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Neuromuscular and Skeletal Adaptations Following Mandibular Forward Positioning Induced by the Herbst Appliance

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ABSTRACT

The purpose of this study was to examine neuromuscular and skeletal adaptations to changes in sagittal jaw relationships induced by the Herbst appliance. Six patients (age, 9 years and 5 months to 11 years and 2 months) with Angle Class II, division 1 malocclusions were studied longitudinally. The structural changes were determined by analyzing serial lateral cephalograms. Electromyographic recordings of specific masticatory muscles were used to evaluate neuromuscular adaptations. Similar cephalometric changes were observed in all patients. In all patients, lateral pterygoid muscle activity increased immediately after insertion of the appliance, but the activity decreased markedly after 4 to 6 months of treatment. In 4 of the 6 patients studied, however, the condyles were located in a slightly more downward and forward position. These findings indicate that the adaptation of muscular function occurs within a relatively short period and precedes the compensatory morphological changes produced through functional appliance therapy.

KEY WORDS: Adaptation, Electromyography, Herbst appliance, Lateral cephalogram, Lateral pterygoid muscle.

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INTRODUCTION Return to TOC

It is well recognized that mandibular growth can be influenced favorably with a variety of functional appliances.[1–10] This treatment response is considered to be the result of both skeletal and neuromuscular adaptations.[11] It has been of great interest to investigate changes in the orofacial muscle activity during functional jaw orthopedic treatment to determine how such so-called “growth guidance” appliances work in terms of the adaptation of muscle function.[12]

Breitner[13] was the first to conduct investigations of functional appliance therapy on nonhuman primates. These studies and those that followed[14–20] were characterized by occlusal alterations from a normal to a Class III relationship. This is similar in concept but different in execution from the correction of a Class II occlusal relationship to a normal occlusion with functional appliance therapy. Because cephalometric and histological analytical techniques were used primarily, these early studies by necessity focused on morphological aspects of the form-function relationship.

The first experimental study to consider both functional and morphological aspects of adaptation to functional appliance therapy was by McNamara.[11,21] He used needle electromyography to determine the pattern and sequence of muscle adaptation to functional protrusion. An increase in lateral pterygoid activity was associated with the forward repositioning of the lower jaw. This new functional pattern was noted first during such phasic activities as swallowing and subsequently during such tonic functions as maintenance of the mandibular postural position. As the experimental period progressed, however, there was a gradual return toward pre-appliance levels of muscle activity, and this change in activity was correlated in time with the skeletal and dentoalveolar adaptations observed in the same animals. The results of these studies indicated that the growth of the temporomandibular joint in young animals is somewhat adaptive in nature and that the condylar cartilage in such animals is responsive to changes in function.

Many investigators have considered the lateral pterygoid muscle to be of critical importance in functional appliance therapy. For example, Charlier et al,[22] Petrovic,[23] and Petrovic et al[24,25] tried to determine the effect of lateral pterygoid function on condylar growth using rats as an experimental model. In their initial study by Charlier et al,[22] they used a mandibular hyperpropulsor to position the mandible forward and reported increased growth of the condylar cartilage and increased deposition along the posterior aspect of the mandibular ramus. In a later study, Petrovic and coworkers[24] protruded the rat mandible with extraoral traction. No jaw movement was possible, however, when the experimental animal wore the appliance. These investigators noted that the animals treated with the Class II extraoral traction did not differ significantly from control animals in either the length of the mandible or in the number of mitotic cells within the condylar cartilage. Further, total surgical resection of the lateral pterygoid muscle resulted in a marked decrease in condylar cartilage proliferation.[24] They also reported that after intervention, animals treated with a postural hyperpropulsor and bilateral lateral pterygoid resection did not differ significantly in mandibular length in comparison to untreated controls. Petrovic et al[24] and Oudet et al[26] concluded that their studies provided evidence that the lateral pterygoid was the “final common” link in the various regulatory actions affecting the growth of the condylar cartilage. Similarly, Easton and Carlson[27] provided empirical evidence of an alteration in the function of the lateral pterygoid muscle and of physiologic adaptation of this muscle to mandibular protrusion, suggesting that it was possible that the lateral pterygoid muscle did have a unique role in the regulation of condylar growth.

