

Original Article

Differential roles of periodontal mechanoreceptors of working-side posterior teeth in triggering nonworking-side temporalis activities

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The purpose of this study was to examine how the periodontal sensory inputs of working-side maxillary posterior teeth affect nonworking-side anterior temporalis activities at the starting jaw position of the slow-closing phase in mastication.

Six subjects with normal occlusion were asked to bite an incisal block to maintain the initial jaw position of the slow-closing phase and to generate jaw-closing muscle activities. Bipolar needle electrodes were inserted into the nonworking-side anterior temporalis to record spike discharges from a single motor unit. To stimulate the periodontal mechanoreceptors, mechanical stimulations were applied to the working-side maxillary first molar, first and second premolar in bucco-palatal, palato-buccal, and apical directions. Meanwhile, we examined changes in the discharge frequency of the motor unit activities of the nonworking-side anterior temporalis. We found that the palato-buccal stimulation to the working-side maxillary first molar and the apical stimulation to each working-side maxillary posterior tooth significantly increased the nonworking-side anterior temporalis activities; however, palato-buccal and bucco-palatal stimulations applied to the first and second premolar didn't. Thus, differential responses of the nonworking-side anterior temporalis are found by the working-side maxillary first

molar and premolar stimulations. These findings may be due to some differences in function between molar and premolar.

Key words: periodontal mechanoreceptors, non-working-side anterior temporalis, working-side posterior teeth, mechanical stimulation, mastication

Introduction

In mastication, rhythmical jaw movement is generated within the central nervous system and sensory feedbacks, particularly from the masticatory muscles, periodontal ligament, and temporomandibular joint modify the basic features of mastication. It is generally well-known that most types of orofacial mechanoreceptors are phasically stimulated during the slow-closing (SC) phase of a chewing cycle¹ and that the periodontal mechanoreceptors are one of the essential factors to transmit food resistance, size and texture to the CNS in order to generate and modify masticatory muscle activities.²⁻⁴

Kamata, et al.^{5,6} have reported that periodontal sensory inputs of the working-side maxillary canine affected the activity of contralateral temporalis during lateral jaw movement from the working-side to the intercuspal position. The results suggested that the working-side canine is under not only tooth-guided control but also muscle control in lateral chewing strokes.

Although it has been said that working-side posterior teeth, especially first molar and premolar, actually crush and grind the food bolus during the SC phase of a chewing cycle^{7,8}, it remains unclear how the periph-

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Received November 11, 2002; Accepted January 14, 2003

eral inputs from the periodontal mechanoreceptors of the working-side maxillary posterior teeth affect the contralateral anterior temporalis activity. Moreover, it is not yet known the differential responses of the temporalis activities by first molar and first/second premolar stimulations.

Therefore, to investigate whether the periodontal input from each working-side maxillary posterior tooth at the simulated start of SC affects the activity of contralateral anterior temporalis and, if so, in which pattern, we conducted electromyographical trials under simulated experimental conditions.

Materials and Methods

Subjects

Six subjects (4 males and 2 females; aged 25-28 years) who had normal occlusion with Angle's Class I interarch relationship and showed normal jaw movements defined by Proschel, et al.⁹ during voluntary habitual unilateral gum chewing were selected from the faculty in our dental school. All subjects showed no signs or symptoms of craniomandibular dysfunction. Before initiation of the study, all subjects given their consent to participate after receiving a full explanation of the purposes and design of our study, and this study approved by the declaration of Helsinki.

Mandibular positioning

To determine the experimental mandibular position as the starting position of the SC phase of a chewing cycle, the subjects were asked to chew on a hard gum unilaterally. Movement of a lower incisor point was recorded by a non-invasive transducer (Kinesiograph Model K-6, Myotronics Inc., Seattle, U.S.A.). The fifth to fifteenth strokes were regarded as stable ones according to a previous study.¹⁰ Therefore, we only selected one stable stroke from them to determine mandibular position. Finally, we prepared an anterior bite block made by hard silicone to maintain the jaw position and to generate masticatory muscle activities. At this point, the teeth were so positioned that the buccal cusps of the mandibular teeth were almost directly under the buccal cusps of the maxillary teeth on the working side.¹¹

