AN ELECTROMYOGRAM STUDY ON MANDIBULAR MOVEMENT IN UNILATERAL CLEFT LIP AND PALATE PATIENTS BEFORE AND AFTER ORTHODONTIC TREATMENT

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Received 6 September, 1999/Accepted for Publication 17 November, 1999

Abstract

The purpose of this study is to investigate masticatory muscle function in subjects with unilateral cleft lip and palate compared with normal occlusion and the extents of improvement before and after orthodontic treatment. Subjects were twenty pretreatment patients, thirty posttreatment patients and ten controls. Electromyograms were recorded from their masticatory muscles during masticatory movement and tapping movement.

Reduction of duration/stroke ratio (D/S) was observed in electromyograms obtained during masticatory movement after orthodontic treatment. The reduction was especially notable in the masseter muscle. In spite of a significant reduction in coefficient of variation (CV) values, a significant difference between the posttreatment group and the control group indicated some persisting irregularity in masticatory movement. Electromyograms taken during tapping movement showed no change in latency in the posttreatment group, but duration of the silent period (SP) was shortened and SP appearance increased. The findings outlined above reveal electromyographically clear improvements in masticatory muscle functions and jaw reflex mechanisms after orthodontic treatment. Nevertheless, parameters for subjects with cleft lip and palate still differed from those for controls with normal occlusion. The influence of plastic surgery in subjects with the defects discussed here causes maxillary retrusion, which in turn results in skeletal malocclusion. Orthodontic treatment should be designed to compensate this dentally and alveolarly. This design and the need to improve masticatory functions would contribute to eliminate the extreme difficulty of the therapeutic process.

Key words: Cleft lip and palate—Electromyogram—Masticatory muscle—Orthodontic treatment

The study is a part of the doctoral theses by Teruo Sakamoto which was published in the Shikwa Gakuho (87: 1035–1057, 1987) in Japan and by Kazuki Ohtsuka (98: 485–500, 1998).
INTRODUCTION

The influence of plastic surgery performed in the early postnatal stage on infants with cleft lip and palate results in various degrees of occlusal abnormalities during growth and development. These abnormalities include maxillary collapse and anterior crossbite caused by maxillary retrusion with masticatory obstruction.

A useful method for analyzing masticatory muscle functions, electromyography, has been widely used in the dental field since Moyers introduced masticatory muscle electromyograms in a study of masticatory movement and occlusal problems from the standpoint of the neuromuscular mechanism. The present study employed electromyograms to record masticatory rhythm and silent periods (SP) to investigate masticatory muscle function. Comparisons were made between controls with normal occlusion and subjects with unilateral cleft lip and palate before orthodontic treatment to determine the extents of their abnormalities of masticatory muscle function. Further comparisons were made to investigate the extents of improvement in masticatory movement resulting from orthodontic treatment.

SUBJECTS AND METHODS

1. Subjects (Table 1)

Subjects were divided into three groups. The pretreatment group consisted of twenty individuals (mean age: 9y9m) with unilateral cleft lip and palate and reversed occlusion who had undergone no treatment. The posttreatment group consisted of thirty individuals (mean age: 17y1m). The control group was ten individuals (mean age: 11y2m) with normal occlusion and a functional stomatognathic system. Experimental procedures were conducted in conformance with the policies and principles contained in the Declaration of Helsinki.

2. Electromyogram recording

Bipolar electrodes were attached to four muscles, the right and left masseter and temporal muscles, and electromyograms were recorded during mastication of chewing gum and tapping movements. Patients with cleft

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>SNA</th>
<th>ANB</th>
<th>Over-jet</th>
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<tbody>
<tr>
<td>Pretreatment</td>
<td>9y9m</td>
<td>74.2°</td>
<td>−1.07°</td>
<td>−6.06mm</td>
</tr>
<tr>
<td></td>
<td>(8y0m–14y3m)</td>
<td>(68.5°–82.5°)</td>
<td>(−8.5°–5.5°)</td>
<td>(−0.8mm–17.0mm)</td>
</tr>
<tr>
<td>Posttreatment</td>
<td>17y1m</td>
<td>77.1°</td>
<td>0.6°</td>
<td>1.5mm</td>
</tr>
<tr>
<td></td>
<td>(13y5m–19y4m)</td>
<td>(70.2°–84.9°)</td>
<td>(−6.5°–5.0°)</td>
<td>(0.3mm–2.0mm)</td>
</tr>
<tr>
<td>Control</td>
<td>11y2m</td>
<td>81.5°</td>
<td>1.9°</td>
<td>1.6mm</td>
</tr>
<tr>
<td></td>
<td>(10y2m–11y10m)</td>
<td>(79.0°–86.0°)</td>
<td>(0.5°–5.0°)</td>
<td>(0.5mm–2.0mm)</td>
</tr>
</tbody>
</table>

Fig. 1 Electromyograms during mastication

D: Duration
I: Interval
S: Stroke (D+I)
lip and palate chewed the gum on the cleft side and controls chewed it on their habitual mastication side.

