Original Article

Influence of Functional Appliances on Masticatory Muscle Activity

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Abstract: The purpose of the present study was to investigate the influence of an activator appliance and a spring active appliance on masticatory muscle activity by means of electromyography (EMG). Twelve adult males with good general health were recruited as subjects. Three functional appliances were used in each subject for long-period EMG recording during daytime and sleep and short-time EMG recording during voluntary biting. Following findings were obtained. (1) The activity of all muscles was greater during biting than during daytime and sleep, (2) the muscle activities tended to increase in the digastric muscle and to decrease in the temporal muscle with activators under all conditions, and (3) the temporalis-masseter ratios became lower with the biting use of appliances. Therefore, this study suggests that functional appliances should be used during sleep and during the day in combination with voluntary biting to achieve adaptation and development of the masticatory muscles. (*Angle Orthod* 2005;75:616–624.)

Key Words: Activator; Spring active appliance; Masticatory muscle activity; Electromyogram

INTRODUCTION

Activators are used to modulate mandibular growth, and the effect of activators on masticatory muscle activity has been reported extensively in previous studies. Ahlgren[1] found no increase in muscle activity during sleep, whereas an increased postural activity was detected in the masseter muscle during the day. Miralles et al[2] found a significant increase in muscle activity during saliva swallowing with activator appliances.

The spring active appliance (SAA) was introduced by Sander and Wichelhaus[3] and Sander.[4] In this appliance, the upper and lower acrylic bite plates with labial arches are consolidated by wire springs on the lingual sides. This appliance has been used primarily for the treatment of dental and skeletal open bites with a small or distally located (or both) mandible. The effect is achieved by exerting continuous tension on the neuromuscular system supporting the mandible to inhibit vertical growth of the maxillomandibular skeleton and to produce forward autorotation of the mandible, leading to the correction of open bite. The nature of morphologic and functional changes produced by such appliances has been reported.[5,6,7]

However, in most of these studies, masticatory muscle activity was measured only for a limited period before and after treatment. Furthermore, in clinical practice, patients are sometimes instructed to bite on the appliance during the day, but there have been only a limited number of studies on the effects of such activity.[8]

The purpose of the present study was to investigate the influences of an activator and SAA on masticatory muscle activity by means of electromyography (EMG) for short and long periods, during the day and during sleep.

MATERIALS AND METHODS

Subjects

Twelve healthy adult males (mean age 26.6 years) were selected from the volunteers in the Hiroshima

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TABLE 1. Summary of Subjects in the Present Study (12 Healthy Adult Males)

Subjects	Age (y)	Overjet (mm)	Overbite (mm)	Molar Relationship Right	Molar Relationship Left	ANB	Mand. Plane Angle
A	26	3.5	2.5	I	I	5.3	115.0
B	32	4.4	3.5	I	I	4.0	106.0
C	25	3.5	3.2	I	I	3.4	134.8
D	27	6.5	3.9	II	I	2.9	106.8
E	27	2.5	2.6	I	I	−0.5	112.3
F	24	3.8	2.5	I	I	2.0	129.2
G	25	4.8	3.4	I	I	7.2	125.8
H	26	1.6	1.1	I	I	0.7	133.5
I	26	4.8	3.9	I	I	5.2	120.5
J	26	3.2	2.0	II	II	6.0	112.7
K	25	2.2	1.8	I	I	0.2	123.0
L	30	4.7	4.8	I	I	2.1	115.9
Average	26.6	3.8	2.9	—	—	3.2	119.6
SD	2.3	1.4	1.0	—	—	2.4	9.8

