Comparison of First Jaw Motor Performance between Bite Task at Anterior and Posterior Teeth

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Abstract

This study aimed to compare bite force and masticatory muscle activity between anterior and posterior teeth during first jaw motor performance.

Twenty-six participants performed two biting tasks; one at the anterior teeth (ATB) and one at the right first molar (PTB). The tooth bite task consisted of three force levels (20%, 40% and 60% maximum voluntary contraction (MVC)). Before measurement, participants performed a maximum tooth bite on a force meter to determine the 100% MVC at the anterior and posterior teeth. During all tasks, electromyographic (EMG) activities were recorded from the left and right masseter muscles, and left and right temporalis muscles and bite force were recorded. The variability at each target force level and for each jaw motor task was determined as the coefficient of variation (CV) of the actual bite force activity and EMG activities.

Actual bite force values and EMG RMS amplitude in each muscle were significantly dependent on target force level during ATB and PTB ($P < 0.01$). CV values of actual bite force level in each jaw motor task were not significantly dependent on target force level or biting task. EMG RMS amplitude during ATB and PTB were significantly dependent on force level ($P < 0.01$). In conclusion, our findings suggest that force control of first jaw motor performance did not vary between anterior teeth and posterior teeth. In addition, the present study suggests that the mechanism of force control with regard to jaw movements contributes masticatory muscle activity and periodontal receptors.

Keywords :

tooth bite, bite force, masticatory muscle, anterior tooth, posterior tooth

Introduction

In daily life, humans unconsciously perform functional jaw movements (mastication, etc.). To elucidate the performance of jaw movements related to functional oral motor tasks, it is essential to investigate the coordination of jaw movements. Our previous study investigated the effects of repeated jaw-motor tasks on masseter muscle performance and demonstrated that repeated tooth clenching improves the performance of masseter muscles in terms of accuracy, but not maximum voluntary contraction (1). Hellmann et al. suggested that the masticatory muscles are remarkably

prone to motor adaptation (2). In addition, some studies also demonstrated motor learning with regard to jaw movements at anterior teeth during biting (3, 4). However, no studies have compared bite force and masticatory muscles between anterior teeth and posterior teeth when humans perform simple jaw motor tasks.

On the other hand, some studies have demonstrated that when humans perform motor tasks on the first attempt, the muscle activation used to achieve the objective of the action does not typically use the muscles available in the most effective manner (5, 6). In jaw motor tasks, although some studies investigated the effects of repeated jaw motor tasks for bite force or masticatory muscle activity, no studies have investigated the first performance of a jaw motor task. To

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clarify the mechanisms of jaw movements, it is essential to investigate the first performance of a jaw motor task. The aim of this study was to compare the bite force and masticatory muscle activity between anterior and posterior teeth during first jaw motor performance.

Materials and Methods

Participants

This study was carried out in 26 participants [8 women and 18 men; mean age $\pm$ standard error of the mean = 28.6 $\pm$ 3.0 years]. Abnormal stomatognathic function or anterior open bite was excluded from, this experiment. There were no participants with any medical, physical, or psychological problems. Informed consent was obtained from all participants before the experiment. The Institutional Ethics Committee approved the study (EC16-012), and the guidelines set out by the Declaration of Helsinki were followed.

Tooth bite task

This study consisted of two tooth bite tasks (a tooth bite task at the anterior teeth (ATB) and a tooth bite task at the right first molar (PTB)) and three target force levels (20%, 40% and 60% maximum voluntary contraction (MVC)). All participants sat upright and relaxed on a dental chair with their head supported by a headrest, and performed each jaw motor task.

Before measurement, participants performed a maximum tooth bite on a force meter to determine the 100% MVC at the anterior teeth and posterior tooth. During all measurements, participants alternated between a 5-s rest-block and a 5-s task-block over a period of 30 s at a given auditory signal for each jaw motor task, which consisted of two jaw motor tasks and three target force levels. Three target force levels at 20%, 40%, and 60% MVC on ATB and PTB in randomized order were performed 3 times. To avoid masticatory muscle fatigue, a 30-s rest period was allowed between each jaw motor task.

A bite force meter (Unipulse F325 Digital Indicator, UNIPULSE, Tokyo, Japan) was used to measure bite force in each jaw motor task during all measurements. The design of the bite force meter (Fig. 1B) ensured that the force measurement was insensitive to the point of force applied onto the plate. A bite force meter was placed on the right side between the first molars or anterior teeth and supported by the participant during the jaw motor task. In this data analysis, initially, actual bite force value during

each jaw motor task was quantified by calculation of the target force level in 5-s intervals from all participants. Second, the variability at each target force level and in each jaw motor task was determined as the coefficient of variation (CV) of the actual bite force activity.