The findings of the Michigan studies in rhesus monkeys[11] indicated that functional mandibular displacement was associated with increased activity of the superior lateral pterygoid muscle and that after 8 to 12 weeks, the level of activity decreased, approaching pretreatment values. In contrast, investigations by the Toronto group[28,29] reported that such increases in the postural and functional electromyographic (EMG) activity of the lateral pterygoid muscle were not observed in their investigations that used nonhuman primates. Sessle et al[28] recorded a decrease in postural EMG activity of the superior and inferior heads of the lateral pterygoid muscle in monkeys by insertion of functional appliances that induced mandibular protrusion. Yamin-Lacouture et al[29] also demonstrated that, in monkeys, the insertion of Herbst, Fränkel, and simulated Clark twin block appliances was associated with a decrease in involuntary swallow-related functional activity of both heads of the lateral pterygoid muscle.

It should be noted that no previous studies have been carried out with regard to changes in human lateral pterygoid muscle activity during treatment with functional appliances. Presumably, the main reason for the lack of human studies was that the insertion of a needle or fine-wire electrode was necessary to record human lateral pterygoid muscle activity.[30–36]

To facilitate the present investigation, we have introduced a type of intraoral surface electrode that can be used to record lateral pterygoid muscle activity in humans without pain or interference to jaw movements.[37] Thus, the purpose of the current study, especially in light of conflicting data concerning the activity of the lateral pterygoid muscle during functional protrusion, is to analyze the change in lateral pterygoid activity after mandibular positional changes induced with the use of the Herbst appliance and to discuss the interactions between neuromuscular and skeletal changes produced during this type of functional appliance treatment.

MATERIALS AND METHODS Return to TOC

Six patients with Angle Class II, division 1 malocclusions were studied. The demographic and cephalometric data for the 6 patients are provided in Table 1. The age of the patients at the beginning of treatment ranged from 9 years and 5 months to 11 years and 2 months (mean, 10 years and 1 month). The mean overbite, overjet, and ANB angle before treatment were 5.7 mm, 9.3 mm, and 6.3°, respectively.

An acrylic splint Herbst appliance was fabricated for each patient to induce a change in mandibular position and orofacial structures in a manner similar to the protocol described by McNamara and Brudon.[38] The upper part of the appliance was bonded to the maxillary dentition, whereas the lower part of the appliance was removable. The amount of anteroinferior mandibular advancement with the appliance ranged from 4.5 mm to 11.5 mm (mean, 8.0 mm), as indicated by the change in condylar position observed in sequential cephalograms. The morphological adaptations that occurred during treatment with the Herbst appliance were examined by analyzing serial lateral head films. The relative positional change of the mandible and the other structural changes were defined with superimpositions of the serial tracings. Cephalometric tracings were superimposed on the Sella-Nasion (SN) plane, registered at Sella (S). To facilitate the accuracy of tracings around the joint area, we used lateral cephalograms taken in the maximum jaw opening. The mandible was traced on the cephalometric radiograph taken in the maximum jaw opening. This tracing was used as a template to accurately trace the condyle in the lateral cephalogram taken in the intercuspal position.

The functional changes during treatment were examined with EMG recordings of the masticatory muscles. The activity of the lateral pterygoid muscle was recorded by way of an intraoral surface electrode. The electrode used was a small Ag-AgCl surface electrode (diameter = 2 mm, N-103-2; Nichiei Keisoku Co, Tokyo, Japan) that was secured on the mucosa in the buccal vestibule distal to the maxillary tuberosity with cyanoacrylate adhesive (Figure 1). EMG recordings from other masticatory muscles such as the temporalis, the masseter, and the anterior belly of the digastric muscles were performed as well to evaluate the relative level of lateral pterygoid muscle activity. Bipolar surface electrodes (interelectrode distance = 20 mm) were placed on both sides of the anterior temporalis, masseter, and digastric muscles parallel to their muscle fibers. Because of the nature of the surface electrode, no distinction was made between the activities of the superior and inferior heads of the lateral pterygoid muscle.

