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Masseter muscle thickness and maxillary dental arch width

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SUMMARY The purpose of the present investigation was to study the relationship between the ultrasonographic thickness of the masseter muscle and the width of the maxillary dental arch. The sample comprised 60 consecutive orthodontic patients (37 females, 23 males), 7–18 years of age with a Class I relationship and minor malocclusion. The thickness of the masseter muscle was measured ultrasonographically. Recordings were performed bilaterally with the muscles both in relaxation and under contraction. Maxillary intermolar width was measured with an electronic calliper as the distance between the palatal surfaces of the first permanent molars.

Intermolar width showed no association with age and gender. However, masseter muscle thickness showed a direct, significant ($P < 0.0001$) association with these two factors together, i.e. the masseter muscle was thicker in older individuals and in males. In the female group, maxillary intermolar width showed a direct, significant association with masseter thickness both during contraction ($P < 0.006$) and relaxation ($P < 0.013$), i.e. females with thicker masseter muscles had a wider maxillary dental arch. In the male group, however, no significant relationship was found between maxillary intermolar width and masseter thickness. The findings of this study indicate that the functional capacity of the masticatory muscles may be considered as one of the factors influencing the width of the maxillary dental arch.

Introduction

Various studies have shown an association between the functional capacity of the masticatory muscles and craniofacial morphology. Individuals with a short facial configuration have high electromyographic activity or a high level of bite force or *vice versa* (Ingervall, 1976; Ingervall and Helkimo, 1978; Proffit *et al*., 1983; Kiliaridis *et al*., 1993; Ueda *et al*., 1998, 2000).

Muscle size as measured with imaging techniques *in vivo* was also found to correlate with craniofacial parameters. The relationship between masticatory muscle thickness and anterior face height seems to be negative (Kiliaridis and Kälebo, 1991; Bakke *et al*., 1992; van Spronsen *et al*., 1992; Raadsheer *et al*., 1996; Benington *et al*., 1999), i.e. individuals with thinner masticatory muscles have longer faces. Such an association has been found for the masseter (Kiliaridis and Kälebo, 1991; Bakke *et al*., 1992; van Spronsen *et al*., 1992; Raadsheer *et al*., 1996; Benington *et al*., 1999), and the anterior temporal and medial pterygoid muscles (van Spronsen *et al*., 1992). On the other hand, a positive association between cross-sectional areas or thickness of masticatory muscles and craniofacial widths has been reported, i.e. subjects with thicker masticatory muscles have broader faces. The muscles found to be involved in this relationship were the temporal muscle (Weijs and Hillen, 1986; van Spronsen *et al*., 1991), the masseter (Weijs and Hillen, 1986; Hannam and Wood, 1989; Raadsheer *et al*., 1996), and the medial pterygoid muscles (Hannam and Wood, 1989).

Since there is an association between masticatory muscle size and craniofacial width, a similar association might be expected to exist regarding dental arch width. A recent study on dry skulls of modern Japanese males showed that the lower molars were more lingually inclined in skulls with a long facial configuration (Masumoto *et al*., 2001). However, the role of the masticatory muscles in the transverse width of the dental arches is not clear.

The purpose of the present investigation was to study the relationship between the ultrasonographic thickness of the masseter muscle and the width of the maxillary dental arch.

Subjects and methods

Subjects

The sample of the present study comprised 60 consecutive orthodontic patients (37 females, 23 males), 7–18 years of age, enrolled from an orthodontic practice. The mean age of the subjects in the female group was 12.3 years (SD = 2.6), and for the male group 11.5 years (SD = 2.6).

In order to exclude factors that might influence maxillary dental arch width or muscle thickness (vertical, sagittal, or transversal skeletal malocclusion, posterior crossbite, or functional problems) only those with a Class I malocclusion were selected. These subjects were in need of only minor orthodontic treatment in the anterior part of one or both dental arches.