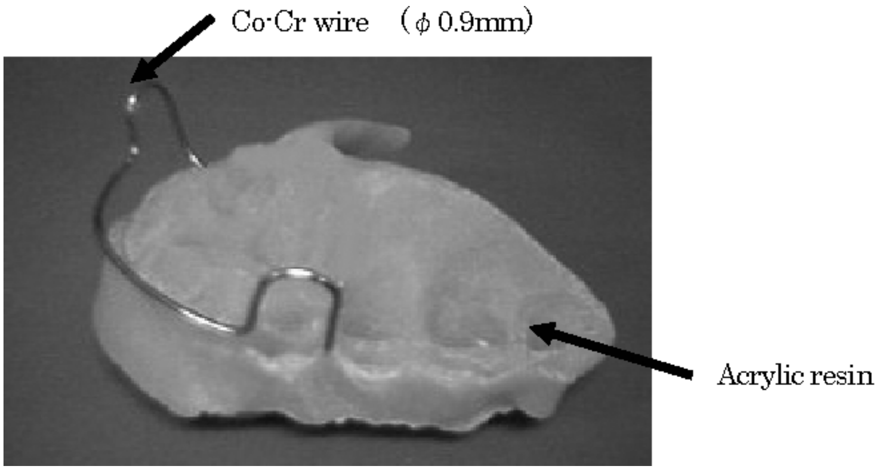

FIGURE 1. Activator (FKOh).

University Faculty of Dentistry (Table 1). They had a variety of skeletal relations and complete dentitions without any serious malocclusions or temporomandibular joint disorders. Informed consent was obtained from all subjects.

Experimental appliances

Three functional appliances, an activator[9] (FKOh), SAAo, and SAAa, were used for each subject. FKOh and SAAo had construction bites taken in an edge-to-edge occlusion with three mm of forward displacement of the mandible and a vertical distance of eight mm at the incisors (Figures 1 and 2). For the SAAa, the construction bite height at the molars was double that of the SAAo (Figure 2).

EMG recording

A digital EMG recording device (Muscle Tester ME3000P, Mega Electronics Ltd., Kuopio, Finland) and bipolar silver-silver chloride electrodes (Blue sensor, type-N-00-S, Medicotest A/S, Ølstykke, Denmark) were used to record the EMG from the right anterior temporal (Temp), superficial portion of the right masseter (Mass), and anterior belly of the right digastric muscles (Dig). The electrodes were placed as reported previously,[10,11] and the EMG was recorded with a sampling frequency of one kHz (Figure 3). The means of rectified EMG data for every 0.1 second were stored in the recording device.

Experimental procedures

Long-term EMG recording during daytime and sleep. In this experiment, three sessions were performed with and without the use of FKOh and SAAo on three different days with an interval of one week. To record muscle activity at rest, each subject was allowed to watch a video or television while sitting in an office chair in a small room. The diurnal recording

