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ORIGINAL ARTICLE

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Masseter muscle thickness as a predictive variable in treatment outcome of the twin-block appliance and masseteric thickness changes during treatment

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Structured Abstract

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Objectives – To estimate the association of initial masseter muscle thickness with treatment outcomes using functional appliances and the effect of treatment on masseter muscle thickness.

Material and Methods – Twenty-two children, aged 8–12, with skeletal and dental class II relationships and increased overjet were treated with twin-block appliances for 9–17 months, until a class I molar relationship and decreased overjet was achieved. Dental casts, lateral cephalograms, and ultrasonographic measurements of the masseter muscle were performed before and after treatment. Twenty-two children, aged 8–12, without immediate need for orthodontic treatment, served as controls. They were observed for 11–17 months, and ultrasonographic masseter muscle measurements were taken before and after the observation period.

Results – Masseter muscles in treated children were thinner at the end of treatment, while untreated controls showed an increase in thickness. Treated children with thinner pre-treatment muscles showed greater mandibular incisor proclination, distalisation of maxillary molars, and posterior displacement of the cephalometric A point during treatment.

Conclusion – Treatment of a dental class II relationship with functional appliances leads to mild atrophy of the masticatory muscles, possibly because of their decreased functional activity. The initial condition of the muscles may be associated with mandibular incisor proclination, and the position of maxillary first molars and A point.

Key words: class II malocclusion; functional orthodontic appliance; masseter muscle

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Introduction

Functional appliances, commonly used in the correction of sagittal discrepancies seen in class II malocclusion growing individuals, have been extensively investigated with regard to skeletal and dental changes in response to treatment. However, factors such as the masticatory musculature and its functional capacity may be equally as important. Several electromyographic studies have been carried out looking into muscle function during activator treatment, but the results are sometimes contradictory. Freeland (1) found that class II subjects treated with activators over a 12-month period display a decrease in muscle activity and class II treated subjects who exhibit the greatest changes in muscle behavior also show the greatest changes in skeletal and dental relations. Sessle et al. (2) also found an initial decrease in masseter muscle activity following appliance wear in monkeys, but this returned to pre-appliance levels after approximately 6 weeks. Miralles et al. (3) on the other hand found similar electromyographic tonic activity with and without activator wear in a cross-sectional study looking at children undergoing activator therapy during a period of 3.5–42 months, which was in agreement with Thilander and Filippson (4) but in opposition to Ahlgren (5) and Moss (6), both showing an increase in tonic activity with activator use. Changes in masticatory muscle activity may cause alterations in the functional characteristics of these muscles such as their thickness. However, limited knowledge exists in this area, and most studies have been carried out using electromyography, which is subject to many shortcomings and as has been suggested, may not represent the true activity of the muscle under investigation (7).

The mode of action of functional appliances is through displacement of the mandible downwards and forwards, causing either a corresponding stretching of the orofacial soft tissues and muscles, or myotatic reflexes (8–11). Myotatic reflexes can be defined as active muscle contraction in combination with the viscoelastic properties of muscles, which may be responsible for the tension exerted on teeth and bony structures during treatment. This muscle action produces the desired orthodontic or orthopedic force, directly or indirectly transmitted to the underlying dentoskeletal tissues, hopefully resulting in a correction of the malocclusion (12). Tension applied by the muscles is related to their thickness, as well as to other factors such as muscle length, fiber type distribution, connective and adipose tissue content, and activation mode. Thus, masticatory muscle thickness may be an important functional factor in the treatment of skeletal discrepancies using functional appliances.

Intermaxillary forces exerted by functional appliances during treatment can vary anywhere between 25 and 500 g (13, 14). In parallel, it is known that masticatory muscle capacity varies significantly between growing individuals, as measured both by bite force (15) and masseter muscle thickness (16). It has been speculated that the considerable variability seen in individual response to functional appliance treatment is possibly in relation to both magnitude and direction of forces and may be directly related to the individuals' muscular and soft tissue characteristics (17).

Apart from the masseter muscle, other masticatory muscles may influence and be influenced by functional appliance treatment, such as the lateral pterygoid, medial pterygoid, digastric, and temporalis, that come into play during mandibular protrusive forces (18). In the present investigation, masseter muscle thickness was looked at as a representative of masticatory muscles thickness (19).