Registration methods

Measurement of masseter muscle thickness (Figure 1). The thickness of the masseter muscle was measured with reference to the method of Kiliaridis and Kälebo (1991). All subjects were examined by the same operator (IG), using a real time scanner (Scanner 480, Pie Medical, Maastricht, The Netherlands) with a 7.5 MHz linear array transducer. The participants were seated in an upright position with their heads in a natural position. To avoid tissue compression, a generous amount of gel was used under the probe. Care was taken to orientate the transducer perpendicular to the ramus, since oblique scanning exaggerates the thickness of the muscle. For that purpose, the angle of scanning was altered until the best echo of the mandibular ramus was achieved. The measurement site was at the thickest part of the masseter close to the level of the occlusal plane, halfway between the zygomatic arch and gonial angle, approximately at the centre of the mediolateral distance of the ramus.

Recordings were performed bilaterally with the muscles both during relaxation and under contraction (during maximal clenching in the intercuspal position).

The imaging and the measurements were performed twice, with an interval of at least 5 minutes between the two recordings. The thickness per side was calculated as the mean of the two measurements. For each individual the mean thickness of the left and right side was used. The measurements were made directly from the image at the time of scanning with a readout of distance to the nearest 0.1 mm. The real-time scans were then printed on film paper by a videocopy printer (Mitsubishi, model P66E, Tokyo, Japan).

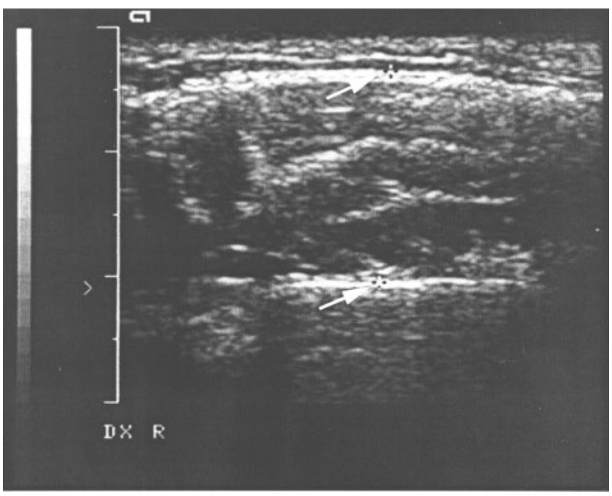

Figure 1 Transverse ultrasound scan of the masseter muscle during contraction. The wide white structure at the top depicts the skin echo, and the narrow white line below (upper arrow) the outer fascia of the masseter muscle. Although difficult to recognize in the photograph, real-time scanning distinguishes between skin and fascia. The intensive white echo at the centre of the image (lower arrow) is the echo of the lateral surface of the ramus. The masseter is seen as a dark area between the fascia and the lateral surface of the ramus. The two crosses (next to the arrows) show the positioning of the electronic calliper used to measure the thickness of the muscle.

Measurement of maxillary arch width. Alginate impressions were taken from all subjects and models were cast in dental stone. Maxillary intermolar width was measured with an electronic calliper as the distance between the palatal surfaces of the first permanent molars. The smallest possible distance was always recorded. This measurement was selected to express the maxillary arch width, since it can be performed in individuals of all age groups.

Statistical methods

Multiple regression analysis was used to show an association between:

1. intermolar width with age and gender
2. masseter muscle thickness with age and gender
3. intermolar width with masseter muscle thickness and age.

Error of the method

Double recordings on 20 subjects were performed in order to evaluate the method error both for the ultrasonographic thickness of the masseter and for the maxillary intermolar width. The time interval between first and second recordings was 4 weeks. The combined method error (Se) was calculated using Dahlberg's formula $Se = \sqrt{\Sigma d^2/2n}$, where d is the difference between the two recordings of the individual and n the number of double recordings (Dahlberg, 1940). The error for masseter thickness was small, not exceeding 0.3 mm in relaxation and 0.2 mm during contraction, whereas the error for the maxillary intermolar width was found to be 0.2 mm.

Results

The mean maxillary intermolar width was 32.1 mm (SD = 1.8) in the female group and 33.0 mm (SD = 2.7) in the male group. The mean masseter muscle thickness was 11.6 mm (SD = 1.4) in relaxation and 11.9 mm (SD = 1.6) during contraction in the female group versus 12.1 mm (SD = 2.2) in relaxation and 12.4 mm (SD = 2.2) during contraction in the male group. For both maxillary intermolar width and masseter muscle thickness the standard deviation in the male group was greater than in the female group.