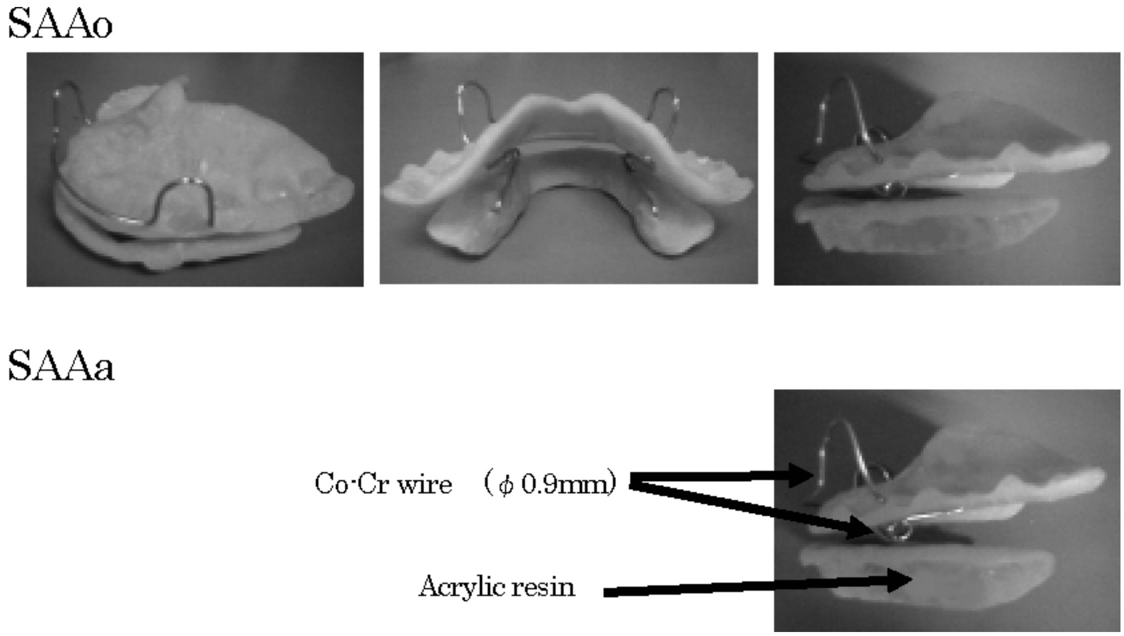

FIGURE 2. Spring active appliance (SAA), SAAo (upper) and SAAa (lower).

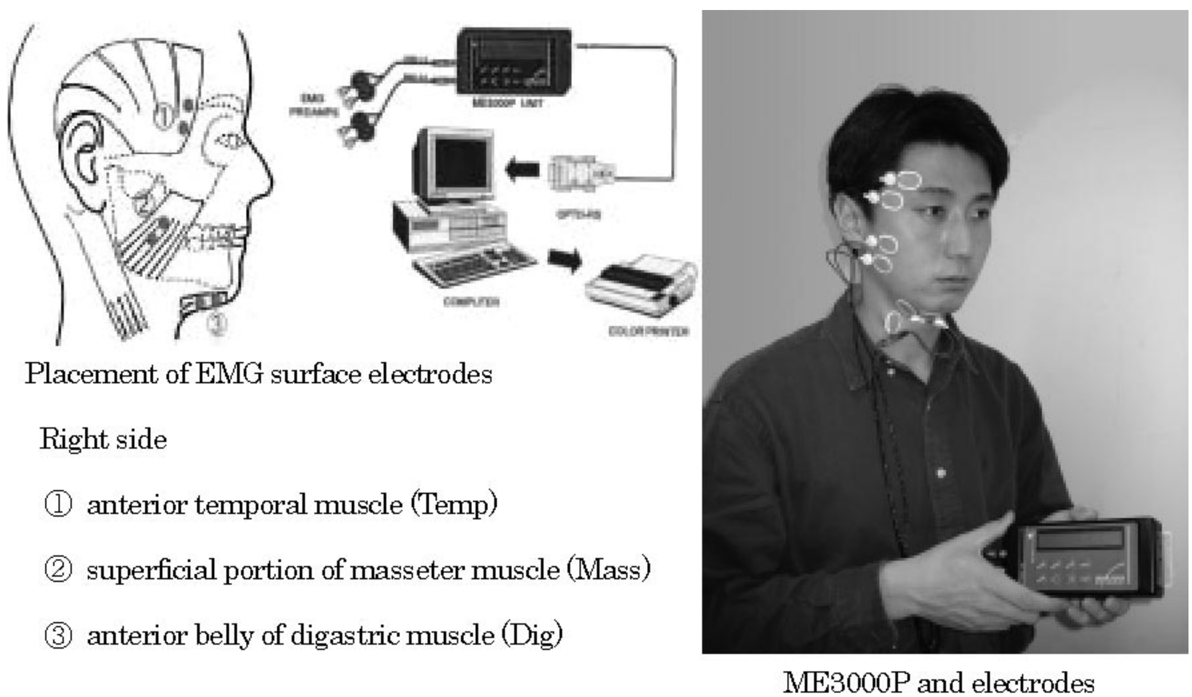

FIGURE 3. Placement of EMG surface electrodes.

was carried out for consecutive 220-minute periods. During recording, subjects were requested to refrain from speaking and moving their head. After the diurnal recording, the subjects were sent home with the electrodes in position, and then the nocturnal EMG recording was performed for 220 minutes again, with subject in bed in the usual sleep posture. The data for the first 30 minutes were excluded because of unstable status. The analysis was executed for the stable 190 minutes during daytime and sleep.