Little is known about the association between the characteristics of the masticatory musculature with treatment effects when using functional appliances, and inversely, the effect of functional appliance treatment on the masticatory musculature. In the current investigation, we aimed to acquire more knowledge in this respect, with the use of the twin-block appliance. Treatment effects of the twin-block appliance as measured cephalometrically have been looked at in depth in a previous investigation (20), which found an increase in the mandibular unit length, an increase in the SNB angle, a decrease in the SNA angle, distalisation of maxillary molars, lower incisor proclination, and mesial movement of mandibular molars in patients treated with the twin-block appliance when compared to controls. There were however variations between patients as regards these treatment effects, and this study attempted to explain this variation, specifically looking into the functional capacity of the masticatory musculature as a possible factor. The aim of this investigation was thus to examine the predictive value of initial masseter muscle thickness in the treatment effects with twin-block appliances, as well as the effect of this treatment on masseter muscle thickness.

Materials and methods

Subjects

The sample of this study was made up of a treatment and a control group. The size of each group was chosen by performing a power analysis based on the results of a previous pilot study, to detect at least a 0.3-mm difference between groups (0.3 mm being the error of the method), and was calculated to be 22. The treatment group consisted of 22 children, between the ages of 8 and 12 at the start of treatment (mean age 9 years 5 months). The first 22 consecutive patients from the 28 patient samples of Mills and McCulloch (20) made up our treatment group. This included eight boys and 14 girls. These children were treated with a twin-block appliance, and the duration of the active treatment period was 9–17 months (mean of 13.1 months), until a class I molar relationship was achieved. Twenty-two growing children, between the ages of 8 and 12 (mean age 9 years 9 months) without immediate need for orthodontic treatment, served as control subjects. This included 12 boys and 10 girls, of whom eight had a class I molar relationship, while the remaining 14 had a class II molar relationship. The duration of the observation period was from 11 to 17 months (mean of 13.5 months).

The criteria for case selection for the treatment group were the following:

- full cusp class II molar relationship on one side and at least half cusp class II molar relationship on the opposite site;
- increased overjet (6 mm or greater);
- ANB angle of 5° or greater;
- skeletal class II malocclusion in which the esthetic appearance of the patient improved when the mandible was postured forward.

Treatment procedure and experimental design

The basic design of the twin-block appliance used in this study is illustrated and described in Mills and McCulloch (20). One particularity of the twin-block appliance used was that the maxillary incisors were not engaged in the appliance (no maxillary labial bow was included). The thickness of the blocks was 7 mm. Patients were instructed to wear the appliance full-time except for meal times and for brushing. Dental casts, lateral cephalograms, ultrasonographic measurements of the masseter muscle, and body height and weight measurement of the patients were performed both before starting treatment (T1) and after completion of this phase of treatment (T2). The control group only had ultrasonographic recordings at the beginning (T1) and end (T2) of the observation period.

Cephalometry

The lateral cephalometric headfilms were traced and digitized using the Dentofacial Planner software program (Dentofacial Software, Toronto, ON, Canada). Details of the cephalometric analyses used here are illustrated and described in Mills and McCulloch (21). A standard Jarabak analysis as well as a custom analysis was generated for each case. The custom analysis used Sella-Nasion as a reference line for superimposition. The anterior cranial base structures were traced in detail, and a superimposition on the best fit of the anterior cranial base, cribriform plate, and inner contours of the anterior cranium as well as the Sella Turcica structures was carried out to ensure that the choice of the points for the Sella and Nasion on the T2 cephalograms were on the same line as for the T1 cephalogram. In addition, a vertical reference plane was constructed through Sella Turcica perpendicular to the palatal plane. A series of horizontal measurements were then made from various landmarks perpendicular to the vertical reference plane. Identifying changes in cephalometric skeletal and dental characteristics during treatment of the treatment sample *per se* were not the objective of this investigation, as both initial cephalometric characteristics and changes during treatment of the original patient sample of Mills and McCulloch (20) have already been published.

Ultrasonography

Muscle thickness was measured by ultrasonography, the details of which are described in Kiliaridis and Kälebo (22), modified by Raadsheer et al. (23). The same technique, carried out by the same examiner, was used both for the treatment group and the control group. In brief, ultrasound measurements were obtained by means of a real-time scanner (Pie Medical Scanner 480, 7.5 MHz linear array transducer; Pie Medical Imaging, Maastricht, The Netherlands). The participants were seated in an upright position, with their heads in a natural position. The masseter was scanned bilaterally on a level halfway between the zygomatic arch and gonial angle. The scan plane was orientated perpendicular to the anterior border of the muscle and perpendicular to the surface of the underlying ramus. The registrations were made under two conditions, relaxed and contracted. The first was obtained by asking the participants to maintain slight interocclusal contacts, the second by asking them to clench maximally in the intercuspal position. Under all registration conditions, light pressure was applied so as to avoid compression of the soft tissues and muscle, thus avoiding erroneous measurements. All registrations were repeated twice, and the final thickness was obtained from the mean of the repeated measurements. Muscle thickness was registered to the nearest 0.1 mm.

