Original Article

Electromyographic Activity of Lower Lip Muscles When Chewing with the Lips in Contact and Apart

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Abstract: Masticatory muscle activity is coordinated with perioral muscle during chewing. Subjects with competent lips usually chew with the lips in light contact, whereas subjects with incompetent lips possibly have dysfunctional chewing. In this study, the electromyographic (EMG) activities of the lower lip and masseter muscles were recorded when chewing with the lips in contact and apart. At first, 37 subjects were divided into an incompetent lip group and competent lip group on the basis of EMG activity of the lower lip muscle at rest. The durations of the masseter nonactive phase and total phase when chewing with lips in contact were shorter in the incompetent lip group than in the competent lip group. In the incompetent lip group, when chewing with the lips apart, the EMG activity of lower lip in the masseter nonactive phase was significantly ($P < .05$) higher than in the competent lip group, but there was no difference in the EMG activity in the masseter active phase between two groups. Our results suggest that subjects with incompetent lips have difficulty chewing while their lips are relaxed. We conclude that the inability of sealing the lips and lip dysfunction could possibly affect masticatory function. (*Angle Orthod* 2004;74:31–36.)

Key Words: EMG; Incompetent lip; Chewing; Lower lip

INTRODUCTION

The lips are said to be incompetent when the lips are unconsciously apart at the mandibular rest position and when the lips are consciously in contact, the lower lip shows an excessive contraction. Lip incompetence as defined by these points was studied by observing the chin skin, facial photograph, and lateral roentgen cephalogram.[1–3]

Incompetent lips are classified mainly into two types.[4] The first type results from anteroposterior and vertical disharmony of the dentofacial complex. In patients with a large overjet or with an excessive anterior facial height, the lips are habitually apart at rest, and the EMG activity of the lower lip is significantly increased when the lips are consciously in contact.[5–9] In the second type, the lips adapt to an altered oral functional environment such as mouth breathing due to nasal obstruction or difficulty of nasal breathing. In mouth breathing, the lip seal may be broken to breathe through the mouth. In our preliminary study, there was no increase in the EMG activity of the lower lip when the lips were consciously in contact in these subjects.[10] Therefore, lip incompetence visually observed in mouth breathers, was not identified by electromyographic (EMG) estimation. In addition, Moyers added another innate type of incompetent lip. In this type, the tonus of the lip might be too weak to keep the lip in contact unconsciously, and the EMG activity of the lower lip also increases to keep the lips consciously in contact.[4] In a previous report, we classified subjects into competent lip and incompetent lip groups on the basis of the difference of the EMG activity between when the lips were in contact and apart at rest.[11] Using this definition, mouth breathers, because of nasal obstruction, are classified into the lip competent group.

The lips have a mechanical function in the transfer of food, and especially drink, into the mouth and in preventing the loss of food from the mouth during mastication.[12] Therefore, in subjects with competent lips, the lips are lightly and unconsciously closed when chewing food, and they chew food without making noise.

In some patients with incompetent lips, however, parents sometimes complain about their children making noise when chewing food. Subjects with incompetent lips some-

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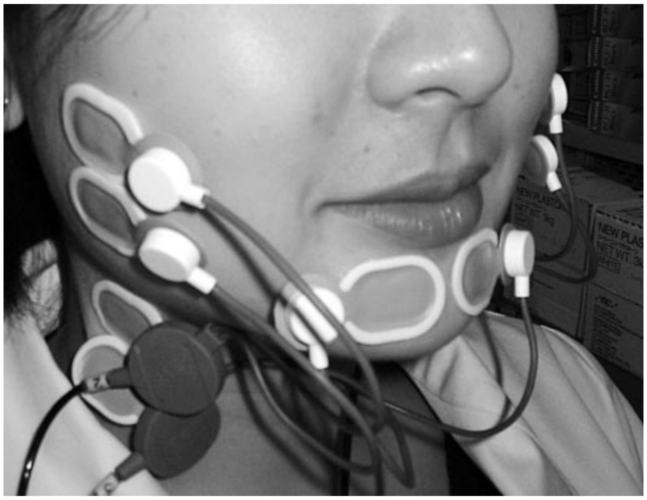

FIGURE 1. Positioning of electrodes.