Tapping movements at a speed of 90 times per minute were performed 50 times with moderate occlusal force so that only the early silent period occurred. Simultaneously, the sound of occlusal contact was recorded as the trigger to start electromyograph addition.

3. Analysis method

1) Electromyograms during mastication (Fig. 1)

Duration/stroke ratio (D/S): Each of the twenty strokes was examined by electromyogram during mastication of chewing gum. The duration, interval and stroke were measured. Then the duration/stroke ratio was calculated.

Masticatory rhythm: The coefficient of variation of stroke was calculated by means of this formula: \[ CV = \frac{\text{S.D.}}{\text{mean}} \times 100 \% \]

2) Electromyograms during tapping movement (Figs. 2 and 3)

Latency and duration of silent period: the original waveform and whole rectified waveforms were averaged, and the following were...
measured. Latency (La): the latent period between tooth contact and the initiation of the silent period. Silent period duration (SPD): the continuous time of suppression between the peak of muscular activity and the reinitiation of muscular activity. Peak to peak duration (PPD): the period between the peak of muscular activity and the peak of muscular activity after restoration from the silent period. SP appearance rate: the appearance percentage probability of the silent period during ten tapping movements. Statistical analysis was performed by Student’s *t*-test and significant level was 5%.

**RESULTS**

1. Electromyograms during masticatory movement

No significant differences were observed between measurement values for the working and the balancing sides in the three groups. Tables 2–5 show values for the working side.

Table 2 shows duration/stroke ratio (D/S). D/S values for the temporal and masseter muscles in the pretreatment group were significantly larger than those for the control group: in the control group, temporal muscle was 35.0% and masseter muscle, 36.7%; in the pretreatment group, temporal muscle was 43.8% (p<0.05) and masseter muscle, 50.2% (p<0.001). In the posttreatment group, the values were 42.7% for temporal muscle and 44.2% for masseter muscle; these were smaller than those for the pretreatment group. The reduction in the masseter muscle was significant (p<0.05). Nonetheless, the values for the posttreatment group remained significantly larger than those for the control group (p<0.05).

Table 3 shows coefficients of variation of stroke. Coefficients of variation for the pretreatment group were significantly larger than those for the control group: in the control group, temporal muscle was 6.8%1.5% and masseter muscle, 7.1%0.9%; in the pretreatment group, temporal muscle was 13.9%3.7% (p<0.001) and masseter muscle, 15.4%5.0% (p<0.001). In the posttreatment group, the values were 10.1%2.7% for temporal muscle and 10.3%2.5% for masseter muscle; these were smaller than those for the pretreatment group. The reduction in the masseter muscle was significant (p<0.05). Nonetheless, the values for the posttreatment group remained significantly larger than those for the control group (p<0.05).
significantly smaller (p<0.01) than those for the pretreatment group.

However, values for both temporal and masseter muscles in the posttreatment group were significantly larger (p<0.01) than those for the control group.

2. Electromyograms during tapping movement

Since no significant differences were observed between the cleft and normal sides of subjects with cleft lip and palate and between the left and right sides of controls, only cleft side and left side values are shown in Table 4.

Table 4 shows latency (La) and duration of the silent period (SPD, PPD).

Temporal and masseter muscle latencies in the pretreatment group were significantly smaller than those in the control group: in the control group, temporal muscle was 10.3±0.6 msec and masseter muscle, 10.3±0.6 msec; in the pretreatment group, temporal muscle was 9.4±1.5 msec (p<0.05) and masseter muscle, 9.2±1.7 msec (p<0.05). There was no significant difference between the values for temporal muscle (9.3±1.1 msec) and masseter muscle (9.0±1.0 msec) in the posttreatment group and those of the pretreatment group. Posttreatment values were, however, significantly smaller (p<0.01) than those in the control group.

