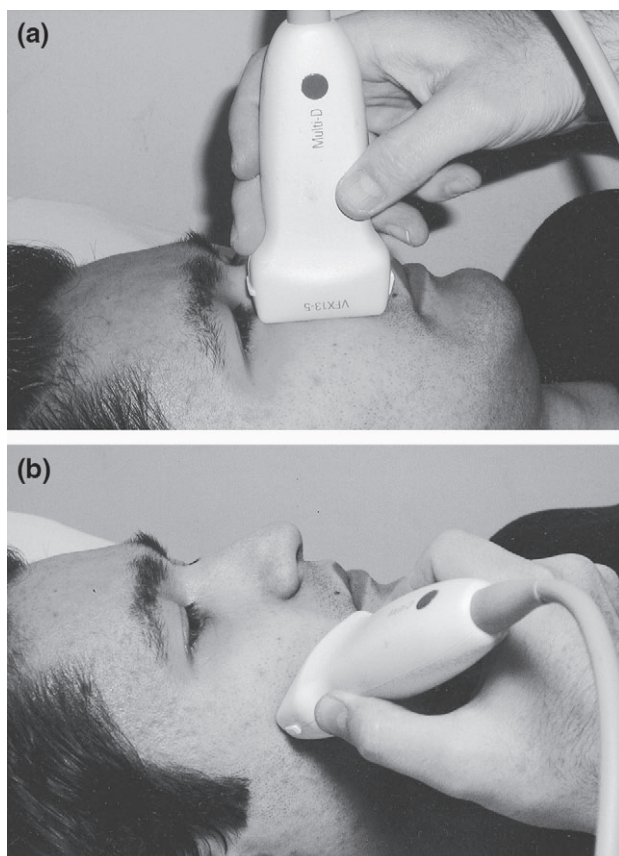


Figure 3 Measurement of the (a) levator labii superioris and (b) zygomaticus major muscles.

of the subjects (Figures 4,5; Table 1). The distribution of subjects into the groups according to their vertical facial pattern is shown in Table 2.

Measurement of body mass index (BMI)

The subject's body weight and stature were measured so that possible relationships between the thickness of the masseter muscle and BMI could be investigated.

Statistical method

The subjects were divided into high ($n = 17$), low ($n = 14$) and normal ($n = 16$) angle groups, according to their vertical facial pattern as determined by analysis of the lateral cephalograms.

Statistical analysis of the data obtained from the ultrasonograph was undertaken using Prisma version 3.0 statistical software (GraphPad, San Diego, California, USA). The intraobserver coefficient of variation was calculated for the three repeated measurements. In order to test whether the variation in thickness of the muscle was related to a variation in facial morphology, a two-way ANOVA was used, followed by Tukey's multiple comparison analysis when required.

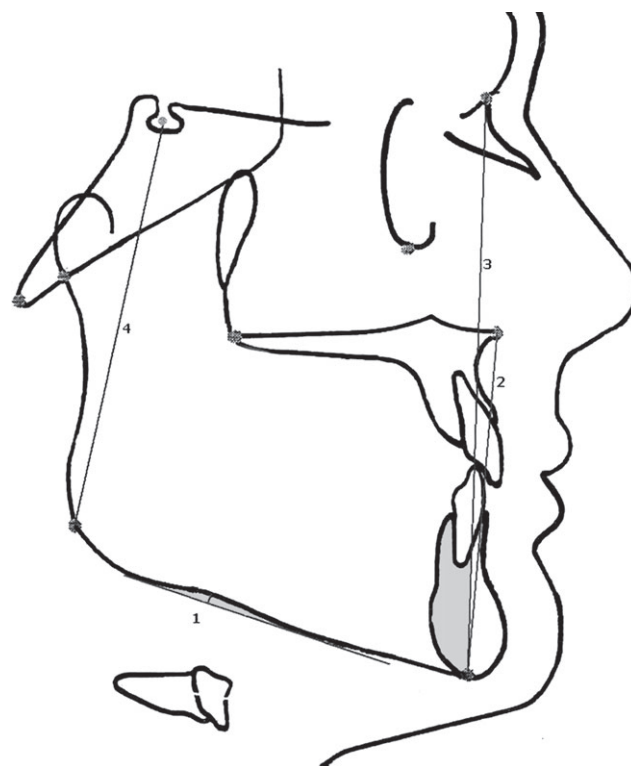


Figure 4 Linear measurements from the lateral cephalometric radiographs: 1. Antegonial notch depth, 2. ANS-Me, 3. N-Me, and 4. S-Go.