Statistics

All statistical analyses were performed using the Statistical Package for Social Sciences version 15.0 (SPSS Inc, Chicago, IL, USA). Descriptive statistics (mean and standard deviation) as well as 95% confidence intervals were calculated for the changes between the two measurement periods for the treatment and control group. Comparisons were made between the two measurement periods using paired *t*-tests to determine significance. Significance was set at the $p < 0.05$ level.

For the treatment group, univariate regression analyses were carried out to investigate possible relationships with masseter muscle thickness and the SN-mandibular plane angle, and the gonial angle (Condylion–Gonion–Gnathion), respectively. Masseter muscle thickness was also analyzed with regard to sex, age, height, and weight of the patient, respectively. In addition, univariate regression analyses were carried out to test the correlation between initial masseter muscle thickness and skeletal and dental cephalometric changes during treatment (T2–T1). The specific cephalometric measurements observed are depicted in Fig. 1. These same cephalometric changes during treatment were also examined with univariate regression analyses in relation to the pre-treatment cephalometric measurements, pre-treatment overjet, sex, age, height, and weight, respectively. Multivariate regression analyses using stepwise regression were subsequently carried out to investigate possible relationships between multiple predictive variables (pre-treatment masseter muscle thickness, age, height, weight, overjet, and cephalometric measurements, as well as sex) and changes in cephalometric measurements during treatment.

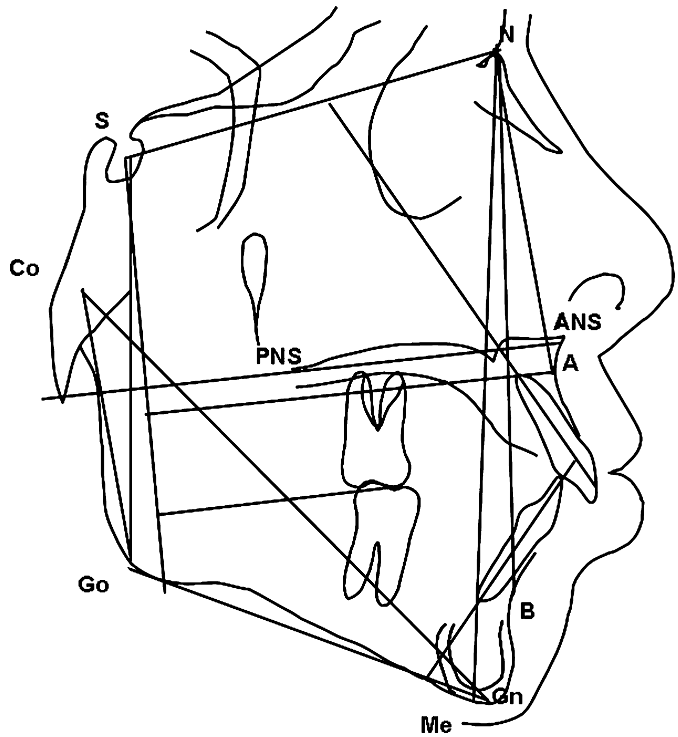

Fig. 1. Cephalometric measurements looked at in relation to changes during treatment. Angular measurements: SNA, SNB, ANB, mandibular incisor angulation to mandibular plane (Go–Gn), maxillary incisor angulation to SN plane, gonial angle (Co–Go–Gn). Linear measurements: posterior facial height (S–Go), anterior facial height (N–Me), condyle-ramus height (Co–Go), mandibular unit length (Co–Gn), A point to vertical reference plane, maxillary first molar to vertical reference plane, mandibular first molar to vertical reference plane. The vertical reference plane was constructed through Sella (S) perpendicular to the palatal plane (ANS–PNS).