Electromyographic measurements

In all measurements, electromyographic (EMG) activities were recorded during each jaw motor task. EMG activities were recorded from the left masseter (LM), right masseter (RM), left temporalis (LT), and right temporalis (RT) during ATB and PTB, using disposable bipolar surface electrodes (NM31; Nihon Kohden, Tokyo, Japan). EMG signals were amplified 2000 times (PL3508 Power Lab 8/35, Bio research center, Japan), filtered in the bandwidth 20 Hz to 1 kHz, sampled at 4 kHz and stored for off-line analysis.

In EMG data analysis, EMG activities during each jaw motor task were quantified by calculation of root mean square (RMS) EMG amplitude in each of the 5-s intervals from each EMG channel in all participants. Second, the variability at each target force level was determined as the CV of the EMG activity in each EMG channel.

Statistical analysis

All data are presented as mean values and standard error of the mean. The actual bite force value in each tooth bite task was analyzed using one-way ANOVA with each target force level (20%, 40%, 60%, and 100% MVC). The CV value of actual bite force level between target force level and actual bite force values were analyzed using two-way ANOVA with each target force level (20%, 40%, and 60% MVC) and tooth bite task (ATB and PTB).

The RMS EMG amplitudes in each muscle (masseter muscle and temporalis muscles) for each tooth bite task (ATB and PTB) were analyzed using two-way ANOVA with each target force level (20%, 40%, 60%, and 100% MVC) and side (left and right). CV values of EMG RMS amplitude in each muscle (masseter muscle and temporalis muscle) in each tooth bite task (ATB and PTB) were analyzed using two-way ANOVA with each target force level (20%, 40%, and 60%) and side (left and right). When appropriate, ANOVA was followed by Bonferroni test to compensate for multiple comparisons. P values of less than 0.05 were considered to be significant.

A **B**

Fig. 1. Overview of study design(A) and bite force meter(B).

Abbreviations: MVC, maximum voluntary contraction; ATB, anterior teeth bite task; PTB, posterior tooth bite task

Results

Fig. 2 shows the actual bite force values for each force level during ATB and PTB. Actual bite force values were significantly dependent on target force levels during ATB and PTB ($P < 0.001$). Post-hoc tests demonstrated that

actual bite force during 100% MVC was significantly higher than during 20%, 40%, and 60% MVC for each tooth bite task ($P < 0.05$), and that actual bite force during 60% MVC was significantly higher than during 20% MVC for each tooth bite task ($P < 0.05$). Figure 3 shows CV values of actual bite

Fig. 2. Comparison of actual bite force values for each target force level during ATB and PTB.

Abbreviations: ATB, anterior teeth bite task; PTB, posterior tooth bite task

* $P < 0.05$

force level for each jaw motor task. CV values of actual bite force level in each jaw motor task were not significantly dependent on target force level ($P = 0.657$) or tooth bite task ($P = 0.506$).

Fig. 4 shows EMG RMS amplitude for each target force level at LM and RM (A) and LT and RT (B) during ATB and PTB at LM and RM (C) and LT and RT (D) during PTB. EMG RMS amplitude during ATB and PTB were significantly dependent on target force level ($P < 0.01$). In ATB, post-hoc tests demonstrated that EMG RMS amplitude during 100% MVC was significantly higher than during 20%, 40%, and 60% MVC in LM and RM ($P < 0.05$) and EMG RMS amplitude during 100% MVC was significantly higher than during 20%, and 40% MVC in LT and RT ($P < 0.05$). In PTB, post-hoc tests demonstrated that EMG RMS amplitude during 100% MVC was significantly higher than during 20%, 40%, and 60% MVC in LM, RM, LT, and RT ($P < 0.05$).

Fig. 5 shows CV values of EMG RMS amplitude for each target force level at LM and RM (A) and LT and RT (B) during ATB and PTB at LM and RM (C) and LT and RT (D) during PTB. CV values of EMG RMS amplitude at LM and RM were significantly dependent on target force level during PTB ($P < 0.05$). In PTB, CV values of EMG RMS amplitude during 40% MVC at LM and RM were significantly higher than during 20% and 60% MVC ($P < 0.05$).

Fig. 3. Comparison of CV values of actual bite force level for each target force level during ATB and PTB. Abbreviations: CV, coefficient of variation; ATB, anterior teeth bite task; PTB, posterior tooth bite task.