Pearson's correlation coefficient was used to determine the relationship between masseter muscle thickness and BMI.

Results

The reliability coefficients for the repeated measurements were 99 per cent for the masseter (both relaxed and clenched), levator labii superioris and zygomaticus major muscles.

Table 3 shows the two-way ANOVA for muscle thickness relative to the vertical facial pattern. During relaxation, the thickness of the masseter muscle in the low angle individuals was significantly greater than in the high ($P < 0.001$) and normal ($P < 0.01$) angle groups. During contraction, the masseter muscle thickness of the low angle individuals was also significantly greater than that of the high ($P < 0.01$) and normal ($P < 0.001$) angle subjects (Table 4).

The thickness of the masseter muscle during both relaxation and contraction was found to be significantly related to BMI for all subjects (Table 5).

The measurements of muscles of facial expression revealed that there was no correlation between the size of these muscles and vertical facial development. Only the thickness of the zygomaticus major muscle showed a statistically significant relationship with BMI (Table 5).

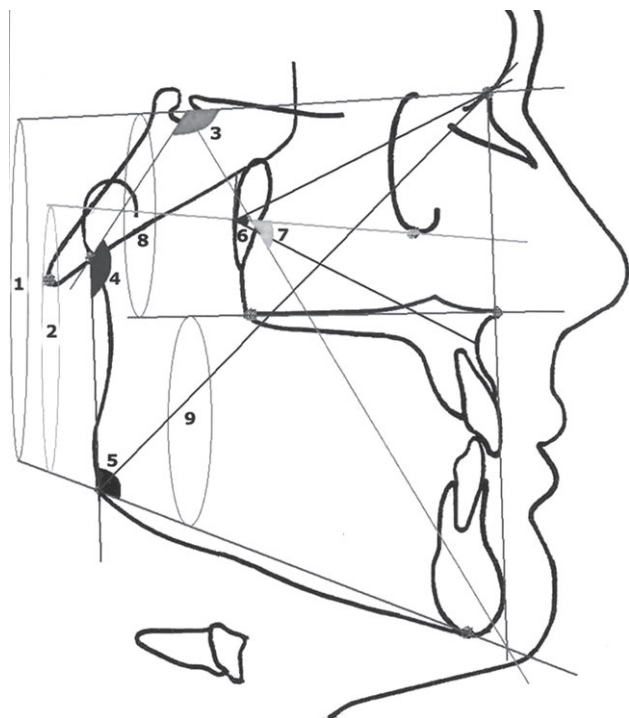


Figure 5 Angular measurements from the lateral cephalometric radiographs: 1. SNGoMe, 2. FMA, 3. Saddle angle, 4. Articulare angle, 5. Gonial angle, 6. Maxillary height angle, 7. Y axis angle, 8. SNPP, and 9. GoMePP.

Table 1 Measurements on the lateral cephalometric radiographs.

Linear measurements	
Antegonial notch depth	Mandibular notch depth
ANS–Me	Anterior lower face height
N–Me	Anterior total face height
ANS–Me/N–Me ratio	Anterior lower face height/ Anterior total facial height
S–Go	Posterior total face height
Jarabak ratio	Posterior/anterior total face height
Angular measurements	
SNGoMe	Cranial base/mandibular plane angle
FMA	Frankfort horizontal plane/mandibular plane angle
SN/SAr	Cranial base/sella-articulare angle
< Ar	Articulare angle
< Go	Gonial angle
Σ	Sum of inner cranial angles
NCF/CFA	Maxillary height angle
< Y axis	Frankfort horizontal plane/Y axis
SN/PP	Cranial base/palatal plane angle
PP/MP	Palatal plane/mandibular plane angle
Gonial ratio	Gonial α/β

Discussion

The aim of this study was to determine the relationship between the thickness of the masseter, levator labii superioris and zygomaticus major muscles and the vertical growth pattern in young adult patients. Various studies have

Table 2 Distribution of subjects into groups according to vertical facial pattern.

High angle (n = 17)		Low angle (n = 14)		Normal (n = 16)		Total
Female	Male	Female	Male	Female	Male	47
8	9	7	7	8	8	

investigated the association between masseter muscle thickness and vertical craniofacial pattern. The facial morphology of subjects participating in those studies was defined by several variables measured either on lateral cephalograms or standardized facial photographs (Kiliaridis and Kälebo, 1991; Bakke *et al.*, 1992; Kubota *et al.*, 1998). In the present investigation, all subjects were classified according to their vertical facial pattern and the masseter muscle thickness compared according to the relevant group.