Error of method

To test the reliability of the ultrasound measurements, a third group was included in the study. This group consisted of adult individuals, where all growth had been completed. Fifteen adults (aged between 21 and 35), nine of which were women and six men, with no need of orthodontic treatment made up this group. They were observed for 2 years. Ultrasound measurements of the masseter muscle were taken before and after the observation period. In adult individuals of this age, no changes in muscle thickness would be expected (24). The rationale for the inclusion of this group was to account for a possible learning curve of the operator. By learning curve, what is implied is that with time there may be a change in the way measurements are

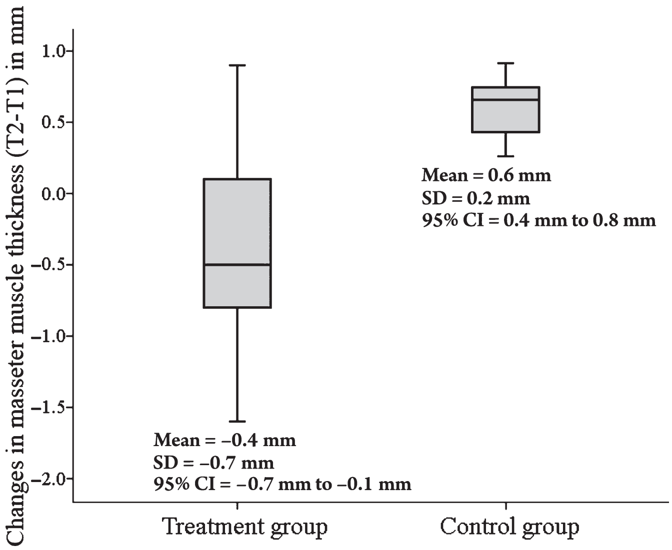

Fig. 2. Box plots showing changes in masseter muscle thickness between the initial and the post-treatment or post-observation measurements, respectively. The lower border of the box represents the lower quartile, the upper border the upper quartile, and the line within the box the median. Whiskers represent maximum and minimum values.

taken, because of experience. The adult group showed no statistically significant differences (an average increase of 0.05 mm) in the masseter thickness measurements during the observation period, indicating that the method was reliable over this period.

To account for any random error, including possible biologic variation, the error of the method for the ultrasound technique was calculated by repeated measurements of 20 patients from the control group, on two separate occasions, 2 weeks apart, using Dahlberg's formula ($SE = \sqrt{\Sigma d^2/2n}$), where n = the number of patients undergoing repeated measurements and d = the difference in measurements. This was found to not exceed 0.3 mm.

The error of the method in locating landmarks and measuring the variables on lateral cephalograms was determined to be 1.0 mm for linear measurements and 1.1 degrees for angular measurements using Dahlberg's formula. The repeated cephalometric measurements were taken for 10 patients from the treatment group, on two different occasions, approximately a year apart.

Results

The pre-treatment (T1) and post-treatment (T2) cephalometric characteristics of the treatment group, as well as the muscle thickness values, are summarized in Table 1.

***Table 1.* Descriptive statistics showing mean and standard deviation (SD) values for muscle thickness measurements as well as cephalometric measurements for the treatment group. Measurements are either shown in millimeters (mm) or degrees (°)**

	T1		T2	
Variable	Mean	SD	Mean	SD
Muscle thickness values				
Masseter muscle thickness (mm)	10.7	1.2	10.3	1.4
Cephalometric measurements				
Anteroposterior skeletal measurements				
SNA (°)	80.8	3.5	80.0	3.7
SNB (°)	74.3	3.0	76.0	3.2
ANB (°)	6.5	1.9	4.1	2.0
Mandibular measurements				
Mandibular unit length (Co-Gn) (mm)	105.9	4.4	111.5	5.1
Condyle-ramus height (Co-Go) (mm)	51.8	3.5	55.9	3.5
Gonial angle (Co-Go-Gn) (°)	126.8	4.2	128.3	4.7
Maxillary measurements				
A-rereference plane (mm)	66.1	4.4	66.6	4.6
Vertical skeletal measurements				
Anterior facial height (N-Me) (mm)	110.2	6.3	115.4	7.0
Posterior facial height (S-Go) (mm)	61.9	3.7	65.0	4.1
Incisor measurements				
Maxillary incisor angulation (1⁄-SN) (°)	104.8	7.2	102.1	5.0
Mandibular incisor angulation (⁄1-GoGn) (°)	92.9	8.3	99.0	8.0
Molar measurements				
6⁄-reference plane (mm)	37.0	3.8	35.9	4.7
⁄6-reference plane (mm)	35.1	3.7	40.4	4.8

