An electromyographic study of the inferior head of the lateral pterygoid muscle during intermaxillary elastics

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We investigated changes in the activity of the lateral pterygoid muscle and in the position of the incisal point created by intermaxillary elastics during orthodontic treatment in ten males with a mean age of 26 years. All Subjects had normal occlusion with no signs or symptoms of temporomandibular disorder. The changes were recorded with and without intermaxillary elastics using the K7 evaluation system. We found that activities of the lateral pterygoid muscle increased with intermaxillary elastics when the mandible was at the rest position. These results suggest that the force of intermaxillary elastics can affect the activity of the lateral pterygoid muscle. (J Osaka Dent Univ 2012; 46: 193–200)

Key words: Electromyography; Intermaxillary elastics; Lateral pterygoid muscle; Digastric muscle; Temporal muscle

INTRODUCTION

The dynamic mechanisms of intermaxillary elastics used frequently in orthodontic dentistry are considered to have various influences on oral and maxillofacial function. Long-term use of intermaxillary elastics has been reported to risk causing instability in the mandibular position and creating abnormalities in jaw functions.¹⁻³ The lateral pterygoid muscle is thought to physiologically determine the mandibular position and to be largely responsible for jaw function. However, no consensus has been formed concerning the role of this muscle.⁴⁻⁶ Although there are several studies on the electromyographic activity of the lateral pterygoid muscle,⁷⁻¹⁴ there are no reports on the reaction of the human lateral pterygoid muscle to orthodontic appliances. One major reason for this is that the deep location of the attachment of this muscle makes observation of electromyographic manifestations difficult. Detailed understanding of jaw function is essential in providing orthodontic treatment. Several reports have noted the risk of temporomandibular disorders induced by orthodontic treatment.¹⁻³ Understanding the influence of intermaxillary elastics on relevant muscles is indispensable in understanding how orthodontic treatment affects jaw function. Conventional studies on the influence of intermaxillary elastics focus on condylar movements and the mouth-closing muscles. However, no evaluation has been made on their influence on the mouth-opening muscles, such as the inferior head of the lateral pterygoid muscle.

We investigated the activity level of the inferior head of the lateral pterygoid muscle, the anterior belly of the digastric muscle and the posterior region of the temporal muscle as well as the incisal point displacement at the mandibular rest position after the patients wore intermaxillary elastics. These values were measured and compared using the K7 Evaluation System EX.

MATERIALS AND METHODS

Subjects
The subjects were male students and faculty members of our university who had individual normal occlusion with no subjective or objective abnormality in jaw function. The in average age was 26 years. The study procedure was explained to the subjects and written informed consent was obtained. This
study was approved by the Ethics Committee of Osaka Dental University (Approval No. 090506).

Methods

**Intermaxillary elastics**

Hooks for the Class II and Class III elastics were constructed by bonding Lingual buttons (TOMY Inc., Tokyo, Japan) to the facial surfaces of the bilateral maxillary and mandibular first molars and canines of the subjects with resin cement (GC Ortholy Co., Tokyo, Japan). The Class II elastics were connected from the hook on the maxillary canine to the hook on the mandibular first molar (Fig. 1), while the Class III elastics were connected from the hook on the mandibular canine to the hook on the maxillary first molar (Fig. 2). The elastics used were a heavy type with a diameter of 8 mm (TOMY Inc.) and were made as bilaterally symmetric as possible so that the strength was 200 grams on each side.

**Electromyograms (EMG)**

The muscles evaluated included the inferior head of the lateral pterygoid muscle, the anterior belly of the digastrius muscle, and the posterior region of the temporal muscle. Fine wire electrodes with a diameter of 0.08 mm (Unique Medical Co., Osaka, Japan) were placed in the inferior head of the lateral pterygoid muscle, whereas surface electrodes were placed over the anterior belly of the digastrius muscle and the posterior region of the temporal muscle. The ground electrodes were attached to the neck.