Mechanical stimulation

Mechanical stimulation was applied manually to each working-side maxillary posterior tooth (first molar/first premolar/second premolar) by a mechanical

stimulator (LVS-2KA, Kyowa electronic Instruments, Tokyo, Japan). Six attachments were bonded to occlusal and buccal surfaces of the working-side posterior teeth by an orthodontic adhesive (Orthomite Super-Bond, SUN MEDICAL, Tokyo, Japan). Before stimulations, a cheek retractor was set at the angles of mouth and the stimulator was bonded to each attachment. The stimulation was applied manually in the following three directions: bucco-palatal, palato-buccal and apical directions. The bucco-palatal and palato-buccal directions were performed parallel to the occlusal plane, and the apical direction was done perpendicular to the occlusal plane, simulating masticatory horizontal and axial force vectors at the start of SC phase (Figure 1). The duration was about 2s, and the intensity of the mechanical stimulations was 600, 800 and 1000g in the preparatory experiment and was 800g in the main experiment, corresponding to the lower range of biting forces during mastication.^{12,13}

Data Recording

The subjects were seated upright in a chair with their occipital region of head held firmly against a rest to eliminate effects of the tonic neck reflex on the masticatory muscles.¹⁴ To register the motor unit (MU) activity, bipolar needle electrodes (NM-220T, Nihon-Kohden, Tokyo, Japan) were inserted vertically into the contralateral anterior temporalis. Before stimulations, we instructed the subjects to bite the anterior bite block slightly to generate MU activities of the temporalis at a low constant discharge frequency level. The MU activities and mechanical stimulation applied by the stimulator were stored for further analyses on a tape

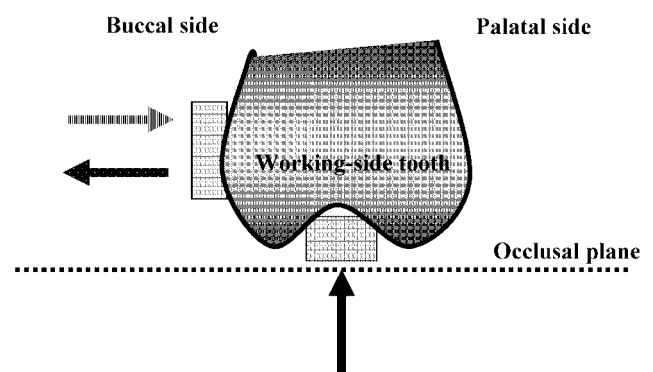


Fig. 1. Before stimulation, attachments (⊞) were bonded to occlusal and buccal surfaces of each working-side posterior tooth. palato-buccal (←), bucco-palatal (→), and apical (↑) stimulations were applied to the working-side maxillary first molar, first premolar and second premolar.

recorder via a bioelectric amplifier (RM 600AG, 621G, Nihon-Kohden, Tokyo, Japan) and a dynamic strain amplifier (DPM-611A, Kyowa electronic Instruments, Tokyo, Japan), respectively. The data were then transferred to a personal computer via an A/D transformer at a sampling rate of 10 kHz (Power Lab system, Bio Research Center, Nagoya, Japan) (Figure 2-a,b).

In the experiment, each procedure was repeated three times and then averaged to reduce experimental scatter.

Data analysis

The responses of contralateral temporal motor units

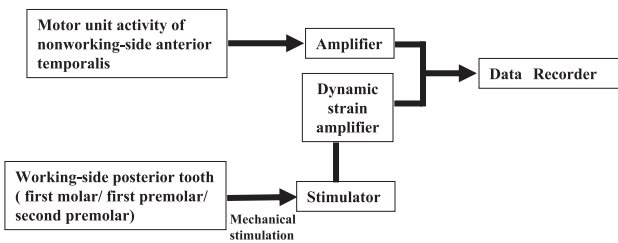


Fig. 2a. The experimental setup. EMG recordings were made from nonworking-side anterior temporalis while mechanical stimulation was applied to each working-side posterior tooth by a stimulator. The subjects bit an anterior bite block slightly at a constant level of EMG activity before stimulation.