Changes in masseter muscle thickness during treatment

At the end of the treatment period, reduction in the increased overjet and a class I molar relationship was achieved. The mean overjet of the treatment sample was 8.2 mm at the start treatment and decreased to a mean of 2.6 mm at the end of treatment. Ultrasonography revealed that masseter muscle thickness in the treated subjects was 0.4 mm (±0.7 mm) thinner at the end of treatment than it was pre-treatment ($p = 0.02$), decreasing from an average 10.7 mm pre-treatment muscle thickness to an average 10.3 mm muscle thickness after treatment. In the control group, however, a significant ($p < 0.001$) increase in masseter muscle thickness of 0.6 mm (±0.2 mm) was seen over a similar time period (Fig. 2), increasing from an average 10.9 mm muscle thickness before to an average 11.5 mm muscle thickness after the observation period. No differences were noted for changes in masseter muscle thickness between class I and class II control subjects in this control sample, as determined by an unpaired t-test. Likewise, no differences were noted for changes in masseter muscle thickness between male and female control subjects in this control sample. The 95% confidence intervals for the treatment and control group were −0.4 ± 0.3 mm and 0.6 ± 0.2 mm, respectively. Initial masseter muscle thickness was not correlated either with the SN-mandibular plane angle or the gonial angle. Neither sex, initial body weight, nor initial body height were correlated with initial masseter muscle thickness in our sample. Similarly, no correlation was found between changes in body weight and height and masseter muscle thickness or changes in any of the cephalometric measurements in our sample.

Table 2. **Regression analyses between the initial masseter muscle thickness and changes in the cephalometric variables during treatment (T2–T1)**

Cephalometric variable	r	p
Anteroposterior skeletal measurements		
SNA	0.233	0.297
SNB	0.022	0.922
ANB	0.232	0.298
Mandibular measurements		
Mandibular unit length (Co–Gn)	0.426	0.048
Condyle-ramus height (Co–Go)	0.464	0.029
Gonial angle (Co–Go–Gn)	0.234	0.259
Maxillary measurements		
A-rerefence plane	0.674	0.001
Vertical skeletal measurements		
Anterior facial height (N–Me)	0.420	0.051
Posterior facial height (S–Go)	0.577	0.005
Incisor measurements		
Maxillary incisor angulation (1/-SN)	0.076	0.738
Mandibular incisor angulation (/1-GoGn)	0.500	0.025
Molar measurements		
6/-reference plane	0.453	0.034
/6-reference plane	0.109	0.631

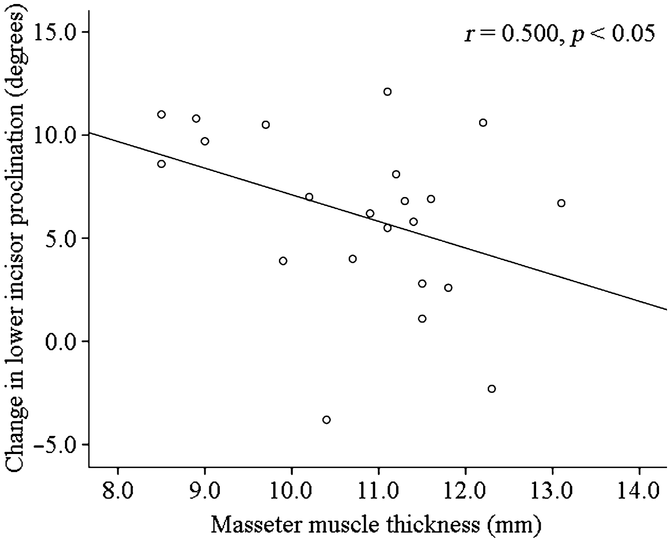

Fig. 3. Scatter diagram showing mandibular incisor tipping during twin-block treatment in relation to initial masseter muscle thickness. Mandibular incisors proclination was measured with reference to the mandibular plane (Go–Gn).

Association between pre-treatment masseter muscle thickness and treatment results

When looking at relationships between pre-treatment masseter muscle thickness and treatment outcomes with the twin-block appliance, several significant relationships were observed. Table 2 summarizes regression analyses carried out in this respect. A significant relationship was observed in relevance to proclination of mandibular incisors (Fig. 3). Namely, individuals with thinner muscles pre-treatment, showed a significantly more pronounced proclination of mandibular incisors, with reference to the mandibular plane (Gonion–Gnathion). Additionally, individuals with thinner masseter muscles also showed more of a distalisation of maxillary molars and posterior displacement of the cephalometric A point (with reference to the vertical reference plane). Those with thicker masseter muscle showed a more pronounced increase in the posterior facial height (Sella–Gonion), condyle-ramus height (Condylion-Gonion), and mandibular unit length (Condylion–Gnathion).