Patients were seated comfortably in a dental chair. After electrode placement was completed, each patient was asked to maintain occlusal contact or appliance contact for at least 5 minutes without any intentional biting force. EMG signals were amplified (Bio-electric amplifier AB-621G; Nihon Kohden Co, Tokyo, Japan) and stored in a data recorder (SR-50; Teac Co, Tokyo, Japan).

On average, the Herbst appliances were worn for 6.1 months (range 5–7 months), a duration similar to the treatment interval used by Pancherz[6–8] in his previous clinical investigations. Both the cephalometric radiograph and the EMG record were obtained from each patient on the same day at the following stages: stage I, just prior to insertion of the Herbst appliance; stage II, immediately after insertion of the Herbst appliance; stage III, 4 to 6 months after stage II; stage IV, immediately after removal of the Herbst appliance (1–2 months after stage III); and stage V, 2 weeks after Stage IV (in patients 4, 5, and 6 only).

Ten episodes (duration: 100 ms) from the individual recording of lateral pterygoid muscle activity were chosen randomly to calculate the integrated lateral pterygoid muscle activity with a Signal Processor (7T18; Nihondenki San-ei Co, Tokyo, Japan). The mean value of the integrated lateral pterygoid muscle activity in 10 episodes, used to represent the muscle activity in each patient at each stage, was standardized to that measured at stage I to make it possible to compare the muscle activity among patients. Analysis of variance and paired comparison test (Contrast) were used for statistical comparison of the EMG records among the 5 stages.

RESULTS Return to TOC

Morphological changes

Cephalometric changes induced by Herbst appliance treatment in 6 patients are demonstrated in Figure 2. Figure 3 shows the intraoral photograph of patient 1 during treatment. Figure 4 summarizes the change in the cephalometric variables for 6 patients in the pretreatment and posttreatment periods. In all patients, a similar pattern of change was observed: the mean overbite and overjet decreased by 2.3 mm and 5.1 mm, respectively, whereas the mean ANB angle decreased by 1.4°. The maxillary incisors tipped lingually and the mandibular incisors tipped labially on average by 4.5° and 2.9°, respectively.

Figure 5 illustrates the condylar movements that represent the trajectory of the center of the condyle in each patient. At stage II, the condyles of all patients were positioned anteroinferiorly as compared with stage I. At stage III, the condyles of all patients tended to approach their positions at stage I: the condyles of patients 1 and 2 virtually returned to their pretreatment orientations within the glenoid fossa. The condyles of the remaining 4 patients, however, still remained more anteroinferior than at stage I; they were 2.0 mm more downward and forward in patient 3, 1.8 mm in patient 4, 3.5 mm in patient 5, and 3.8 mm in patient 6. At the end of Herbst treatment (stage IV), the condyle of patient 3 returned to the stage I position, but the condyles of patients 4, 5, and 6 remained more anteroinferior than at stage I. At stage V (2 weeks after appliance removal), the condyles of patients 4 and 5 returned to their stage I positions, but the condyle of patient 6 remained more anteroinferior.

Functional changes

Typical examples of 4 stages of the EMG recording in patient 1 are shown in Figure 6. The muscle activity was barely recognizable when the patient was at rest when maintaining occlusal contact at stage I (Figure 6I). An increased EMG activity was recorded in the lateral pterygoid muscles bilaterally at stage II, although the patient was at rest while maintaining appliance contact (Figure 6II). There were no significant changes in the activity of the other monitored muscles. The lateral pterygoid muscle activity at stage III decreased remarkably from that recorded immediately after appliance insertion (Figure 6III). A slight increase in lateral pterygoid muscle activity was seen at stage IV as compared with stage III (Figure 6IV).

Figure 7 summarizes the change in lateral pterygoid muscle activity at 5 stages in 6 patients. The vertical axis represents the standardized EMG activity. In all 6 patients, lateral pterygoid muscle activity was increased significantly at stage II ($P < .01$). At stage III, the muscle activity in all patients was decreased to the level at stage I. At stage IV, immediately after appliance removal, slight increases in muscle activity were identified ($P < .05$). The slight increase in the muscle activity observed at stage IV decreased to the level seen at stage I in 3 patients.