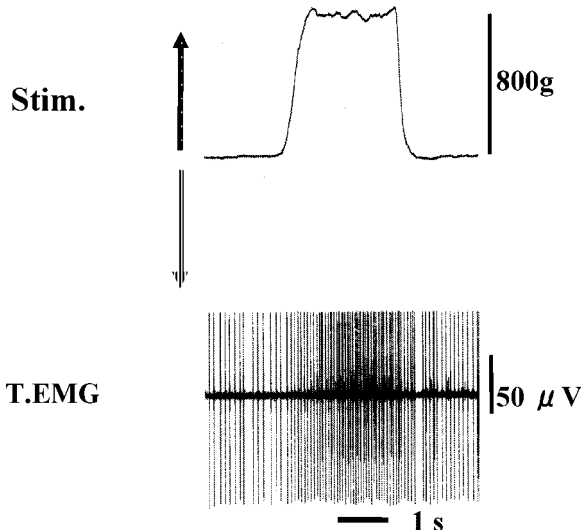


Fig. 2b. One of the electromyographic response of contralateral temporalis made from nonworking-side anterior temporalis while palato-labial stimulation (↑) was applied to the working-side maxillary first molar by a stimulator. T.EMG, temporal electromyogram; Stim., stimulation; (↓) bucco-palatal stimulation

were analyzed quantitatively. The discharge frequency of a MU for 1s prior to stimulation was compared with that during 1s of stable discharge frequency during stimulation.^{5,6,13} Then they were analyzed with an analytical software (Power Lab system, Bio Research center, Nagoya, Japan).

We adopted Wilcoxon Signed Rank test for comparison of the data between before and during stimulation. *P* values of < 0.05 were regarded as significant. These tests were done by means of a statistical analysis software (Stat View V, Abacus Concepts, Inc., CA, U.S.A.).

Results

In the preparatory experiment on 1 subject, palato-buccal and bucco-palatal stimulations of 600, 800 and 1000g were applied to the working-side first molar, first premolar and second premolar to clarify the relationship between the intensity of the mechanical stimulations and the response of the contralateral temporalis (Figure 3).

When palato-buccal stimulations of 600, 800 and 1000g were applied to the working-side first molar, one

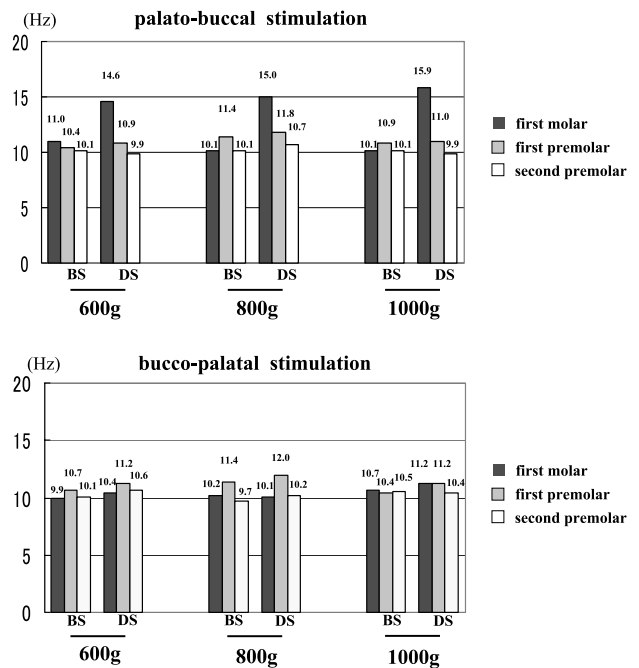


Fig. 3. Discharge frequency of 1 motor unit of nonworking-side anterior temporalis before stimulation (BS) and during stimulation (DS). Palato-buccal and bucco-palatal stimulations with forces of 600, 800, 1000 g were applied to the working-side maxillary first molar, first premolar and second premolar.