Pairs of fine wire electrodes were used to record EMG signals from the inferior head of the lateral pterygoid muscle. The urethane insulation was removed from the last 0.5 mm of the two wires, which were inserted into a 32 mm, 23-gauge needle. One wire was bent back 3 mm and the other 1.5 mm from the tip of the needle respectively so that the bare tips would not contact each other (Fig. 3). The electrode was inserted from the mucobuccal fold, which is distal to the maxillary second molar to a depth of about 25 mm through the fascia. The EMG signals, which indicate muscle activity level, and the incisal point displacement were recorded by a K7 Evaluation System EX (Myo-Tronics Inc., Kent, WA, USA) through the bipolar electrodes.

EMG data and the incisal point displacement were recorded at the mandibular rest position be-
before and after wearing Class II and Class III elastics. The mandibular rest position was defined as where the lowest activity levels were recorded on the monitor for the inferior head of the lateral pterygoid muscle, the anterior belly of the digastric muscle and the posterior region of the temporal muscle. Comparative analysis of EMG data is significantly affected by subject-to-subject variation in muscle activity. To minimize the influence of individual variations, the muscle activities in each subject were measured before the experiment at the following positions: the inferior head of the lateral pterygoid muscle at the maximum protruded position, the anterior belly of the digastric muscle at the maximum opening position, and the posterior region of the temporal muscle at the maximum retruded position. Assuming the reference activity level of each muscle as 100%, the percentage of muscle activity measured under each respective test condition was calculated. The subjects were provided with enough rest between taking records to minimize the muscle fatigue caused by the intermaxillary elastics. Each measurement was repeated five times.

Analysis
The average of five measurements was calculated for each of the 10 subjects for the activity levels of the inferior head of the lateral pterygoid muscle, the anterior belly of the digastric muscle, and the posterior region of the temporal muscle at the mandibular rest position before and after wearing intermaxillary elastics. Comparative analysis was done by student’s t-test with significance at the 5% level.

RESULTS
Change in the position of the mandibular incisal point
When wearing Class II elastics, the incisal point measured with the mandible at its rest position showed a backward displacement of an average of 0.03 mm, a lateral displacement of 0.01 mm, and a vertical displacement of 0.05 mm. No significant difference was observed when compared with the values measured before and after wearing the elastics. In the case of Class III elastics, the incisal point measured with the mandible at its rest position showed a backward displacement averaging 0.6 mm, a lateral displacement of 0.02 mm and a vertical displacement of 0.05 mm. No significant difference was observed when compared with the values measured before and after wearing elastics (Table 1).

The inferior head of the lateral pterygoid muscle
The average muscle activity with the mandible in maximum protrusion without intermaxillary elastics was 29.5 μV. The difference in muscle activity at the mandibular rest position after wearing Class II elastics was 12.1 μV at the maximum and 4.5 μV at the minimum, with an average of 8.6 μV. In the case of Class III elastics, the muscle activity difference was 13.3 μV at the maximum and 6.4 μV at the minimum, with an average of 9.6 μV (Table 2). Assuming that the muscle activity at the maximum protruded position of the mandible is 100%, we calculated the ratio of the difference of the activity level of the inferior head of the lateral pterygoid muscle while wearing Class II and Class III elastics. When compared with the values measured at the mandibular rest position after wearing intermaxillary

| Table 1 Changes in the position of the mandibular incisal point |
|----------------------|-------------------|
| Displacement        | Elastics          |
|                     | II    | III   |
| Backward            | 0.03 ± 0.02 | 0.6 ± 0.24 |
| Vertical            | 0.05 ± 0.04 | 0.05 ± 0.02 |
| Lateral             | 0.01 ± 0.01 | 0.02 ± 0.01 |

(mm)

| Table 2 Changes in electromyogram of the inferior head of the lateral pterygoid muscle |
|----------------------|-------------------|
| Change               | Elastics          |
|                     | II    | III   |
| Maximum             | 12.1  | 13.3  |
| Average             | 8.6   | 9.6   |
| Minimum             | 4.5   | 6.4   |

(μV)
elastics, the muscle activity level with the elastics demonstrated a statistically significant increase of 30.4% and 34.6%, respectively (p<0.05) (Figs. 4 and 5).