Intermolar width showed no association with age and gender. Masseter muscle thickness showed a direct, significant association with these two factors together (Table 1), i.e. the masseter muscle was thicker in older individuals and in males.

Table 1 Multiple regression analysis to test the significance of age and gender on masseter muscle thickness.

(a) Dependent variable (Y): masseter muscle thickness during contraction (mm). $Y = 6.064 + b_1\text{age} + b_2\text{gender}$

Variables	Coefficient b	Standard error	Significance
Age	0.404	0.076	$P < 0.0001$
Gender	0.846	0.402	$P < 0.04$

Significance of the model: $R = 0.59$, $R^2 = 35\%$, $P < 0.0001$.

(b) Dependent variable (Y): masseter muscle thickness in relaxation (mm). $Y = 6.175 + b_1\text{age} + b_2\text{gender}$

Variables	Coefficient b	Standard error	Significance
Age	0.378	0.073	$P < 0.0001$
Gender	0.806	0.386	$P < 0.04$

Significance of the model: $R = 0.58$, $R^2 = 34\%$, $P < 0.0001$.

Multiple regression analysis: $Y = b_0 + b_1\text{age} + b_2\text{gender}$.
Independent variables: age (y), gender (0 = female, 1 = male).
b_0 = constant, b_1, b_2 = regression coefficients, R = correlation coefficient, R^2 = percentage of explained variance.

The relationship between masseter muscle thickness (both in relaxation and during contraction) and maxillary intermolar width was tested separately for males and females with age as a covariable.

Female group

Maxillary intermolar width showed a direct, significant association with masseter thickness during contraction, whereas age was found to have no statistically significant relationship (Table 2).

A similar association was found between maxillary intermolar width and masseter thickness in relaxation. Age was not found to have any statistically significant relationship (Table 3).

Male group

In the male group maxillary intermolar width was not related to masseter thickness, either in relaxation or during contraction (Tables 2 and 3).

Discussion

The findings of the present study suggest that there is a significant association between masseter muscle

Table 2 Multiple regression analysis to test the significance of age and masseter muscle thickness (during contraction) on maxillary intermolar width.

(a) Female group (n = 37, age = 7–18 years). $Y = 25.057 + b_1\text{age} + b_2$ (MT-Co)

Variables	Coefficient b	Standard error	Significance
Age	0.120	0.123	NS
MT-Co	0.474	0.203	$P < 0.025$

Significance of the model: $R = 0.51$, $R^2 = 26\%$, $P < 0.006$.

(b) Male group (n = 23, age = 8–17 years). $Y = 31.510 + b_1\text{age} + b_2$ (MT-Co)

Variables	Coefficient b	Standard error	Significance
Age	–0.327	0.300	NS
MT-Co	0.423	0.365	NS

Significance of the model: $R = 0.27$, $R^2 = 7\%$, NS.

Multiple regression analysis: $Y = b_0 + b_1\text{age} + b_2(\text{MT-Co})$.
Dependent variable (Y): maxillary intermolar width (mm).
Independent variables: age (y), masseter thickness during contraction (MT-Co) (mm).
b_0 = constant, b_1, b_2 = regression coefficients, R = correlation coefficient, R^2 = percentage of explained variance, NS = not statistically significant.

Table 3 Multiple regression analysis to test the significance of age and masseter muscle thickness (in relaxation) on maxillary intermolar width.

(a) Female group (n = 37, age = 7–18 years). $Y = 25.159 + b_1\text{age} + b_2$ (MT-Re)

Variables	Coefficient b	Standard error	Significance
Age	0.145	0.124	NS
MT-Re	0.448	0.226	$P < 0.05$

Significance of the model: $R = 0.48$, $R^2 = 23\%$, $P < 0.013$.

(b) Male group (n = 23, age = 8–17 years). $Y = 31.658 + b_1\text{age} + b_2$ (MT-Re)

Variables	Coefficient b	Standard error	Significance
Age	–0.320	0.301	NS
MT-Re	0.413	0.368	NS

Significance of the model: $R = 0.26$, $R^2 = 7\%$, NS.