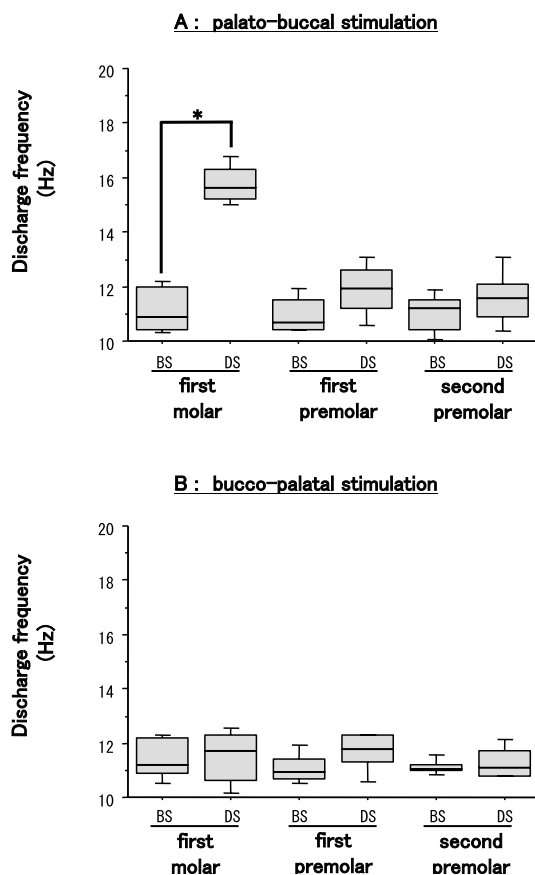


Fig. 4. Overview of electromyographic responses of nonworking-side anterior temporalis motor units before stimulation (BS) and during stimulation (DS). Palato-buccal stimulation (A) and bucco-palatal stimulation (B) were applied to the working-side maxillary first molar, first premolar and second premolar. An asterisk indicates statistically significant difference with $P < 0.05$.

of the motor units (MUs) in the contralateral temporalis was measured and markedly increase of the discharge frequency was observed. On the other hand, when bucco-palatal stimulations of 600, 800 and 1000 g were applied to the first molar, the discharge frequency of the MU didn't vary markedly. When palato-buccal and bucco-palatal stimulations of 600, 800 and 1000 g were applied to the working-side first premolar and second premolar, the discharge frequency of the same MU in the temporalis didn't vary markedly. From these data, we confirmed that the same data were obtained regardless of the intensity of the mechanical stimulations from 600 g to 1000 g. Therefore, the stimulation of 800 g was used in the main experiment.

In the main experiment on 6 subjects, when palato-buccal stimulation was applied to the working-side first molar, the discharge frequencies of all 6 MUs of the

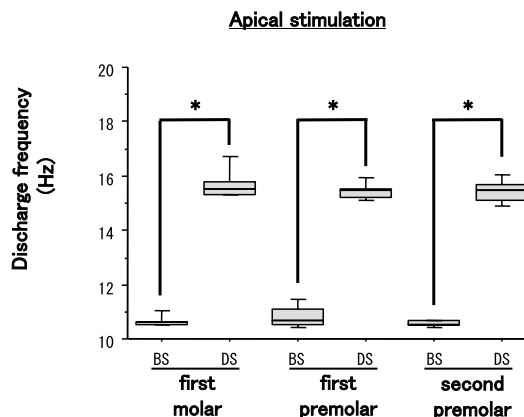


Fig. 5. Overview of electromyographic responses of nonworking-side anterior temporalis motor units before stimulation (BS) and during stimulation (DS). Apical stimulation was applied to the working-side first molar, first premolar, and second premolar. Asterisks indicate statistically significant difference with $P < 0.05$.

contralateral temporalis significantly increased (Figure 4-A) ($P < 0.05$), whereas when bucco-palatal stimulation was applied to the first molar, the discharge frequencies of the 6 MUs changed little (Figure 4-B). Meanwhile, when palato-buccal and bucco-palatal stimulations were applied to the first and second premolar, the discharge frequencies of the 6MUs didn't vary significantly (Figure 4-A, B).

When apical stimulation was applied to the working-side first molar, second premolar, and first premolar, the discharge frequencies of 6 MUs in the contralateral temporalis of the subjects significantly increased (Figure 5) ($P < 0.05$).

Discussion

In general, the human chewing cycle consists of 3 phases (opening, fast closing, and slow closing). Slow-closing (SC) phase is a period when food particles are being destroyed.¹ At the start of the SC phase, food resistance (hard gum) radically decelerates jaw movement and displaces working-side teeth. Kato¹⁵ showed that working teeth were rapidly displaced into the dental alveoli under the low masticatory forces below 1000 g at the start of the SC phase. Moreover, it is reported that periodontal feedback would play a major role in generating a quick buildup of masticatory forces.¹⁶ From these studies, we assume that periodontal receptors would be affected by the rapid tooth displacement and periodontal feedback has great effect on the masticatory muscle activity.

Therefore, we examined how the periodontal inputs from the working-side maxillary first molar, first premolar and second premolar at which 90% of masticatory function occurs⁷ affect the contralateral temporalis activity at the simulated start of the SC phase.