Short-term EMG recording during voluntary biting. In this experiment, four sessions were performed. Each subject was requested to sit in an office chair in an upright position without head support. All the subjects were requested to bite with their teeth in the intercuspal position so as to be able to continue biting indefi-

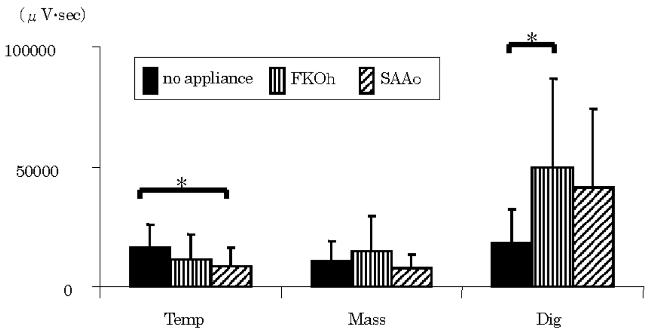

FIGURE 4. Muscle activity with and without the appliances during daytime; *significantly different ($P < .05$).

nitely and also to bite with FKOh, SAAo, and SAAa between their teeth on the same day. To investigate the changes in muscle activity while biting the appliances, the masseter, temporal, and digastric muscle activity was recorded for each subject with and without the appliances (four sessions) for 12 minutes in each session. Each session was analyzed for the stable 9.5 minutes, which was converted to 190 minutes for the comparison with the long-time data.

Data analysis

Data analysis was performed with accessory software (Muscle Tester ME3000P Software v.1.4-program, Mega Electronics Ltd., Kuopio, Finland), and the integrated EMG values (μV/sec) were calculated. Furthermore, T:M ratio as the proportion of the temporal and masseter muscle activities was calculated for each session.

For statistical analysis, paired *t*-tests were performed to examine the difference in muscle activity with and without the use of different functional appliances under the same conditions. Analysis with *t*-tests was also performed for each appliance under different conditions.

RESULTS

Muscle activity with and without the appliances during daytime

Muscle activity with the FKOh tended to be more predominant than that with the SAAo for all the muscles as shown in Figure 4. Muscle activity also tended to increase in the digastric muscle and to decrease in the temporal muscle with the appliances, whereas the changes were small in the masseter muscle.

The muscle activity induced by FKOh and SAAo was increased in the digastric muscle ($P < .05$). Temporal muscle activity with use of SAAo was significantly decreased. Meanwhile, no significant changes in masseter muscle activity were induced by the appliances.

Muscle activity with and without the appliances during sleep

The activity of all the muscles was less during sleep than during daytime in all situations (Figure 5). The activity of temporal and masseter muscles was significantly less with the appliance than without ($P < .01$). In contrast, the digastric muscle activity tended to be greater with the appliances. No substantial differences were found in the activity of three muscles with two appliances.