Multiple regression analysis: $Y = b_0 + b_1\text{age} + b_2(\text{MT-Re})$.
Dependent variable (Y): maxillary intermolar width (mm).
Independent variables: age (y), masseter thickness in relaxation (MT-Re) (mm).
b_0 = constant, b_1, b_2 = regression coefficients, R = correlation coefficient, R^2 = percentage of explained variance, NS = not statistically significant.

thickness and maxillary arch width in female subjects. The multiple regression model that used masseter muscle thickness and age as independent variables could explain approximately one-quarter of the total variance in intermolar width.

In male subjects, no significant association between maxillary arch width and masseter thickness was recorded. This finding could be related to the lack of relationship between masseter muscle thickness and measurements describing the width of the face in adult males (Kiliaridis and Kälebo, 1991).

In patients suffering from myotonic dystrophy, a decreased width of the palate has been reported. This might be due to muscle weakness but also to other factors (e.g. head posture) that affect equilibrium (for review see Kiliaridis and Katsaros, 1998).

Maxillary intermolar width increases significantly in both sexes between 3 and 13 years of age, after which it remains stable in males, whereas it decreases slightly in females (Bishara *et al*., 1997). Males have been found to have a significantly larger maxillary intermolar width than females in all age groups (Bishara *et al*., 1997). The fact that no significant association was found between intermolar width and gender in the present study might be due to a greater intragroup variation of growth stage in the male than in the female group. This might be reflected in the greater standard deviations of intermolar width in the male than in the female group.

One of the factors influencing maxillary arch width is the growth potential of the midpalatal suture. The bone apposition rate in the midpalatal suture has been shown to be smaller in rats with decreased functional demands, whereas their maxillary arch is narrower (Yamamoto, 1996; Katsaros *et al*., 2002). Also the greater arch width found in medieval dentitions compared with those from a modern control sample is considered to be due mainly to differences in diet and masticatory function (Harper, 1994). Besides sutural growth, differences in the transverse width of the alveolar process or in the buccopalatal inclination of the posterior teeth might also contribute to differences in maxillary dental arch width. The present findings might be related to those of Masumoto *et al.* (2001) who reported that the lower molars of skulls with a long facial configuration were more lingually inclined than in skulls with an average or short facial configuration, this difference possibly being related to variations in the functional capacity of the masticatory muscles. This might reflect a compensatory mechanism of the dental arches to offset a smaller maxillary base.

Ultrasonography was used to measure the thickness of the masseter muscle. This method has been found to be a reliable, accurate, and easily reproducible method for the study of masseter muscle thickness (Kiliaridis and Kälebo, 1991; Raadsheer *et al*., 1994). In the present investigation, the method for recording in relaxation was modified from that used by Kiliaridis and Kälebo (1991) with the aim of avoiding tissue compression. The thickness of the masseter muscle has a significantly positive correlation with the magnitude of bite force (Raadsheer *et al*., 1999).

In the present study and for the age period examined, masseter muscle thickness showed a significant association with age and gender, i.e. the masseter muscle was thicker in older individuals and in males. It seems that a greater masseter muscle width develops in males during pubertal growth (Raadsheer *et al*., 1996). Newton *et al*. (1987) showed a correlation between masseter thickness and age, examining subjects with a large age range (20–90 years of age). On the other hand, Kiliaridis and Kälebo (1991) found no such correlation when studying a group of young adults with a small age range.

The subjects enrolled in the present investigation were selected from a sample of orthodontic patients. Patients with skeletal malocclusions were excluded, since the width of their maxillary arch might differ from that of subjects with a normal skeletal relationship. Class II division 1 patients, for example, are characterized by a narrow maxillary dental arch (Berg, 1983). Patients with functional malocclusions were not taken into consideration, since the dimensions of their masseter muscles might deviate from those of normal subjects. The masseter muscle has been found to be thinner on the crossbite side than on the normal side in patients with functional lateral crossbite (Kiliaridis *et al*., 2000).

Although it is unlikely that the minor orthodontic problems in the anterior aspect of the dental arches (maxillary, mandibular, or both) in the present sample could be associated with the maxillary arch width, a larger sample enrolled from subjects with no malocclusion would have been ideal.

Conclusions

The findings of this study suggest that the functional capacity of the masticatory muscles should be considered as one of the factors influencing the width of the maxillary dental arch.

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