DISCUSSION Return to TOC

During the last half-century, many investigators have examined histologically the effect of anterior displacement of the mandible on condylar growth in nonhuman experimental animals.[11,17,18,39–41] In these studies, proliferation of condylar cartilage was preceded by anterior displacement of the mandible in young animals. This increase in condylar growth was associated with the activation of the lateral pterygoid muscle induced by mandibular postural changes.[12,22–27,42] Universal agreement does not exist, however, concerning the role of the lateral pterygoid muscle in mandibular growth. Whereas McNamara[11] demonstrated an increase in superior lateral pterygoid muscle activity associated with anterior displacement of the mandible, conflicting findings were reported by Sessle et al[28] and Yamin-Lacouture et al,[29] whose experimental investigations have raised doubts about the so-called lateral pterygoid muscle hypothesis.

Few studies have examined changes in human lateral pterygoid muscle activity during functional jaw orthopedic treatment, a type of treatment considered by many to induce mandibular growth by anterior displacement of the mandible. Thus, our first goal was to examine the short-term changes in the postural activity of human lateral pterygoid muscle during Herbst appliance treatment.

Morphological changes

According to Mitani,[43] the mean growth increment of the mandible at the equivalent age of the Japanese patients involved in this study (range: 9 years and 5 months to 11 years and 2 months) is 1.9 mm/y in patients 1, 2, and 6 (9 years of age), 2.1 mm/y in patient 4 (10 years of age), and 2.2 mm/y in patients 3 and 5 (11 years of age). In the current study, the increase in mandibular length observed within the first 6 months of treatment was approximately 2.5 mm in 4 patients, 4.0 mm in patient 3, and 3.5 mm in patient 5. These gains suggest that mandibular growth was stimulated during the treatment with the Herbst appliance. Pancherz[6] reported an average increase in mandibular length of 3.2 mm in 10 growing boys with Class II, division 1 malocclusions during 6 months' treatment with a banded Herbst appliance, a value significantly greater than the increase observed in his control group (1.0 mm). McNamara et al[9] reported similar results in their study of patients wearing the acrylic splint design of the Herbst appliance for nearly 1 year. In the current study, the average increase in mandibular length observed in the 6 patients during the treatment period was 2.9 mm, an average consistent with other reports of mandibular length increases in the literature. This comparison indicates that the skeletal and dentoalveolar changes noted in our modest sample of patients were consistent with those reported in previously published studies.

Although an increase in mandibular length was observed in all patients in this study, the degree of improvement in the anteroposterior intermaxillary relationship varied considerably. For example, the ANB angle in patients 1 and 2 showed a reduction of 0.6° and 0.3°, respectively. Pancherz[6–8] reported that the ratio of skeletal and dental changes contributing to the improvement in the overjet was about equal. In this study, however, the anteroposterior skeletal changes that contributed to the improvement in the overjet in patients 1 and 2 were negligible, whereas the dental changes played a much greater role. It is expected that when a Herbst appliance is inserted in a Class II deep-bite patient, there is not only a correction in the molar relationship, but also an opening of the bite vertically. McNamara[44] has shown that an increase in lower anterior facial height negates an approximately equivalent amount of forward mandibular growth, resulting in no change in the anteroposterior position of the chin. Thus, although an increase in mandibular growth was observed in all patients, the minimal improvement in the sagittal intermaxillary relationship in patients 1 and 2 may have resulted from a concomitant increase in the vertical dimension in these 2 patients.

Methodology

We used the Herbst appliance to induce mandibular positional changes and to create forced protrusion for the purpose of examining the instantaneous and short-term response of the activity of the lateral pterygoid muscle. The patients had slight complaints during jaw movement immediately after insertion of the appliance. They became accustomed to this condition within a few days, however, and had no specific difficulties in wearing the appliance thereafter.

One obvious question that arises concerning the methodology of this study is the accuracy of the surface electrode used to record lateral pterygoid function. We previously have described the usefulness of the intraoral surface electrode (Figure 1) in recording the EMG activity of the lateral pterygoid during normal function.[37] In this earlier study, EMG activities were monitored during various jaw movements, with the intraoral surface electrode secured on the mucosa in the buccal vestibule distal to the maxillary tuberosity (Figure 8).