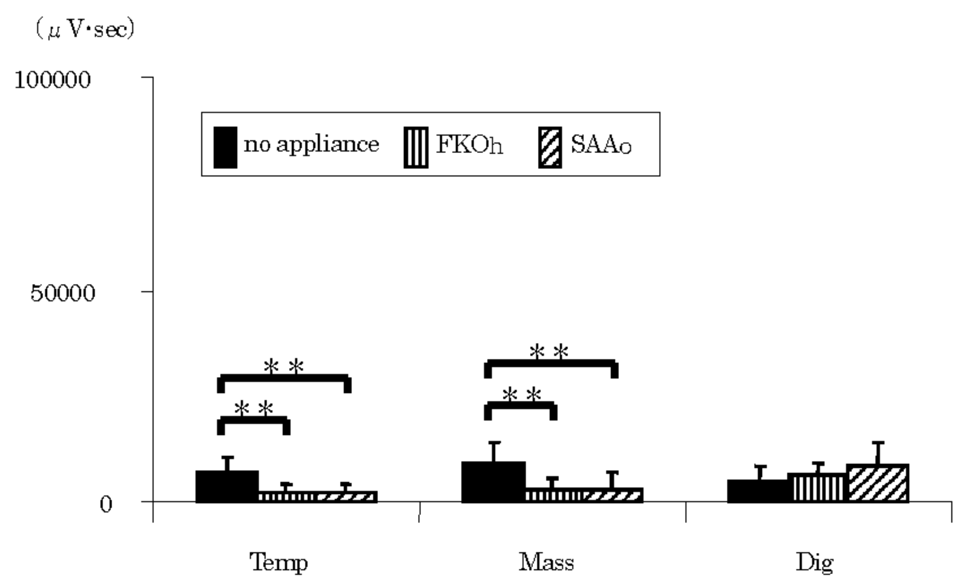

FIGURE 5. Muscle activity with and without the appliances during sleep; **significantly different ($P < .01$).

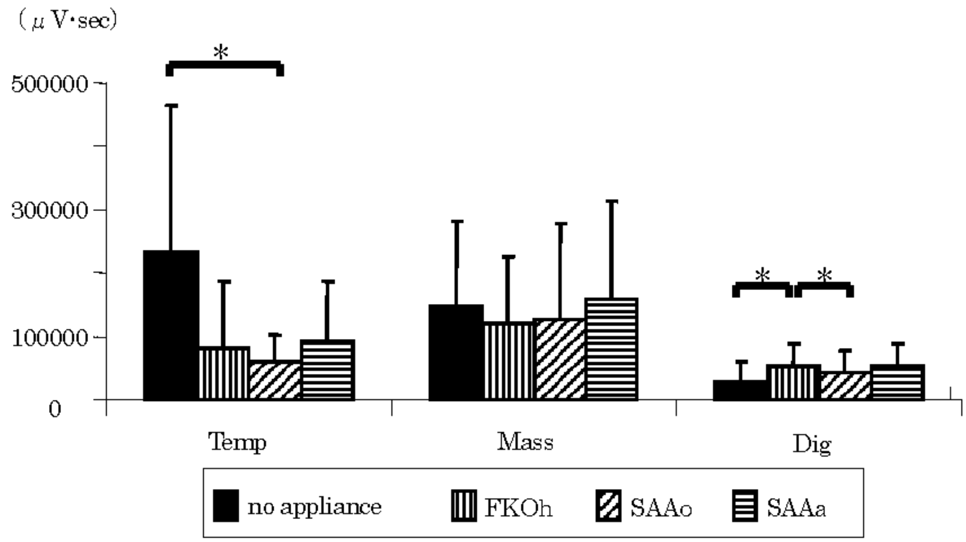

FIGURE 6. The mean integrated values of muscle activity in the temporal, masseter, and digastric muscles during conscious biting with and without the appliances; *significantly different ($P < .05$).

Muscle activity with and without the appliances during voluntary biting

With the use of the SAAo, the activity of the temporal muscle significantly decreased, see Figure 6 ($P < .05$). The digastric muscle activity significantly increased with the use of FKOh as compared with SAAo use or with no appliance use. Changes in the masseter muscle were not significant, both with and without the three appliances.

The activity of all three muscles with SAAa tended to be larger than that with SAAo (Figure 6), although this was not significant. The activity of temporal and masseter muscles during biting was greater than during daytime and sleep with or without appliances, whereas these differences were not significant in the digastric muscle during biting and daytime (Figure 7).