Silent period durations in the pretreatment group were significantly larger than those in the control group: temporal muscle was 11.5±2.1 msec and masseter muscle, 12.4±1.7 msec; in the pretreatment group, temporal muscle was 15.2±3.0 msec (p<0.001) and masseter muscle, 16.2±3.1 msec (p<0.001). The values for temporal muscle (12.4±1.5 msec) and masseter muscle (13.3±1.6 msec) in the posttreatment group were significantly smaller (p<0.001) than those in the pretreatment group. There was no significant difference between the values for the posttreatment group and those of the control group.

Table 5 shows SP appearance rate. The silent period occurred with 100% probability in both the temporal and masseter muscles in all controls. In the pretreatment group, its appearance rate dropped to 88.5% in the temporal muscle and 92.5% in the masseter muscle. In the posttreatment group, it increased to 94.8% in the temporal muscle and

<table>
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<th></th>
<th>La</th>
<th>SPD</th>
<th>PPD</th>
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<tbody>
<tr>
<td>Pretreatment group</td>
<td>Temporal muscle</td>
<td>9.4±1.5*</td>
<td>15.2±3.0***</td>
</tr>
<tr>
<td></td>
<td>Masseter muscle</td>
<td>9.2±1.7*</td>
<td>16.2±3.1***</td>
</tr>
<tr>
<td>Posttreatment group</td>
<td>Temporal muscle</td>
<td>9.3±1.1**</td>
<td>12.4±1.5††</td>
</tr>
<tr>
<td></td>
<td>Masseter muscle</td>
<td>9.0±1.0**</td>
<td>13.3±1.6</td>
</tr>
<tr>
<td>Control group</td>
<td>Temporal muscle</td>
<td>10.3±0.6</td>
<td>11.5±2.1</td>
</tr>
<tr>
<td></td>
<td>Masseter muscle</td>
<td>10.3±0.6</td>
<td>12.4±1.7</td>
</tr>
</tbody>
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Significance between pretreatment group and posttreatment group: †5%, ††1%
Significance between patients and control subjects: *5%, **1%, ***0.1%

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96.3% in the masseter muscle. SP appearance rate in the control group occurred in two out of twenty (10%) of the pretreatment group; in constant, the incidence was eighteen out of thirty in the posttreatment group (60%).

DISCUSSION

1. Electromyograms during masticatory movement

Past attempts using electromyograms to analyze masticatory movement from masticatory rhythm have shown a regular rhythm in subjects with normal occlusion\(^{10}\) and rhythm disturbances in subjects with temporomandibular dysfunction\(^{11}\) and malocclusion\(^{6,7}\). This information has been applied to diagnosis and prognosis. In the present study, we investigated masticatory rhythm and the D/S ratio in subjects with normal occlusion and cleft lip and palate before and after orthodontic treatment.

D/S ratio was used as a parameter indicating masticatory muscle activity. The values were greater in the pretreatment subjects than in normal occlusion subjects. This was more pronounced in the masseter muscle than in the temporal muscle. D/S values are great in subjects with complete dentures\(^{14}\) and in subjects with poor masticatory abilities\(^{9}\). This suggests that increases in D/S express difficulty in masticating. In the pretreatment subjects, who have malocclusion and missing teeth, D/S has to be increased in order to supplement masticatory efficiency. Although, in the posttreatment group, D/S values for the temporal muscle were still significantly larger than those of the control group, the improvements in the masseter muscle suggested increments in mastication efficiency.

The coefficient of variation (CV) was employed as a indicative parameter of disturbance in masticatory rhythm. Significantly higher CV values in the pretreatment group than in the control group indicate disturbed masticatory rhythm. This rhythm can be set in a cadence according to learned patterns and is influenced by signals from proprioceptors and nociceptors in the oral region\(^{13}\). Therefore, disturbances in masticatory rhythm are thought to result from impulses from various receptors tending to upset the regularity and operating on the masseter muscle via reflex pathways. CV values in posttreatment group were significantly smaller than those of the pretreatment group. They were, nonetheless, still significantly larger than CV values for the control group. Even after clear improvement was obtained by treatment, masticatory movement was still far from the smooth and regular masticatory movements in subjects with normal occlusion. The significant difference between pretreatment and posttreatment values means that CV together with D/S can be useful as indicators of improved masticatory function after treatment.