Because we are investigating lateral pterygoid function during Herbst appliance treatment in the current study, we will review here the change in EMG activity related to anteroposterior changes in mandibular position evaluated previously[37] (Figure 8E). Increased EMG activity was recorded from the intraoral surface electrode overlying the lateral pterygoid muscle during mandibular protrusion; there were no changes in the levels of EMG activity of other masticatory muscles. This observation indicates that the EMG activity recorded from the intraoral surface electrode was not an artifact of the simultaneous EMG activity of the temporal, masseter, or digastric muscles, but rather was a reflection of lateral pterygoid activity during changes in the anteroposterior postural position of the mandible.

Furthermore, when the electrical potential recorded with the intraoral surface electrode was averaged with the single motor unit activity of the lateral pterygoid muscle recorded with a needle electrode in our previous investigation,[37] an apparent synchronization with the trigger (the single motor unit of the lateral pterygoid muscle recorded during mandibular protrusion) was observed in the recording obtained with the intraoral surface electrode (Figure 9Ba′). On the other hand, there was no apparent synchronization with similar triggers in the temporal (Figure 9Bb′) and masseter (Figure 9Bc′) muscles. On the basis of the above findings, we are confident that the type of intraoral surface electrode used here can record the EMG activity of lateral pterygoid muscle.

In the present study, the intraoral surface electrode was repositioned at each recording session, which was similar to the method of electrode placement employed in the Michigan animal studies.[11,21] Sessle et al[28] postulated that chronically implanted electrodes used in the Toronto studies[28,29] were advantageous when used in longitudinal studies. He attributed the differences between the Michigan and Toronto studies to the reinsertion of electrodes and the use of an extraoral approach for temporary placement of electrodes. In the current study, however, acutely placed intraoral surface electrodes were employed because the chronic electrode placement recommended by Sessle and co-workers[28] could not be used ethically in humans.

In the present study, the EMG activities of the temporalis and the masseter muscles were also recorded simultaneously to monitor the jaw-closing muscle activity. Indeed, we recognized that there was a possibility that the EMG activity recorded with the intraoral surface electrode at stage II (immediately after appliance placement) was increased by the stretch reflex of the jaw-closing muscles because the vertical dimension was increased after appliance insertion. This possibility could be discarded, however, because little increase in the EMG activity of the jaw-closing muscles per se was recorded simultaneously. Therefore, the methodology used in this study was appropriate for evaluating the change in the lateral pterygoid muscle activity after the mandibular positional changes induced by the Herbst appliance.

Functional changes

The response of the lateral pterygoid muscle to functional appliance therapy has been thought by some investigators to play a very important role in stimulating mandibular growth. For example, it was documented that condylar growth was facilitated by an increased activity in the lateral pterygoid muscle induced by insertion of a functional appliance that forced the mandible into an anterior position.[12] In the present study, the activity of the lateral pterygoid muscle was increased significantly at stage II, and the growth of the mandible was facilitated. This indicates that a similar relation could exist between the human neuromuscular and skeletal responsiveness to mandibular forward positioning to that reported in previous animal experiments.

At stage III (4 to 6 months into treatment), lateral pterygoid muscle activity was decreased to the level observed at stage I (before treatment). The condyles were still located slightly forward from their original positions documented at stage I, however, except for patients 1 and 2, whose condylar positions were almost the same as they were at the beginning of treatment. This observation supports the concepts that the adaptive change in muscle function preceded the compensatory morphological change in the anatomical relationship between the condyle and the glenoid fossa.[1l,41]

Pancherz and Anehus-Pancherz[45] studied the changes in the temporalis and masseter muscle activities during 6 months of treatment with the Herbst appliance. At the insertion of the appliance, the EMG activity from the 2 muscles was reduced markedly during maximal biting and chewing because of the disclusion of the posterior teeth. However, after 3 months, the level of muscle activity was similar to that observed before treatment and, at the conclusion of 6 months of Herbst appliance treatment, the activity of both muscles exceeded pretreatment values. Although we must be careful in comparing the Pancherz study[45] to ours, the results of the study seem to imply that orofacial muscle function has the potential to adapt within a relatively short period to the new conditions created by the bite-jumping appliance. This conclusion also can be inferred from the findings of the present study, even though the muscles evaluated were not exactly the same as those monitored in the Pancherz EMG study.[45]

Immediately after appliance removal (stage IV), lateral pterygoid muscle activity was increased slightly in all patients. The change in muscle activity may be caused by an unstable occlusion attributable to the posterior open bite. In any case, the abrupt change in the intraoral conditions immediately after appliance removal may account for the increased lateral pterygoid muscle activity.