T:M ratio

Without the use of an appliance, the mean ratio of the temporal muscle activity to the masseter muscle (T:M) was significantly smaller during sleep than during daytime and biting. With use of the appliances, the T:M ratios increased during daytime and sleep, but a significant decrease was found during biting (Table 2).

DISCUSSION

Subjects

Subjects in the present study were all healthy adult males because it was considered unethical to recruit children for prolonged EMG recordings.

Changes in muscle activity with functional appliances under subconscious condition during daytime and sleep

During sleep, decreases in the temporal and masseter muscle activity were found in response to the use of functional appliances. Therefore, the activity of the temporal and masseter muscles was not enhanced by wearing the functional appliances. This supports a concept that no increases are induced in the postural EMG activity while using functional appliances or bite planes during sleep.[1,12,13] Even during daytime, no increases in the activities of these muscles, especially in the temporal, were found with the use of the appliances. This supports previous results that the use of functional appliances or bite planes at rest did not increase EMG activity of the temporal muscle,[1,14–17] the masseter muscle,[14–16,18] and the lateral pterygoid muscle.[18]

Why the decrease in the temporal muscle activity is induced by the appliance under subconscious conditions might be explained by the principle of splint therapy. When activator appliances are used and the elevator muscles are stretched beyond their static length, the active and total tension of the muscles is reduced. Recently, it is understood that passive tension associated with viscoelasticity of soft tissues and tonic stretch reflex of muscles play an important role in the effect of functional appliances, rather than active contraction of the jaw closing muscles, because of a much longer duration of forces from passive tension rather than from active contraction.[9,12,14,16,19] In general, light continuous forces are thought to be more effective for orthodontic tooth movement. The present study appears to support this hypothesis. Sessle et al[19] in-