Association between pre-treatment vertical cephalometric variables and treatment results

With regard to pre-treatment SN-mandibular plane and gonial angles, and their relationships with treatment outcomes with the twin-block appliance, only one

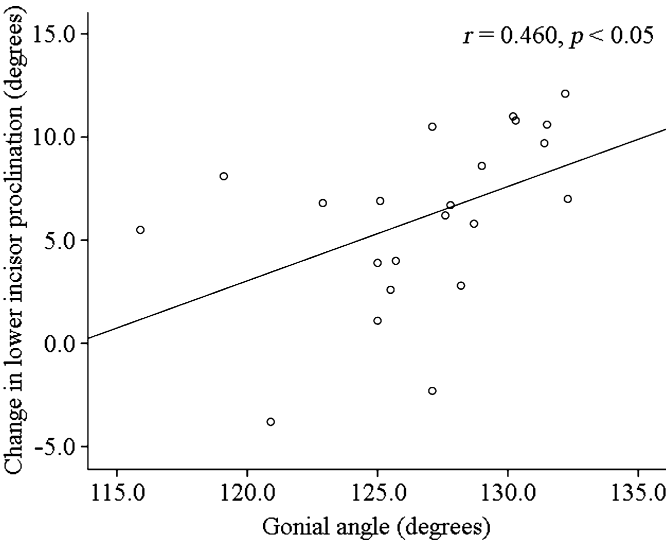

Fig. 4. Scatter diagram showing mandibular incisor tipping during twin-block treatment in relation to the pre-treatment gonial angle measurement. Mandibular incisors proclination was measured with reference to the mandibular plane (Go–Gn).

significant relationship was perceived. A larger pre-treatment gonial angle was correlated with a larger proclination of mandibular incisors with reference to the mandibular plane (r = 0.460, p = 0.031) (Fig. 4).

Association between multiple pre-treatment predictive variables and treatment results

Multivariate regression analyses using stepwise regression revealed that sex is another variable that is related to treatment results. When adding sex as an independent variable, the following cephalometric changes still showed statistical significance as regards relationships with pre-treatment masseter muscle thickness. Individuals with thinner pre-treatment masseter muscles demonstrated a larger proclination of mandibular incisors (r = 0.537, p = 0.039) and reduction in the cephalometric A point with reference to the vertical reference plane (r = 0.666, p = 0.004), while individuals with thicker pre-treatment masseter muscles exhibited a larger increase in posterior facial height (r = 0.580, p = 0.02). However, multivariate regression requires that each of the independent predictive variables is also independent from each other. This may not be the case with sex and masseter muscle thickness. Likewise, pre-treatment vertical cephalometric measurements and masseter muscle thickness are also interdependent and thus cannot be examined as independent variables in a multivariate regression analysis. Pre-treatment sagittal cephalometric measurements, or any of the other variables examined, did not seem to show statistical significance as regards associations with treatment results.

Discussion

This investigation illustrates that treatment of individuals presenting a dental and skeletal class II relationship with twin-block appliances leads to a reduction in masseter muscle thickness. In addition, the initial condition of the masseter muscles may influence treatment effects. Namely, those with thinner pre-treatment muscles show greater mandibular incisor proclination, distalisation of maxillary molars and posterior displacement of the cephalometric A point during treatment, as well as a less pronounced increase in the posterior facial height, condyle-ramus height, and mandibular unit length. These findings may explain part of the variation in the results presented by Mills and McCulloch (20), which show that the use of the twin-block appliance in a class II malocclusion population, when compared to untreated individuals leads to an increase in mandibular unit length, an increase in ramus height, an increase in the SNB angle, a reduction in the SNA angle, a distalisation of maxillary molars, and lower incisor proclination. Pre-treatment masseter muscle thickness may thus give an indication as to the outcomes of treatment when a twin-block appliance is used.