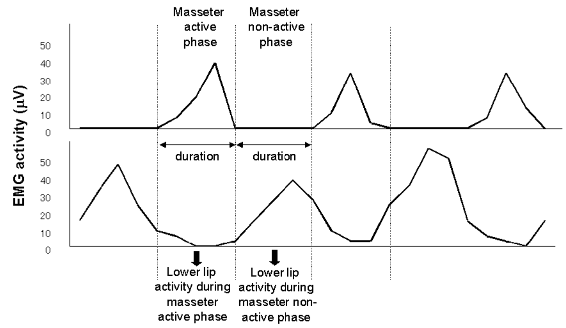

FIGURE 2. Estimation of each phase of the chewing stroke. In the averaged EMG activity, a chewing stroke was divided into two phases. Upper: masseter muscle. Masseter active phase is from the beginning to the end of the EMG activity. Masseter nonactive phase was between two successive masseter active phases. Lower: lower lip. The mean EMG activity of the lower lip was recorded during each phase.

times chew food with the lips apart.[1] Chewing with the lips in contact is an unconscious act for subjects with competent lips and a conscious act for incompetent lip subjects. Similarly, chewing with the lips apart is a conscious act for competent lip subjects and an unconscious act for incompetent lip subjects. Chewing with lips in contact or with the lips apart may have different effects on the muscular activity of the lips for lip competent and incompetent subjects.

Retraction of anterior teeth and mandibular mesial displacement are important treatment planning features for patients with a large overjet. If the patients with poor lip function possibly have difficulty chewing food, the lip posture at rest and orofacial function as well as the esthetic problem should improve with treatment.

The purpose of this study was to evaluate the muscle activity of the lower lip when chewing with the lips in contact and apart.

MATERIALS AND METHODS

Subjects

Thirty-seven subjects, 18 adult volunteers and 19 patients, in treatment were selected without visual examination of lip competence. The mean age of the participating individuals was 21.8 ± 6.7 years. The purpose and methods of this study were explained in detail, and informed consent was obtained from all subjects.

Positioning of electrodes

Bipolar surface electrodes were placed over the right and left masseter muscles along the main direction of the muscle fibers as ascertained by palpation of the muscles. The electrodes for recording the muscles of the lower lip were placed symmetrically below the vermilion border of the lower lip (Figure 1).

EMG recording

Subjects sat on a dental chair in an upright position in a shielded room. EMG signals obtained using a 1000-Hz sampling frequency were transformed into absolute values and averaged every 0.1 second using the Muscle Tester ME3000P system (Mega Electronics Kuopio, Finland). The amplifier was connected directly to the ground electrodes to eliminate any electrical disturbance caused by unexpected movement of the electrodes.

Mean EMG activity of the lower lip at rest and sleep

In all subjects, the EMG activity of the lower lip was recorded for 30 seconds with the lips in contact and apart at mandibular rest position. The recording was repeated five times, and the mean EMG activity with the lips in contact was designated EMLC and that with the lips apart was designated EMLA.

Subjects were divided into two groups on the basis of the difference (EMLA − EMLC) in the EMG activity of the lower lip with the lips in contact and apart at mandibular rest position. Subjects with a positive or a small value were classified into the competent lip group, and those with a marked negative value were classified into the incompetent lip group. The competent lip group consisted of 17 subjects with Class I malocclusion and mild crowding, and Class III malocclusion. The incompetent lip group consisted of 20 subjects with Class I, Class II, and Class III malocclusions (Table 1). Subsequently, the EMG activity of the lower lip was recorded during a two-hour sleep in the supine posture in 15 subjects (eight subjects had incompetent lips and seven subjects had competent lips). The mean EMG activity of the lower lip during the sleep period was calculated, and the EMG activity of the lower lip was compared between those with the lips in contact and those with the lips apart at rest.

TABLE 1. Classification of Subjects by Lip Competence and Occlusion

	Class I	Class II	Class III
Incompetent lip group (n = 20)	9	8	3
Visual incompetence (n = 14)	6	7	1
Visual competence (n = 6)	3	1	2
Competent lip group (n = 17)	15	0	2

Chewing cycle according to the masseter muscle activity

Twenty-two subjects, 12 incompetent lip and 10 competent lip subjects, were asked to chew a gum (Xylitol gum, Lotte, 13 mm × 19 mm × 6 mm) freely with the lips in contact and apart. Fifteen chewing strokes, excluding the first five strokes, were selected for the study. By transforming EMG signals into absolute values and averaging them every 0.1 second, it was easy to find out the beginning and end of the EMG activity of the masseter muscle. Each chewing stroke was divided into two phases according to the beginning and end of the EMG activity of the masseter muscle. The first was the active phase in which the masseter muscle was contracting, whereas the second represented the nonactive phase when the masseter muscle was relaxing. The duration of chewing for 15 strokes and that of the active and nonactive phases of the masseter muscle were measured (Figure 2).