As for lateral stimulations to the working-side teeth, our results show that palato-buccal stimulation to the first molar significantly increases the contralateral temporalis activities but bucco-palatal stimulation to the first molar doesn't trigger the temporalis activities. Many studies have reported that the harder the food, the wider the lateral closing jaw movement would be.¹⁷⁻²⁰ This lateral jaw excursion is due to preparations for powerful grinding for harder foods during the SC phase.^{19,21,22} Moreover, Inoue, et al.²³ found that after bilateral section of the maxillary and inferior alveolar nerves in a rabbit, lateral jaw excursion of the mandible was significantly reduced. The findings indicate that periodontal feedback from periodontal mechanoreceptors of molars plays a crucial role in making powerful grinding movement. From our data, we saw that only the maxillary first molar can fulfill this function among the working-side maxillary posterior teeth. To elucidate this, the following explanation can be considered. It is reported that the working-side maxillary first molar was mainly displaced to the apical direction during the SC phase.^{24,25} Besides, Masai²⁶ found that the working-side maxillary first molar was initially displaced to the buccal direction before displacing to the apical direction. In addition, masticatory horizontal force vectors are more dependent on the lateral excursion of the mandible and the angle of approach to intercuspal position.²⁷ These findings may indicate that the hard food on the mandibular first molar was pressed on the inner surface of the buccal cusp of the maxillary first molar heavily at the starting jaw position of the slow-closing phase. Therefore, it is possible that the wider the lateral jaw movement, the larger the buccal and apical displacement of the maxillary first molar to trigger more contralateral temporalis activities so as to pull up the jaw mesiolaterally and to generate powerful grinding jaw movements.

On the other hand, it is interesting to note that neither palato-buccal nor bucco-palatal stimulation applied to the first and second premolar increases the temporalis activities. The reason of these findings is that working-side maxillary first and second premolars should be pressed down to the apical direction at the start of the SC phase during premolar chewing regardless of food hardness. Nishida, et al.²⁸ reported that vertical jaw movement occurred when the food bolus (chewing

gum) was masticated by premolar region, while grinding jaw movement occurred when the food bolus was masticated by molar region. Therefore, we further examined whether the apical stimulation to the working-side posterior teeth affects the contralateral temporalis activity. As a result, the apical stimulation to the working-side premolar as well as first molar significantly increased the temporalis activities. Also, it is reported that periodontal feedback affects the jaw-closing muscles during the slow-closing phase in both man and rabbits.^{21,22,29} From these findings, we assume that there might be a pathway for triggering the contralateral anterior temporalis activities by stimulating the periodontal mechanoreceptors of the working-side maxillary posterior teeth, as well as working-side maxillary canine.^{5,6} In fact, it has been found that the periodontal mechanoreceptors were directionally selective in man and dogs.^{30,31} Above these findings, it is possible that the distribution of the periodontal mechanoreceptors of each posterior tooth is formed to be adapted to each tooth displacement, and also is formed to generate contralateral temporalis activities effectively by periodontal feedback in mastication.

However, the experimental conditions differ on several points from those of natural chewing. First, our experiments were done in a static position when a bite block was positioned between the anterior teeth. It is well known that sensory information may not be used in the same way in the control of static and dynamic condition, e.g., during stance and locomotion or during static biting and chewing. Second, sensory inputs of the anterior teeth affected the temporalis activities. Furthermore, the force was applied only one direction, whereas during natural chewing the food bolus presses the working teeth in various directions. Anyhow, our results have provided insight into the functional differences among the posterior teeth during artificial circumstances and further work is required to distinguish between first molar and premolar function considering time factors because our findings are only at the simulated start of the SC phase.

In conclusion, our results indicate that differential responses of motor units of the contralateral anterior temporalis are found between first molar and first/ second premolar while mechanical stimulations were applied to the teeth at the simulated start of the SC phase. These findings lead us to summarize that periodontal sensory inputs of first molar and premolar control the contralateral temporalis functionally in a varied way in mastication.

Acknowledgements

A special thank to Dr. Kazuo Toda for his advice on the experiment. We gratefully acknowledge the volunteers participating in this study. This study was supported by Grants-in-aid for Scientific Research (no. 12307050, no. 11470448 and no. 13877350) from the Ministry of Education, Science, Sports and Culture, Japan.

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