2. Electromyograms during tapping movement

The silent period is thought to be as a neuromuscular mechanism that controls and regulates the stomatognathic system and is the inhibitory phase of EMG for jaw-closing muscles during masticatory and tapping movements. The silent period during tapping movement is generally considered a parameter indicating the elaborate nature of movement. Since a report by Schäfer et al.\(^{15}\),

<table>
<thead>
<tr>
<th></th>
<th>Temporal muscle</th>
<th>Masseter muscle</th>
<th>Number of 100% SP appearance</th>
</tr>
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<tbody>
<tr>
<td>Pretreatment</td>
<td>88.5</td>
<td>92.5</td>
<td>2/20 (10%)</td>
</tr>
<tr>
<td>Posttreatment</td>
<td>94.8</td>
<td>96.3</td>
<td>18/30 (60%)</td>
</tr>
<tr>
<td>Control group</td>
<td>100.0</td>
<td>100.0</td>
<td>10/10 (100%)</td>
</tr>
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it has been used in dentistry for diagnostic purposes and in evaluating therapeutic effectiveness.\(^1\,^3\,^5\)

Latency in the posttreatment group demonstrated no change from that in the pretreatment group. Both were significantly shorter than latency in the control group. Latency is the latent period between tooth contact and the initiation of the silent period. Mechanical stimuli caused by tooth contact are accepted by receptors in the stomatognathic system, and the neuronal signals inhibit the motoneurons of masticatory muscles via the reflex pathway. In other words, latency is the period from tooth contact to the initiation of this inhibition in the jaw-closing muscles. Latency shortening results from a protective reflex mechanism in the jaw-closing movement accompanying abnormal occlusal contact. Failure of therapeutic improvement in occlusal relations without an effect on latency suggests that the abnormality in the pretreatment group was very serious and that a longer period of treatment is needed to improve the jaw reflex mechanism.

In pretreatment subjects, the duration of the silent period, SPD, was significantly longer than that in the control group. In the posttreatment group, however, it had shortened (especially in the temporal muscle) from the values for the pretreatment group to values similar to those for the control group. PPD is a period which belongs to a category similar to SPD. PPD was significantly shorter in both the temporal and masseter muscles in the posttreatment group than in the pretreatment group. In this connection, there was no significant difference between the posttreatment and control groups. PPD is the period between the peak of masticatory activity and the peak of muscular activity after restoration from the silent period and has been selected as a parameter indicating the period which jaw-closing muscles are effected by inhibitory interneuron of inhibitory pathway. The existence of occlusal interference disturbs generation of afferent impulses from the muscular spindle and the periodontal membrane. This is thought to bring about changes in SPD. Improvement of such occlusal interference as malocclusion is considered to cause changes in the duration of silent period after orthodontic treatment, thus approximating those of the control group. Therefore, the duration of silent period, PPD, is thought to be a useful indicator.

A drop in SP appearance rate below the normal level was observed in both pre- and posttreatment groups in instances of cleft palate. Overall, SP increased slightly in the posttreatment group over pretreatment levels. The number of subjects demonstrating the 100% appearance rose from 10% in the pretreatment group to 60% in the posttreatment group. This is thought to have resulted from a reduction of abnormal signals to reflex pathway. Investigation of whether reductions in the silent period had occurred or not proved to be a convenient, exact, and useful clinical method permitting clear “on or off” discrimination in EMG recordings.

**CONCLUSION**

The purpose of this study was to investigate changes in masticatory muscle function in subjects with unilateral cleft lip and palate before and after orthodontic treatment. Subjects included twenty pretreatment patients, thirty posttreatment patients, and ten controls. Electromyograms were recorded from their masticatory muscles during masticatory movement and tapping movement. The following results were obtained by comparisons of measurement values.

1. Reduction of D/S was observed in electromyograms obtained during masticatory movement after orthodontic treatment. The reduction was especially notable in the masseter muscle. In spite of a significant reduction in CV values, a significant difference between the posttreatment group and the control group indicated some persisting irregularity in masticatory movement.
2. Electromyograms taken during tapping
movement showed no change in latency in the posttreatment group, but duration of the silent period was shortened and SP appearance increased.

The findings outlined above reveal electromyographically clear improvements in masticatory muscle functions and jaw reflex mechanisms after orthodontic treatment. Nonetheless, parameters for subjects with cleft lip and palate still differed from those for the controls with normal occlusion. The influence of plastic surgery in subjects with the defects discussed here causes maxillary retrusion, which in turn results in skeletal malocclusion. Orthodontic treatment should be designed to compensate this dentally and alveolarly. This design and the need to improve masticatory functions would contribute to eliminate the extreme difficulty of the therapeutic process.

REFERENCES