Mean EMG activity of the lower lip muscles when chewing with the lips in contact and apart

The mean EMG activities of the lower lip when chewing gum with the lips in contact (EMCLC) and apart (EMCLA) were calculated for 15 strokes. In addition, the EMCLC and EMCLA during active and nonactive phases of the masseter muscle were calculated for one stroke (Figure 2).

Statistical analysis

In each group, each variable was tested for a normal distribution with a chi-square test, and the homogeneity of all variances was tested with the F test. The Friedman test was used to examine differences among two groups, two phases, and two lip positions. When a statistically significant difference was calculated, Scheffe's F test for multiple comparisons was used.

RESULTS

EMG activity of the lower lip at rest

There was no significant difference (EMLA − EMLC) in EMG activities of the lower lip between EMLC and EMLA in the competent lip group. However, in the incompetent lip group, EMLC was significantly ($P < .05$) higher than EMLA. In addition, EMLC was significantly ($P < .05$) higher in the incompetent lip group than in the competent lip group, but there was no significant difference in EMLA between the two groups. On the other hand, there was no difference in the EMG activity of the lower lip at rest with the lips in contact compared with that during sleep in the competent lip group. In the incompetent lip group, there was no difference in the EMG activity of the lower lip at rest with the lips apart when compared with that during sleep (Figure 3).

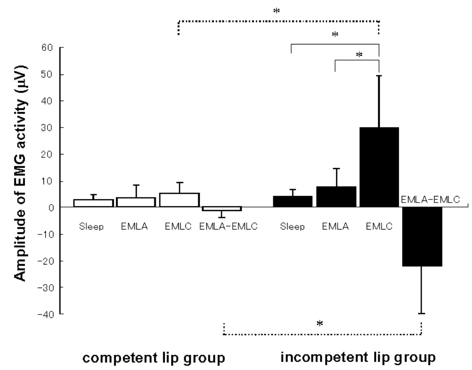

FIGURE 3. Amplitude of EMG activity of lower lip muscles at rest and during sleep. EMLC, EMG activity of the lower lip at rest with the lips in contact; EMLA, EMG activity of the lower lip at rest with the lips apart. Data are mean ± SD. $*P < .05$.

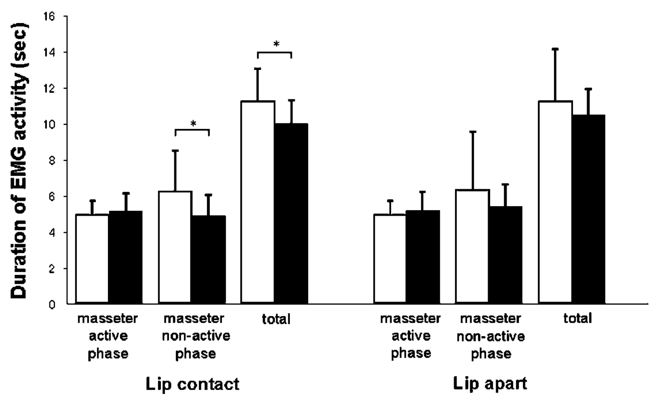

FIGURE 4. Duration of EMG activity of masseter muscle in 15 chewing strokes. Open bars, competent lip group; closed bars, incompetent lip group. Data are mean ± SD. $*P < .05$.