Two weeks following appliance removal (stage V), the lateral pterygoid muscle activity in 3 patients (4, 5, and 6) decreased to the initial level. It seemed that the function of the masticatory muscles was stabilized and became adapted to this mandibular position within 2 weeks.

CONCLUSIONS Return to TOC

In the present study, we longitudinally examined the relationship between neuromuscular and skeletal adaptations during functional jaw orthopedic therapy with the Herbst appliance, focusing on lateral pterygoid muscle activity recorded with the intraoral surface electrode. The increased activity of the lateral pterygoid muscle, seen immediately after insertion of the appliance, decreased markedly after 4 to 6 months of treatment, when the presumed remodeling of the temporomandibular joint was not complete in some patients. In considering the results, however, one should keep in mind the limitations of the present investigation, such as the sample size, the possibility of sample selection bias, and the EMG recording technique used in this type of human study, which must be less invasive than those possible in animal experiments. In spite of these complicating factors, and on the basis of the changes in the lateral pterygoid muscle function and the skeletal and dentoalveolar changes observed during Herbst appliance treatment, we infer that the adaptation of muscular function occurs within a relatively short period (4 to 6 months) and precedes the compensatory morphological changes (various structural changes which compensate the altered fossa-condyle relationship induced by the Herbst appliance). The findings of the current study support the results observed in previous animal experiments.[11,21]

Although particular attention has been paid to functional changes in the lateral pterygoid muscle in the present study, results of a recent investigation suggested that other muscles (eg, masseter) could affect condylar growth[46] through the mechanical loading on the condyle.[47] Future studies should clarify the mechanism through which the Herbst appliance produces an effect on condylar growth, including the modification in the magnitude and direction of reaction forces that are placed on and through the condyle.[47]

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TABLE 1. Demographic and Cephalometric Data for 6 Patients[a]

Patient	Initial Age	Sex	Hellman Dental Age	Overbite, mm		Overjet, mm		ANB, degrees	
				Pre	Post	Pre	Post	Pre	Post
1	9 y, 6 mo	F	IIIB	5.5	4.5	10.0	5.0	5.0	4.4
2	9 y, 5 mo	F	IIIB	5.0	2.0	6.5	2.0	7.1	6.9
3	11 y, 2 mo	F	IIIC	5.0	1.5	8.5	2.0	5.5	3.8
4	10 y, 2 mo	M	IIIB	6.0	5.0	10.0	6.5	8.0	5.6
5	11 y	F	IIIB	6.0	3.2	10.0	4.0	5.1	3.8
6	9 y, 6 mo	F	IIIC	6.5	4.0	10.5	5.5	7.0	5.1

[a] Pre indicates the value at stage I; Post, the value at stage IV in patients 1, 2, and 3, or at stage V in patients 4, 5, and 6; ANB, the difference between the SNA and the SNB.

FIGURES Return to TOC

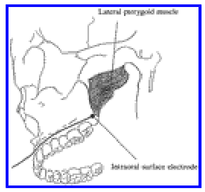

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FIGURE 1. A schematic drawing of the intraoral surface electrode used to record the activity of the lateral pterygoid muscle

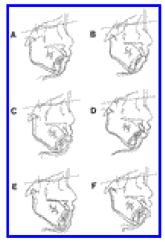

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FIGURE 2. Superimpositions of the lateral cephalometric radiograph of each patient at stage I, II, III, IV, and V. (A) Patient 1, (B) patient 2, (C) patient 3, (D) patient 4, (E) patient 5, (F) patient 6. ___ indicates tracing of the film at stage I; ___, tracing of the film at stage II; …, tracing of the film at stage III; - - -, tracing of the film at stage IV; and ··-··-, tracing of the film at stage V. The reference plane and the reference point for the superimposition of the tracings are the SN plane and the midpoint of the sella turcica