Measuring the functional capacity of the masseter muscle

The functional capacity of the masseter muscle can be estimated by means of electromyography, or by measuring its thickness using magnetic resonance imaging or ultrasonography. The two latter methods have been found to display a high correlation (25). In this study, ultrasonography was used to measure the thickness of the masseter muscle *in vivo*, which gives an indication of the muscle cross-sectional area as has been shown by studies looking at quadriceps muscles (26). This in turn provides quantitative information about the functional capacity of the muscle (26). Masseter muscle thickness measurement using ultrasonography has been found to be uncomplicated, easily accessible, reliable, and reproducible, and a strong correlation has been found between these thickness measurements and the muscle electromyographic activity (27). Electromyography measurements however are associated with a larger error of the method than are thickness measurements obtained using ultrasonography, possibly because of factors such as electrode placement, impedance of the skin, the subcutaneous fat layer, and the depth of the muscle under study (27).

Changes in masseter muscle thickness during treatment

Treatment of class II individuals with twin-block appliances reduces masseter muscle thickness. Treatment with functional appliances may thus lead to mild atrophy of the masticatory muscles, possibly because of their decreased functional activity. Our findings may be related to those of Freeland (1), who detected a reduction in muscle activity during swallowing and mastication in patients undergoing activator treatment. In contrast to the children treated with functional appliances, our findings revealed that the untreated children, in the control group, showed an increase in the masseter muscle thickness throughout this period, which is in line with the findings of Raadsheer et al. (16) in their cross-sectional study. This increase in masseter muscle thickness with age seen in the control group is in all probability nothing but the result of normal growth and may explain the increase in bite force during the growth period (15, 25).

Another possible hypothesis explaining the reduction in masseter muscle thickness, besides the gradual development of mild muscular atrophy, may be the stretching of the muscle, with a consequent adaptation within the muscle to compensate for the increase in length. However, although this could be the case in the short term, within the first few weeks of appliance wear, adaptation of the length of the muscle is expected to take place by the end of treatment, as had been shown by Bresin et al. (28) and Carlson and Schneiderman (29). For this reason, we believe that the initial stretching of the muscle was not the decisive factor influencing the thickness of the muscle in our findings, which can better be explained by the gradual development of mild muscular atrophy. Masticatory muscles must adapt to a new functional length with concomitant changes in muscle structure (30).

Dentoalveolar effects and incisor proclination during treatment

The initial condition of the masticatory muscles may influence the proclination of the mandibular incisors. Thin pre-treatment masseter muscles were observed to be correlated with a greater proclination of mandibular incisors during twin-block treatment. Masseter muscles are in the group of jaw elevator muscles, along with the temporalis, medial pterygoid, and the superior belly of the lateral pterygoid (31). These would consequently not be directly involved in the sagittal muscle tension evident when the mandible is protruded forward with the use of functional appliances (in contrast to the digastric, geniohyoid, mylohyoid, and inferior belly of the lateral pterygoid muscles). Masseter muscles are therefore more important as regards vertical forces. It can be hypothesized that children with thinner masseter muscles will probably generate less vertical intermaxillary forces, and as a consequence, resistance to dentoalveolar effects will be less. Thicker masticatory muscles may increase the anchorage of the mandibular dentition because of the exertion of larger masticatory forces. A similar explanation can be given for the position of the first maxillary molar and point A with respect to the vertical reference plane. The extraoral traction-like effect of functional appliances on the maxillary molars and the maxillary skeleton was more visible in individuals with thinner muscles, while those with thicker muscles show a larger resistance to this effect. The influence of the masticatory muscle capacity, as evaluated by masseter muscle thickness, was not apparent as regards proclination of maxillary incisors, possibly because of the fact that they were not engaged in the appliance.

Functional appliances have been criticized for their tendency to procline mandibular incisors and retrocline maxillary incisors. An increase in mandibular incisor proclination translates to less of a skeletal effect in overjet reduction. O'Brien et al. (32), in a multicenter randomized controlled trial, found the average percentage of skeletal change contributing to the reduction in overjet to be 27%, with variation between individuals, the remaining amount being dentoalveolar. They further go on to reason that this variation in apparent skeletal change may be because of other factors, probably reflecting individual growth variation as opposed to growth modification because of appliance wear. Previous studies using the twin-block appliance display a large variation in mandibular incisor proclination among the treated subjects, namely a 5.2 ± 3.9° proclination detected by Mills and McCulloch (20) and an 8.2 ± 7.1° proclination revealed by Lund and Sandler (33). Variation of the proclination of lower incisors may possibly be because of many factors, such as the construction bite, the initial overjet, the thickness of the mandibular symphysis (34), and muscular characteristics. The results of this investigation suggest that part of the variation may be able to be explained by the functional capacity of masticatory muscles, that is to say, individuals with thin muscles permitting more pronounced proclination of mandibular incisors during treatment than those with thick muscles.