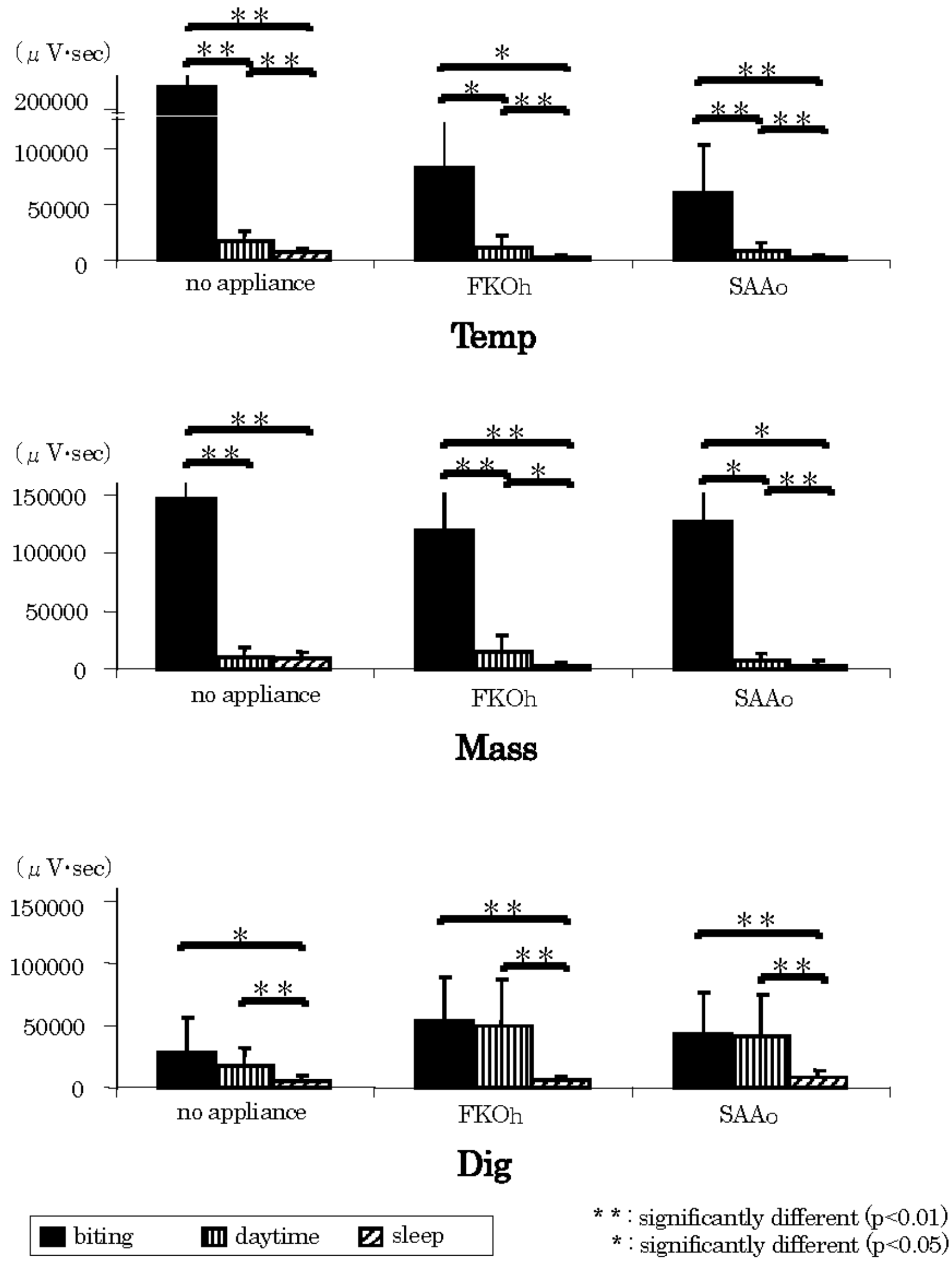

FIGURE 7. Comparison of integrated muscle activity during biting, daytime, and sleep; *significantly different ($P < .05$), **significantly different ($P < .01$).

vestigated muscle activity in juvenile monkeys with functional appliances. Despite the significant decrease in the masseter and digastric muscle activities, the mandible exhibited substantial forward growth.

Why the T:M ratio with and without functional appliances became lower during sleep than during the daytime might be related to body position. It was reported that the temporal[17,20,21] and digastric muscles[17,20] showed decreases, whereas the masseter muscle[17] had no change with different body postures without appliances.

During daytime, the activity of the digastric muscle was greater than that of the masseter muscle without appliances. But during sleep, the masseter muscle presented higher activity than the digastric muscle because the occurrence of occlusal contacts was reduced during daytime subconscious conditions. Masseter muscle activity thus became reduced, and the digastric muscle exhibited increased activity mainly during saliva swallowing, although it is well known that the frequency of saliva swallowing during sleep is reduced.[22] At the same time, masseter muscle activity

TABLE 2. Mean Ratio of the Temporal Muscle Activity to the Masseter Muscle (T:M)

	T:M Ratio			
	No Appliance	FKOh	SAAo	SAAa
Biting	1.9 ± 1.5**]*	0.6 ± 0.3	0.8 ± 0.7	0.7 ± 0.6
Sleep	0.8 ± 0.4*	1.1 ± 1.2	1.0 ± 0.5	
Daytime	1.9 ± 1.2**]**	3.6 ± 6.6	2.8 ± 4.4	

* Significantly different ($P < .05$).
** Significantly different ($P < .01$).

without appliances showed no significant differences between daytime and sleep. In addition, the digastric muscle activity increase by the use of the appliances was more prominent during daytime than during sleep and biting. The increase in the activity might be produced by opening the mouth to displace the mandible and stimulate the muscle with the construction bite, moving of the tongue, or swallowing the increased salivary secretion resulting from the change in intraoral environment produced by wearing the appliances.