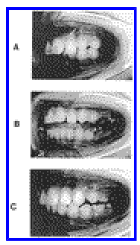

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FIGURE 3. The intraoral photographs of the patient 1. (A) Stage I, (B) stage II, and (C) stage IV

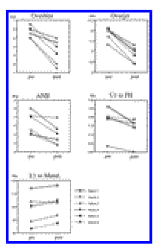

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FIGURE 4. Changes in the cephalometric variables in 6 patients. Pre indicates the value at stage I; post, the value at stage IV (patients 1, 2, and 3) or at stage V (patients 4, 5, and 6)

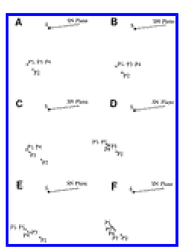

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FIGURE 5. Changes in the position of the center of condyle of each patient during treatment. (A) Patient 1, (B) patient 2, (C) patient 3, (D) patient 4, (E) patient 5, and (F) patient 6. P1 indicates the condylar position at stage I; P2, condylar position at stage II; P3, condylar position at stage III; P4, condylar position at stage IV; and P5, condylar position at stage V. The reference plane and the reference point for the superimposition of the tracings are the SN plane and the midpoint of the sella turcica

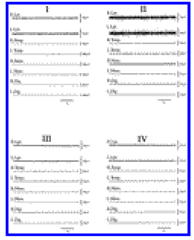

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FIGURE 6. EMG recording of the patient 1 at each stage. R indicates right side; L, left side; Lpt, the lateral pterygoid muscle; Temp, the temporalis muscle; Mass, the masseter muscle; and Dig, the digastric muscle. (I) The recording obtained with the patient at rest in the intercuspal position at stage I, (II) the recording obtained at rest with the mouth closed at stage II, (III) the recording obtained at rest with the mouth closed at stage III, and (IV) the recording taken at rest in the intercuspal position at stage IV

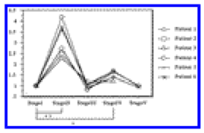

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FIGURE 7. Changes in the lateral pterygoid muscle activity of 6 patients at 5 stages. The vertical axis represents the standardized EMG activity

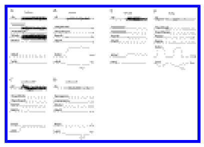

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FIGURE 8. Pattern of EMG activities recorded with surface electrodes during each jaw movement.[37] A, Clenching; B,Jaw-opening; C, Contralateral shift; D, Ipsilateral shift; E, Protrusion; F, Tapping. ISE indicates intraoral surface electrode; Temporalis (ant), anterior part of temporal muscle; Temporalis (post), posterior part of temporal muscle; Masseter, masseter muscle; Digastric, digastric muscle; Vertical, vertical mandibular movement; and Lateral, lateral mandibular movement

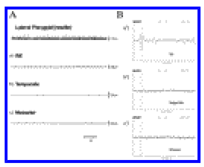

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FIGURE 9. Result of the spike-triggered averaging by using the single-motor unit of the lateral pterygoid muscle as the trigger. (A) The EMG activities during slight mandibular protrusion. Lateral pterygoid (needle) indicates the single-motor unit activity of the lateral pterygoid muscle recorded with a needle electrode. (a–c) EMG activities simultaneously recorded with surface electrodes from the lateral pterygoid muscle (a), the temporal muscle (b) and the masseter muscle (c). ISE indicates intraoral surface electrode; Temporalis, temporal muscle; and Masseter, masseter muscle. (B) The result of the spike-triggered averaging. (a′-c′) Averaged EMG activities recorded with surface electrodes from the lateral pterygoid muscle (a′), the temporal muscle (b′) and the masseter muscle (c′). Vertical axis: 2 mV/Div. Horizontal axis: 20 ms/Div. The vertical dotted line represents the timing of the trigger. Apparent potential synchronized with the trigger is observed only in (a′).[37]

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