Duration of EMG activity of masseter muscle when chewing

The duration of EMG activities during the nonactive phase and the total phase with the lips in contact was significantly shorter ($P < .05$) in the incompetent lip group than in the competent lip group when chewing gum (Figure 4). The duration of EMG activity when chewing gum with the lips apart also tended to be shorter, albeit insignificantly, in the incompetent lip group compared with the competent lip group. There were no significant differences in the duration of EMG activity during active and nonactive phases

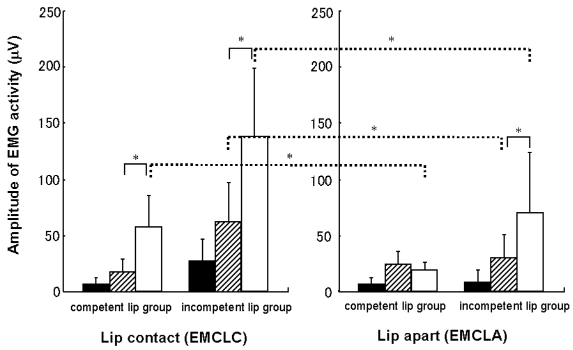

FIGURE 5. Amplitude of EMG activity of lower lip muscles at rest and during chewing. Closed bars, EMG activity of lower lip muscles at rest; hatched bars, EMG activity of lower lip during the active phase; open bars, EMG activity of lower lip during the nonactive phase. Data are mean ± SD. *$P < .05$.

in chewing with the lips in contact or apart in each group (Figure 4).

EMG activity of the lower lip when chewing

EMCLC during the nonactive phase was significantly higher than that during the active phase in both the competent and incompetent groups (Figure 5). Furthermore, EMCLA during the nonactive phase was also significantly higher than that during the active phase in the incompetent lip group. However, there was no significant difference in EMG activity between the two phases in the competent lip group (Figure 5). During the nonactive phase, EMCLC was significantly ($P < .05$) higher than EMCLA in the competent lip group (Figure 5); however, there was no significant difference between EMCLC and EMCLA during the active phase. On the other hand, in the incompetent lip group, EMCLC was significantly higher than EMCLA during the two chewing phases.

DISCUSSION

Classification of subject

The diagnosis of lip incompetence by visual examination of conscious and unconscious lip posture is difficult. Using a morphological definition of lip competence, normal lip posture is defined as that tonus in the lips that should provide constant contact of the upper and lower lips. Incompetent lip closure is defined as lips not in contact when lips are relaxed at mandibular rest position. Incompetent lip requires conscious contraction of the muscle to come into contact and is recognized by dimpling of the chin skin. In patients with a large overjet, it is easy to diagnose lip incompetence.

Lip open posture in mouth breathing, due to nasal obstruction or difficulty in nasal breathing, is called incompetent. Because the incompetent lips require conscious contraction of the lower lip to come into contact, lip incompetence is estimated by EMG activity of the lips.[11,13] In our preliminary study in humans, we found that there was no decrease in the EMG activity of the lower lip when the subject was forced to open the lips by nasal obstruction. Therefore, the lips of the mouth breather are classified as competent lips by EMG estimation. In this study, during the two-hour sleep in the supine posture, we supposed that the lips will be held in contact unconsciously for the competent lip subjects and held apart unconsciously for the incompetent lip subjects. In the competent lip group, there was no difference in the EMG activity of the lower lip at rest with the lips in contact compared with that during sleep. In the incompetent lip group, there was no difference in the EMG activity of the lower lip at rest with the lips apart when compared with that during sleep. Therefore, EMG activity of the lower lip with the lips in contact for the competent lip group and that with the lips apart for the incompetent lip group was unconsciously recorded at rest. Thus, we divided our subjects into incompetent lip group and competent lip group on the basis of the increased EMG activity of the lower lip when the lips were in contact at mandibular rest position as several studies indicated.[11,13]

Subjects

In this study, subjects were randomly selected without using classification of occlusion or making visual examination of lip competence. Actually, when electromyography was used to select the 20 incompetent lip subjects of our study, the incompetent lip was visually recognized in 14 subjects, but the incompetent lip in six subjects was not identified by visual observation. Nine subjects with Class I occlusion were included in the incompetent lip group (Table 1).

EMG activities of the lower lip when chewing

Chewing cycle. It is known that the pattern generator governs chewing. However, it is reported that many factors can alter the chewing pattern and cycle. Throckmorton et al[14] studied changes in the masticatory cycle before and after treatment of posterior unilateral crossbites and found that a longer chewing cycle was shortened to become equal to control values after treatment. Miyawaki et al[15] reported on the changes of masticatory jaw movement after surgical orthodontic treatment. They stated that the mean duration of the chewing cycle decreased after treatment. Sohn et al[16] reported the duration of muscle activity, and the incidence of the silent periods of the masseter muscle when chewing significantly decreased after the treatment. Matsuka et al[17] stated that rabbits exhibited a prolonged chewing cycle after placement of bite-raising splints. On the other hand, Karkazis et al[18] indicated that the duration of the chewing cycle, the chewing rate, and the relative contraction time when chewing were significantly higher for chewing of carrots than that for chewing nonadhesive chewing gums. Papargyriou et al[19] reported that the chewing cycle duration and the opening and occlusal time of the chewing cycle increased during development.