Discussion

This study compared the bite force and masticatory muscle activities between anterior teeth and posterior tooth during first jaw motor performance. Actual force values, EMG RMS amplitude, and CV values of actual bite force were significantly dependent on target force level in ATB and PTB. Although CV values of EMG RMS amplitude in masseter muscles during PTB were significantly dependent on target force level, CV values of EMG RMS amplitude in masseter muscles during PTB and masseter and temporalis muscles during ATB were not.

Our previous studies investigated the effects of repeated tooth bite tasks on the first molars with device or tooth clenching tasks without device on masseter muscle accuracy performance and demonstrated that repeated tooth clenching tasks improve the performance of masseter muscles in terms of accuracy but not MVC (2). On the other hand, some studies demonstrated motor learning in the tooth bite task at anterior teeth (3, 4). These studies suggested that repeated jaw motor tasks lead to motor learning in jaw motor performance, regardless of anterior or posterior teeth. The present study demonstrated that actual force values, EMG RMS amplitude, and CV values of actual bite force did not differ between ATB and PTB during the first jaw motor performance. The present study suggests that the mechanism of control in the jaw motor task was similar between ATB and PTB. However, humans unconsciously perform jaw motor tasks in their daily lives. Our previous study showed that repeated tooth clenching can trigger neuroplastic changes in the central nervous system (7). This finding suggests that if humans perform jaw motor

Fig. 4. Comparison of EMG RMS amplitude for each target force level in masseter muscles during ATB (A), temporalis muscles during ATB (B), masseter muscles during PTB (C), and temporalis muscles during PTB (D).

Abbreviations: EMG, electromyography; RMS, root mean square; ATB, anterior teeth bite task; PTB, posterior tooth bite task; LM, left masseter muscle; RM, right masseter muscle; LT left temporalis muscle; RT, right temporalis muscle.

**P<0.01

*P<0.05

tasks in their daily lives, the central nervous system undergoes neuroplastic changes. Further studies are needed to investigate the effects of oral behavior (e.g., waking or sleep-related bruxism) for the first jaw motor performance during ATB and PTB.

In comparison of the occlusal contact area in individual teeth, the occlusal contact area at the first molar was higher than at the front tooth (8). However, the present study showed that force values, EMG RMS amplitude, and CV values of actual bite force during jaw motor performance was not different between ATB and PTB. On the other

hand, periodontal receptors contribute positive feedback to the jaw-closing muscles during mastication (9). Although a force meter was placed on the right side between the first molars or anterior teeth during jaw motor task in the present study, it suggested that force control of jaw movements was regulated by periodontal receptors, not occlusal receptors.

Interestingly, CV values of EMG RMS amplitude in masseter muscle during PTB were significantly dependent on target force levels, but not the temporalis muscle during PTB, or the masseter muscle and temporalis muscle during

Fig. 5. Comparison of CV values of EMG RMS amplitude for each target force level in masseter muscle during ATB(A), temporalis muscle during ATB(B), masseter muscle during PTB(C), and temporalis muscle during PTB(D).

Abbreviations: CV, coefficient of variation; EMG, electromyography; RMS, root mean square; ATB, anterior teeth bite task; PTB, posterior tooth bite task; LM, left masseter muscle; RM, right masseter muscle; LT, left temporalis muscle; RT, right temporalis muscle. *P<0.05

ATB. However, CV values of actual bite force levels in each jaw motor task were not significantly dependent on target force levels. Although our previous study showed that CVs of RMS EMG amplitude from masticatory muscles were significantly influenced by visual feedback (1), the present study did not apply visual feedback during jaw motor tasks. The present study suggests that the mechanism of force control of jaw movements contributes between masticatory muscle activities and periodontal receptors. To clarify the force control of jaw movements, further studies are needed to investigate the contribution of periodontal receptors and masticatory muscle activity to the force control of jaw

movements.

In clinical settings, several studies have demonstrated the usefulness of contingent electrical stimulation based on EMG activities on a portable device for patients with sleep bruxism (10, 11, 12). To evaluate the number of sleep bruxism events from temporalis EMG activities using this portable device, participants perform 60% MVC tooth clenching without feedback, and the threshold value of sleep bruxism set at 20% MVC. As the present study demonstrates that actual force values and EMG RMS amplitude are significantly dependent on target force levels in ATB and PTB at first performance, our results suggest that 60%

MVC tooth clenching without feedback is reliable when participants use this portable device.

In conclusion, the present study suggests that force control of first jaw motor performance did not differ between anterior teeth and posterior tooth, and a negative correlation was found between target force levels and CVs of actual bite force levels in each jaw motor task. The present study suggests that the mechanism of force control of jaw movements contributes to masticatory muscle activities and periodontal receptors.

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