In the literature, measurement of relaxed muscle thickness has been considered less accurate, owing to the higher susceptibility to the pressure with which the probe is placed on the cheek (Kiliaridis and Kälebo, 1991; Raadsheer *et al.*, 1994). In the present study, during muscle relaxation, the participants were asked to maintain light interocclusal contacts; to achieve muscle contraction, the subjects were asked to clench maximally in the intercuspal position. It is possible that this position does not always coincide with maximal muscle contraction, and therefore may not be indicative of the true contraction potential of the muscles (Raadsheer *et al.*, 1996). Although the relaxed and contracted conditions under which the measurements were made were based on subjective criteria and were difficult to control, the reliability coefficients of the repeated measurements were high (99 per cent). This may, however, be related to the short interval (5 minutes) between the repeated measurements.

The results of this study show that there is a large variation in masseter muscle thickness among individuals, during both relaxation and contraction. Inter-individual differences in the cross-section of the masseter muscle may be due to a variable number of muscle fibres, variation in fibre size, or both (Kiliaridis and Kälebo, 1991).

A strong correlation was found between facial morphology and masseter muscle thickness, indicating that individuals with a thin masseter have a relatively longer face. These results are in agreement with previous studies which have shown that the masseter muscle is especially thick in short-face individuals (Weijs *et al.*, 1984; Kiliaridis and Kälebo, 1991; Benington *et al.*, 1999; Raadsheer *et al.*, 1996).

Ultrasonographic measurements carried out on the muscles of facial expression showed no statistically significant relationships other than that between the zygomaticus major and BMI. Previous studies on the muscles of facial expression have shown that the thickness

Table 3 Two-way ANOVA of muscle thickness relative to vertical facial pattern.

Masseter		High angle	Low angle	Normal	F2	P
Relaxed	Males	15.50 ± 1.99	15.87 ± 1.83	14.92 ± 1.59	48.93	ns
	Females	12.08 ± 1.89	13.55 ± 0.74	12.74 ± 1.69		ns
	Total	13.29 ± 2.52	15.20 ± 1.90	13.56 ± 1.95		< 0.001
Maximum clenching	Males	17.19 ± 2.05	17.01 ± 2.15	15.92 ± 1.89	52.41	ns
	Females	13.37 ± 1.82	14.57 ± 0.98	13.76 ± 1.24		ns
	Total	14.72 ± 2.63	16.31 ± 2.18	14.57 ± 1.83		< 0.001
Levator labii superioris	Males	3.68 ± 0.47	3.50 ± 0.47	3.60 ± 0.49	0.01	ns
	Females	3.68 ± 0.48	3.77 ± 0.40	3.41 ± 0.44		ns
	Total	3.68 ± 0.47	3.57 ± 0.46	3.48 ± 0.46		ns
Zygomaticus major	Males	3.80 ± 0.49	3.94 ± 0.43	3.62 ± 0.38	2.76	ns
	Females	3.49 ± 0.68	3.98 ± 1.02	3.33 ± 0.39		ns
	Total	3.60 ± 0.63	3.95 ± 0.63	3.44 ± 0.40		ns

ns, not significant.

Table 4 Comparison of masseter thickness in different facial patterns using Tukey's multiple comparison analysis.

	Masseter	
	Relaxed	Maximum clenching
High angle/low angle	$P < 0.001$	$P < 0.01$
High angle/normal	ns	ns
Low angle/normal	$P < 0.01$	$P < 0.001$

ns, not significant.

Table 5 Pearson's correlation test to investigate the relationship between BMI and muscle thickness.

	Masseter			
	Relaxed	Maximum clenching	Levator labii superioris	Zygomaticus major
r	0.41	0.39	-0.07	0.21
P	< 0.001	< 0.001	ns	< 0.05

ns, not significant.

of the zygomaticus major muscle is greater in females compared with males (McAlister *et al.*, 1998), but this was not verified in the current investigation.

Conclusions

Ultrasonography of the masseter muscle was found to be a relatively simple, rapid and reproducible method of accurately measuring muscle thickness, as long as the operator adheres to a strict imaging protocol and avoids excessive pressure with the transducer. The results showed a significant association between vertical facial pattern and masseter muscle thickness. The thickness of the masseter and zygomaticus major muscles was shown to be correlated with BMI.

Previous studies have revealed an association between masseter muscle thickness and several features of the dental arches, such as the thickness of the alveolar process or maxillary dental arch width (Kubota *et al.*, 1998). The effect of jaw and facial expression muscle thickness on the dimensional and structural characteristics of the posterior and anterior alveolar bone should be investigated in further studies.

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