In normal chewing, the lips act to seal the mouth and prevent food leakage from the oral cavity during low excursions of the mandible. Therefore, chewing with the lips in contact is an unconscious task and chewing with the lips apart is a conscious one for subjects with competent lips. However, in subjects who have difficulty in closing the lips at rest, it is difficult to chew with the lips in contact. So, the lips are unconsciously apart when chewing food. Chewing with the lips apart disrupts the fine coordination required to pass the bolus back and forth over the occlusal surfaces of the teeth. Chewing with the lips apart is a conscious task for subjects with competent lips and an unconscious one for those with incompetent lips.

Therefore, we expect that the open lip posture when chewing affects chewing movements. In this study, we proposed that the chewing cycle was shortened during the nonactive phase of the masseter activity. When chewing food with the lips apart, it is difficult to achieve the chewing task without the cooperation of the tongue, cheek, and dentition. Thus, there should be a limitation of mandibular movement when chewing food with the lips apart. This will be further examined in the future.

EMG activity. Previous studies examined the activity of the mentalis muscle in subjects with incompetent lips under various functions.[2,3,9,20–22] Takada et al[23,24] studied the relation between EMG activity of the inferior orbicularis oris muscles and jaw movement and showed the timing of activities of jaw and lip muscles when chewing. Schieppati et al[25] investigated the pattern of EMG activities of perioral muscles during mastication. They reported that the duration and amplitude of facial muscle activity were influenced by the duration of the masticatory cycle and whether lip-to-lip contact was made. In our study, the difference between incompetent lips and competent lips with regard to lower lip activity was associated with mastication. The nonactive phase is the opening phase of the chewing cycle, and the lips are extended when chewing with the lips in contact; however, the lips are not extended when chewing with the lips apart. Therefore, in both the competent and incompetent lip groups, the EMG activity of the lower lip was greater with the lips in contact when chewing in the nonactive phase compared with the active phase. In the competent lip group, the EMG activity when chewing with the lips in contact was greater compared with chewing with the lips apart during the nonactive phase.

In the competent lip group, there was no significant difference in the EMG activity of the lower lip when chewing with the lips apart during the active phase compared with that during the nonactive phase. However, in the incompetent lip group, EMG activity increased when chewing with the lips apart during the nonactive phase compared with that during the active phase. These results suggested that in the incompetent lip group, chewing with the lips apart is still associated with problematic masticatory activity. Further studies are necessary to carefully examine the chewing task before and after orthodontic or orthognathic surgical treatment.

CONCLUSIONS

In this study, the EMG activity of the lower lip muscles was recorded during chewing. Subjects with incompetent lips showed higher EMG activities at rest and when chewing with the lips in contact, compared with those with competent lips. When chewing with the lips apart, only in nonactive phase, the EMG activity of lower lip in the incompetent lip group was higher than that in competent lip group. Furthermore, there was a significant difference in the EMG activity of the lower lip between the two phases only in the incompetent lip group. The duration of masseter nonactive and total phases when chewing with lip contact was shorter in the incompetent lip group compared with the competent lip group. Our results suggest that subjects with incompetent lips have difficulty chewing while their lips are relaxed. We conclude that the inability to seal the lips is lip dysfunction and could possibly affect masticatory function.