Effects on the mandible during treatment

In the vertical dimension, individuals with thicker masticatory muscles seem to develop a greater posterior facial height and condyle-ramus height, and this finding is perhaps attributable to muscular stimulation on the gonial angle of the mandible. It has been put forward that the size and shape of the gonial process, being a site of muscle attachment, is dictated by the relative development and organization of the muscles, as they provide a major mechanical stimulus for bone formation (35, 36). This can also explain the observation that individuals with thicker masticatory muscles develop a greater mandibular unit length (Condylion–Gnathion distance). Likewise, individuals with a more obtuse gonial angle tended to show greater proclination of mandibular incisors. This may again be related to the fact that the gonial process has not been subject to mechanical muscular stimulation because of lower contraction forces, and thus less anchorage of the mandibular dentition is present. It can be put forward that children with unfavorable vertical mandibular growth patterns have thinner masseter muscles and thus exert lower masticatory forces, and as a result have a poorer skeletal prognosis, showing a greater dentoalveolar effect.

Measurements from the Condylion may be judged as unreliable as this point is sometimes difficult to locate accurately on a cephalogram. This difficulty was somewhat overcome by looking at T1 and T2 cephalograms from the same patient when tracing, to obtain a more certain outline of the condyle. In addition, wooden ear rods with plastic covers were used, as opposed to metal ear rods, so as to avoid obscuring the condylar structures. A large random error of the method may obscure existing true differences by increasing the variation of the sample (type II error). However, if despite the large random error statistically significant differences are detected, as is the case in this investigation, this substantiates the findings.

Compliance and wear of functional appliances

The question of compliance with regard to the wear of functional appliances is always an issue when carrying out human studies. Despite that however a class I molar relationship was achieved in all patients taking part in this study, perhaps indicating a high level of compliance among this patient sample. The twin-block appliance, in contrast to other removable functional appliances, is worn full-time, allowing a greater amount of time where favorable dentoalveolar and skeletal changes can take place. Cozza et al. (37) in their systematic review looking at mandibular changes produced by functional appliances concluded that twin-block appliances show a higher efficiency when compared to all functional appliances. A meta-analysis looking at the short-term anteroposterior effects of functional appliances found a similar result, namely that twin-block appliances demonstrate a larger increase in angle SNB, and a larger reduction in angle ANB and overjet than activator-type functional appliances (38).

Clinical recommendation

Because of the fact that orthodontists treating patients with functional appliances usually do not have access to an ultrasound machine to measure masseter muscle thickness, a clinical recommendation can be made according to the finding concerning the gonial angle in relation to mandibular incisor proclination. This angle can be measured cephalometrically and used as an indication of expected mandibular incisor proclination. In other words, patients presenting with an obtuse gonial angle may prepare the treating orthodontist to anticipate a greater degree of mandibular incisor proclination during activator treatment, than patients presenting with a more acute gonial angle.

Conclusions

Treatment of a dental class II relationship with functional appliances, namely the twin-block appliance, leads to mild atrophy of the masseter muscle, possibly because of its decreased functional activity. Functional appliance therapy is thus associated with an adaptation of the masticatory muscles. The initial condition of the masticatory muscles, represented by masseter muscle thickness, may be one of the factors that influence treatment outcomes. Individuals with thinner pre-treatment masseter muscles show greater proclination of mandibular incisors, distalisation of maxillary molars and a posterior displacement of the cephalometric A point during treatment. Individuals with thicker muscles show a greater increase in posterior facial height, condyle-ramus height, and mandibular unit length during treatment. Part of the variation in treatment outcomes seen during functional appliance therapy may consequently be explained to some extent by muscular characteristics.

Clinical relevance

Treatment of class II malocclusion with functional appliances can lead to both dental and skeletal improvement to some extent, with these improvements being variable from individual to individual. This study presents an attempt to explain this variation, specifically looking into the functional capacity of the masticatory musculature as a possible factor for differences seen in the outcomes of treatment. Results suggest that the properties and functional capacity of the muscles may influence how a particular individual responds to functional appliance treatment, namely those with weaker muscles showing greater dentoalveolar effects.

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