**Anterior belly of the digastric muscle**

The average muscle activity at the maximum opening position without intermaxillary elastics was 27.5 $\mu$V. The difference in muscle activity at the mandibular rest position and after wearing Class II elastics was 10.0 $\mu$V at the maximum and 4.2 $\mu$V at the minimum, with an average of 6.6 $\mu$V. In the case of Class III elastics, the muscle activity difference was 10.5 $\mu$V at the maximum and 4.3 $\mu$V at the minimum, with an average of 6.9 $\mu$V (Table 3). Assuming that the muscle activity level at the maximum opening position of the mandible is 100%, we calculated the ratio of the difference in the activity level of the anterior belly of the digastric muscle before and after wearing Class II and Class III elastics. When compared with the values measured at the mandibular rest position after wearing intermaxil-
Table 3 Changes in electromyogram of the anterior belly of the digastric muscle

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Table 4 Changes in electromyogram of the posterior region of the temporal muscle

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The posterior region of the temporal muscle

The average muscle activity level at the maximum retruded position without intermaxillary elastics was 11.5 μV. The difference in muscle activity at the mandibular rest position after wearing Class II elastics was 1.5 μV at the maximum and 0.2 μV at the minimum, with an average of 0.6 μV. In the case of Class III elastics, the muscle activity difference was 4.6 μV at the maximum and 0.5 μV at the minimum, with an average of 2.1 μV (Table 4). Assuming that the muscle activity level at the maximum retruded position of the mandible is 100%, we calculated the ratio of the difference in the activity level of the posterior region of the temporal muscle before and after wearing Class II and Class III elastics. The muscle activity level at the mandibular rest position after wearing the intermaxillary elastics was significantly increased by 6% and 15.3%, respectively (p<0.05) (Figs. 8 and 9).

DISCUSSION

Experimental methods

We attempted to elucidate how wearing intermaxillary elastics that are frequently used in orthodontic clinic treatment influence the activity of the masticatory muscles, including the inferior head of the lateral pterygoid muscle. Although electromyographic research on the inferior head of the lateral pterygoid muscle has been conducted under various conditions, there have been no such stud-
ies on humans during orthodontic treatment. Treatment with these elastics has been reported to risk affecting jaw function and the progress of occlusal changes. When taking into account the mechanics of the intermaxillary elastics, there is a possibility that jaw function changes may result, not only from occlusal changes, but also from changes in the condylar position at the mandibular rest position. Intermaxillary elastics vary in the degree and direction of force they impart. In the present study, we used 200 grams of force, which is typical for Class II and Class III elastics.17

Electromyograms
EMG signals of the lateral pterygoid muscle are detected either by the intraoral or extraoral method. The electrodes normally used are the needle type. However, there have been reports on EMG data obtained from surface electrodes.18 EMG measurements with surface electrodes are known to demonstrate electric discharge even when the mouth is closed. Anatomically, surface electrodes detect the electric discharge from the peripheral muscles such as the buccinator muscle. Despite some invasiveness, use of needle electrodes is considered appropriate. Compared with intraoral EMG signal detection, the extraoral technique poses a higher risk of damaging vessels or nerves during insertion of the needle electrodes. A longer distance to the muscle belly is another disadvantage of the extraoral technique. Therefore, the technique reported by Uchida9 was used in the present study. Uchida used fine wire electrodes. The fine wire electrode, which has bipolar leads, has a superior ability to detect EMG signals with his technique. Also, this technique can minimize the pain during insertion, damage to the tissue, and interference in jaw movements. This is because it has a thinner diameter than other electrodes such as single-needle and bipolar concentric electrodes.

RESULTS
Incisal point
Wearing the Class II and Class III elastics only caused slight displacement of the incisal point. Okabayashi16 reported that the displacement caused by the intermaxillary elastics was as small as less than 0.02 mm, despite increased activity of the jaw closing muscles. This finding indicates the possibility that certain regulation mechanisms act to maintain the mandibular position when the intermaxillary elastics are worn.