REFERENCES

1. Barrett RH, Hanson ML. *Oral Myofunctional Disorder*. St Louis, Mo: CV Mosby Co; 1974:193–194.
2. Tosello DO, Vitti M, Berzin F. EMG activity of the orbicularis oris and mentalis muscles in children with malocclusion, incompetent lips and atypical swallowing—part I. *J Oral Rehabil.* 1998; 25:838–846.
3. Tosello DO, Vitti M, Berzin F. EMG activity of the orbicularis oris and mentalis muscles in children with malocclusion, incompetent lips and atypical swallowing—part II. *J Oral Rehabil.* 1999;26:644–649.
4. Moyers RE. *Handbook of Orthodontics, Maturation of the Orofacial Musculature.* Chicago, London, Boca Raton: Year Book Medical Publisher Inc.; 1988:73–97.
5. Lowe AA, Takada K. Associations between anterior temporal masseter, and orbicularis oris muscle activity and craniofacial morphology. *Am J Orthod.* 1984;86:319–330.
6. Simpson MMcF. Lip incompetence and its relationship to skeletal and dental morphology—an electromyographic investigation. *Br J Orthod.* 1976;3:177–179.
7. Simpson MMcF. An electromyographic investigation of the perioral musculature in Class II div.1 malocclusion. *Br J Orthod.* 1977;4:17–22.
8. Gustafsson M, Ahlgren J. Mentalis and orbicularis activity in children with incompetent lips. *Acta Odont Scand.* 1975;33:355–363.
9. Harradine NW, Kirschen RH. Lip and mentalis activity and its influence on incisor position—a quantitative electromyographic study. *Br J Ortod.* 1983;10:114–127.
10. Yamaguchi K. Effects of experimental mouth breathing on dentofacial growth. *J Jpn Orthod. Soc.* 1980;39:24–45.
11. Yamaguchi K, Morimoto Y, Nanda RS, Ghosh J, Tanne K. Morphological differences in individuals with lip competence and incompetence based on electromyographic diagnosis. *J Oral Rehabil.* 2000;27:893–901.
12. Jenkins GN, *The Physiology and Biochemistry of the Mouth*. 4th ed. London: Blackwell Scientific publications; 1978:502–506.

13. Yamaguchi K, Morimoto Y, Nanda RS, Tanne K. Lower lip activity during clenching in incompetent lips subjects. *J Ind Orthod Soc.* 1997;30:71–79.
14. Throckmorton GS, Buschang PH, Hayasaki H, Pinto AS. Changes in the masticatory cycle following treatment of posterior unilateral crossbite in children. *Am J Orthod Dentofacial Orthop.* 2001; 120:521–529.
15. Miyawaki S, Yasuda Y, Yashiro K, Takada K. Changes in masticatory jaw movement and muscle activity following surgical orthodontic treatment of adult skeletal Class III case. *Clin Orthod Res.* 2001;4:119–123.
16. Sohn BW, Miyawaki S, Noguchi H, Takada K. Changes in jaw movement and muscle activity after orthodontic correction of incisor crossbite. *Am J Orthod Dentofacial Orthop.* 1997;112:403–409.
17. Matsuka Y, Kitada Y, Mitoh Y, Adachi A, Yamashita A. Effect of a bite-raising splint on the duration of the chewing cycle and the EMG activities of masticatory muscles during chewing in freely moving rabbits. *J Oral Rehabil.* 1998;25:159–165.
18. Karkazis HC, Kossioni AE. Re-examination of surface EMG activity of the masseter muscle in young adults during chewing of two test foods. *J Oral Rehabil.* 1997;24:216–223.
19. Papargyriou G, Kjellberg H, Kiliaridis S. Changes in masticatory mandibular movements in growing individuals: a six-year follow-up. *Acta Odontol Scand.* 2000;58:129–134.
20. Itsuki Y. Functional differences in tongue, perioral and masseter muscle activities during swallowing in normal and open bite subjects—an electromyographic and cephalomrtric appraisal. *J Jpn Orthod Soc.* 1996;55:461–476.
21. Gustafsson M, Ahlgren J. Mentalis and orbicularis oris activity in children with incompetent lips. *Acta Odontol Scand.* 1975;33: 355–363.
22. Vitti M, Basmajian JV, Ouellette PL, Mitchell DL, Eastmen WP, Seaborn RD. Electromyographic investigations of the tongue and circumoral muscular sling with fine-wire electrodes. *J Dent Res.* 1975;54:844–849.
23. Takada K, Miyawaki S, Tatsuta M. The effects of food consistency on jaw movement and posterior temporalis and inferior orbicularis oris muscle activities during chewing in children. *Arch Oral Biol.* 1994;39:793–805.
24. Takada K, Yashiro K, Sorihashi Y, Morimoto T, Sakuda M. Tongue, jaw, and lip muscle activity and jaw movement during experimental chewing efforts in man. *J Dent Res.* 1996;75:1598–1606.
25. Schieppati M, Di Francesco G, Nardone A. Patterns of activity of perioral facial muscles during mastication in man. *Exp Brain Res.* 1989;77:103–112.