Changes in muscle activity with functional appliances when biting

When biting voluntarily without the appliances, the activity of the temporal muscle was greater than the masseter muscle. A significantly reduced activity of the temporal muscle while biting on the appliances may be explained by the change in muscle length resulting from wearing the appliances. In contrast, a construction bite with three mm forward displacement of mandible and vertical distance of eight mm at the incisors may affect the masseter muscle activity less substantially because of occlusal contacts through the appliances during biting. Given these considerations, T:M ratio was significantly decreased by biting FKOh, SAAa, and SAAo in comparison with no appliance. In addition, when SAAo was used, the activity of the temporal muscles became the most reduced among the three conditions. Because the mandibular position is controlled by two springs, which have mobility, the construction bite in SAAo seems to be unstable than in FKOh.

The appliances exert a more substantial influence on the activity of the temporal muscle than the masseter muscle during biting. This may be because the masseter muscle is a jaw-closer whereas the temporal muscle is a jaw-stabilizer.[23] Thus, masseter muscle activity is changed less compared with that of the temporal muscle when biting on the appliance.

When comparing SAAo and SAAa, the activity of all three muscles with SAAa tended to be more predominant than that with SAAo. Therefore, larger vertical activation of SAA on the molars may induce higher activity of masticatory muscles.

It has been suggested that functional appliances should be used during the day to obtain better results because of the increased activity of the masticatory muscles.[2,14] Furthermore, several investigations have shown a correlation between masticatory muscle activity and craniofacial growth patterns or morphology.[10,24–29] According to Ingervall and Bitsanis,[27] individuals with a long face have weak masticatory muscles, and if facial form is partly determined by the strength of the masticatory muscles, this could suggest therapeutic possibilities. Strengthening the masticatory muscles could have a beneficial effect on facial growth in long-faced children. They have also demonstrated a gradual increase in bite force and an increased anterior rotation during one year of muscle training. Suto et al[8] suggested that biting use of activator appliances on short and long facial skeletal patterns reduce the skeletal differences seen pretreatment. Furthermore, according to Niide,[24] T:M ratio was higher in open bite than in the controls for both children and adults. From these suggestions, the decrease in T:M ratio induced by biting functional appliances may strengthen the masticatory muscles, activating the masseter muscle, exerting a beneficial effect on forward mandibular growth.

On the other hand, a conventional use of activator appliances especially for long-face cases may result in a clockwise rotation of mandible or little or no additional growth of the mandible (or both).[30–33] The reason may be associated with an increase of the T:M ratio and decrease of the jaw closing muscle activity, which is seen in appliance use during sleep or daytime at rest. Therefore, we suggest that functional appliances should be used during sleep and during the day in combination with voluntary biting to achieve adaptation and development of the masticatory muscles.

The activator and SAA

Comparing the muscle activities from FKOh and SAAo, any significant differences were not detected in the present study. However, during daytime, the mean integrated value of muscle activity with FKOh tended to be more predominant than that with SAAo. It is speculated that the difference in total muscle activity between FKOh and SAAo might have some association with differences in the isometric and isotonic contractions of muscles.

With use of SAA during daytime in particular, it may be accepted that patients could repeatedly bite the appliance automatically, because the springs in SAA are activated by biting the appliance voluntarily and swallowing saliva. Furthermore, by increasing the vertical height of posterior dentoalveolar region and use with biting, the SAA may exert more effective orthopedic forces than the activator to correct skeletal discrepancy.

CONCLUSIONS

The following findings were obtained.

- The activity of all muscles was greater during biting than during daytime and sleep.
- With activators, the muscle activities tended to increase in the digastric muscle and to decrease in the temporal muscle under all conditions.
- The T:M ratios became lower with the biting use of appliances.

Therefore, this study suggests that functional appliances should be used during sleep and during the day in combination with voluntary biting to achieve adaptation and development of the masticatory muscles.

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