Muscle activity
Wearing Class II and Class III elastics caused the EMG data from the inferior head of the lateral pterygoid muscle to show a significant increase of 30.4% and 34.6%, respectively. Class II elastics had been thought to decrease the activity of the inferior head of the lateral pterygoid muscle because they exert a force that displaces the mandible forward. In reality, however, the Class II elastics increased the activity of the muscle in every subject. The reason for this phenomena is thought to be that Class II elastics exert a force not only in the anteroposterior direction, but also in the direction of mandibular closing. The regulation mechanism is thus activated to maintain the mandibular rest position, resulting in an increase in activity of the lateral pterygoid muscle. The results of our study support the findings of an animal experiment by Graber et al.19 in which an increased activity of the lateral pterygoid muscle was observed in young rats provided with Class II elastics and a functional appliance designed to guide mandibular advancement. In a study on human subjects, Graber et al.20 analyzed the EMG data derived from the lateral pterygoid muscle induced by Fränkel's function regulator and activator, which used a protruded position as the constructed occlusion. He reported a significant increase in muscle activity immediately after placement of the appliances. This finding also supports the results of the present study. The increased mandibular muscle activity caused by the Class III elastics is thought to have resulted when the force generated by the muscle's reflective resistance to the force pulling the mandible backward was added to the force generated by the muscle activity that maintains the mandibular rest position.

The Class II elastics caused the activity of the
anterior belly of the digastric muscle to significantly increase 27.4% at the mandibular rest position. The anterior belly of the digastric muscle is primarily activated during mandibular opening movements. As a result, the mandibular opening force is thought to be reflectively generated to maintain balance when a strong mandibular closing force is exerted by the Class II elastics. When wearing Class III elastics, the activity level increased significantly by 29.5%, which is greater than the situation with Class II elastics. The anterior belly of the digastric muscle relates to hinge axis movement. Therefore it is speculated that this might lead to a reflectively increase in the active mass of the muscle.

Activity in the posterior region of the temporal muscle showed a significant increase of 6.0% and 15.3% with Class II and Class III elastics, respectively. These values in this muscle activity were less than those in the inferior head of the lateral pterygoid muscle. The reason for this is thought to be that the reaction of the posterior region of the temporal muscle to the force of the intermaxillary elastics was less than that of the inferior head of lateral pterygoid muscle. According to Wood et al., the inferior head of the lateral pterygoid muscle works not only to protruded the mandible, but also to move it forward and inward. On the other hand, the posterior region of the temporal muscle is generally thought to retract the mandible, although it also works adductively with the lateral pterygoid muscle during lateral movement. Therefore, there is a possibility that these two muscles work in a coordinated manner. Regarding the activity of the posterior region of the temporal muscle during mandibular protrusive contraction, Uchida indicated the possibility that the posterior region of the temporal muscle played a complex role in stabilizing the mandible. Takano and Wood et al. observed the activity of the inferior head of the lateral pterygoid muscle when the mandible was in the retruded position. The reason that Class III elastics produced greater changes than Class II elastics may be that the posterior region of the temporal muscle cooperates with the muscle activity of the inferior head of the lateral pterygoid muscle. Our results agreed with theirs.

Effect of orthodontic treatment
Some orthodontists think that the force applied to the mandible or TMJ with orthodontic appliances can cause temporomandibular disorders (TMD). Wyatt noted that the forces retruding the mandible, in particular those on the condyle, can be a cause of TMD. Ricketts also indicated that the application of Class II and Class III elastics or orthopedic force can cause TMD. On the other hand, Gianelly et al., Dibbets et al., Hirata et al. and Rendell et al. based on the experimental studies demonstrated that orthodontic treatment might not necessarily be the cause of TMD. Many reports have stated that orthodontic treatment is unrelated to the development of TMD and may even prevent it. Examining whether the extraction of maxillary premolars and the use of Class II elastics might cause TMD, O'Reilly et al. conducted a detailed investigation on TMD symptoms in 60 patients, and concluded that orthodontic treatment had no association with the development of TMD. However, it should be noted that all these previous studies focus only on the occlusal changes and the effect of intermaxillary elastics on the TMJ. No studies have investigated the masticatory muscle reaction to the use of intermaxillary elastics as we did in this study. Although, orthodontic treatment in general is not considered to be causally-related to TMD, the use of orthodontic appliances requires caution. Further investigations should be carried out.

CONCLUSIONS
We measured and compared the activity levels of the inferior head of the lateral pterygoid muscle, the anterior belly of the digastric muscle and the posterior region of the temporal muscle at the mandibular rest position and after wearing intermaxillary elastics. Every muscle tested demonstrated a significant increase in its activity level after wearing intermaxillary elastics, which demonstrated that these muscles are responsible for the regulation mechanism that maintains the mandibular rest position.
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REFERENCES