

ORIGINAL ARTICLE

Influence of changing occlusal support on jaw-closing muscle electromyographic activity in healthy men and women

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Abstract

Objectives. To test whether changes in occlusal support differentially modulate masseter and anterior temporalis muscle electromyographic (EMG) activity during controlled maximal voluntary clenching. **Material and methods.** Forty-seven healthy subjects (32 M and 15 F, 22.9 ± 1.3 years) were recruited. Cotton-rolls were used to modify the occlusal contact relations and were positioned on the right, left, or both sides, and either in the molar or premolar regions, i.e. six different occlusal combinations. Surface EMG activity was recorded bilaterally from the masseter and anterior temporalis area and normalized with respect to maximal voluntary clenching in the intercuspal position. Analysis of variance and the paired *t*-test were used to test the data. **Results.** Normalized EMG activity was influenced by changes in cotton-roll modified occlusal support, and there were differences between muscles ($p < 0.001$). In general, EMG activity decreased in both muscles when occlusal support was moved from the molar to the premolar region. When occlusal support was moved from bilateral to unilateral contacts, EMG activity in the balancing-side anterior temporalis muscle and in bilateral masseter muscles decreased. Unilateral clenching on the molars, but not on the premolars, was associated with lower EMG activity in the balancing-side masseter and always associated with lower EMG activity in the balancing-side anterior temporalis compared to the working side ($p < 0.05$). **Conclusions.** Masseter and anterior temporalis muscles respond differently to changes in occlusal support, which may have implications for stability of the mandible during intense clenching.

Key Words: Dental occlusion, electromyography, jaw-closing muscles, mandibular position, trigeminal neurophysiology

Introduction

Clinical experience and controlled studies support the notion that mandibular stability in the closing position depends on the mechanical support offered by the occlusion. Baba et al. [1] reported that clenching on the 1st premolars on both sides without any molar support causes a larger upward movement of the mandible in the posterior region compared to clenching on the 2nd molars. They also reported that clenching on unilateral occlusal stops causes a larger upward movement on the contralateral side of the mandible. Kozawa et al. [2] found that losing more posterior teeth causes greater displacement of the condyle and a lower level of bite force. This kind of larger upward movement of the mandible and greater displacement of the condyle during clenching

implies instability of the mandible, which is obviously associated with occlusal support. Occlusal stability keeps the muscles fit and enables the masticatory system to meet its functional demands [3]. The masseter muscle generates the highest activity assessed by electromyography (EMG) during isometric contractions in the maximum intercuspal position (ICP). If stability of the mandible is not supported by the occlusion, the jaw-closing muscles will contribute to the stabilization and reduce the magnitude of the EMG activity to avoid damage to the structures involved in the compensatory stabilization [4]. In a recent study, Hosoda et al. [5] suggested that the masseter muscle may even contribute to the entire body stability when an unexpected sway occurs in a standing postural position.

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However, the literature on mandibular stability is often confused with occlusal stability due to unclear definitions [6,7]. Jimenez [4] found that the stabilizing splint, aimed to position the mandible either in the retruded contact position (RCP) or ICP by a precisely designed cusp-fossa contact relationship, increased the EMG activity in the masseter muscle during clenching in both positions. Based on these results, Jimenez suggested that the actual position of the mandible had less influence on the maximal EMG activity than on the stability of occlusal contact [4].

Overall, the EMG activity of jaw-closing muscles in humans has been reported to be influenced by the insertion of bite force transducers [8–10] and occlusal appliances made of hard materials [4,6,7,11–13]. The effect of location [14], number [14–16], height [6,7], and size [15,16] of occlusal contacts, and the direction of biting [16–18], are also associated with the EMG activity. Moreover, factors such as pain and muscle fatigue [19–21] may also exert control on the jaw-closing muscle EMG activity. Furthermore, studies on both humans and animals have demonstrated distinct differences between females and males in terms of muscle pain endurance [20], jaw movement [22,23], muscle fiber composition, twitch forces, and torques [24]. These factors need to be kept in mind when relationships among the jaw-closing muscles, occlusal support, and mandibular stability are being discussed.

Cotton-rolls have been used as a convenient method for altering the occlusion to determine the effects of the number and position of occlusal contact on EMG activity in the jaw-closing muscles during clenching [15]. The good adaptability of the cotton-rolls is assumed to provide an even occlusal support and avoid unbalanced occlusal contacts between pairs of upper and lower teeth and thus to prevent the possible tipping movement of teeth [25]. We therefore decided to use cotton-rolls to modify occlusion and systematically examine the influence of changes in occlusal support on EMG activity in the masseter and anterior temporalis muscles in healthy female and male subjects. The hypothesis was that there would be differential effects of occlusal support changes on the masseter and anterior temporalis muscles reflecting different contributions to maintain mandibular stability during maximal clenching.

Methods

Subjects

Forty-seven healthy subjects (32 M and 15 F; mean age 22.9 ± 1.3 years) who had at least 28 permanent teeth and with no signs or symptoms of any painful temporomandibular disorders [26] were recruited. None of them had ever had orthodontic treatment. All volunteers gave informed consent and the study

was approved by the local ethics committee at the Fourth Military Medical University.

EMG recordings

EMG recordings were made with a commercial EMG device (EM-2; Myotronic Co., Seattle, Wash., USA) and surface electrodes (Myotronic Co., Seattle, Wash., USA) in accordance with previous reports [11,27]. The EMG filters were set at 10 and 1000 Hz. The noise of each EMG channel was carefully minimized by cleaning the skin with alcohol and standardized placement of the electrodes. Disposable surface silver bipolar electrodes (diameter 10 mm; inter-electrode distance was fixed at 20 mm with adhesion tape) with electrode gel were attached to the skin overlying the center of masseter and anterior temporalis areas. For both muscles, the electrodes were placed parallel to the direction of the fibers of the muscle belly, which was observed and palpated during repeated bouts of clenching. A common reference electrode was placed over the 7th cervical vertebral segment.

Each EMG recording lasted 10 s and the root-mean-square (RMS) value of the EMG activity was calculated by a computer. The subjects were allowed to practice prior to the start of the experiment. They were instructed when to start and stop and continuously encouraged to obtain the maximal clenching level. Each EMG recording was repeated at about a 1-min interval to avoid muscle fatigue, and during that interval the cotton-rolls were left in place. The average RMS-EMG of the two repeated recordings was used for the statistical analysis. The interval between any two of the 6 different tasks was 5 min and the total recording time for each subject was around 40 min.

MVC tasks and task order

The reference condition was maximal voluntary clenching (MVC) in the intercuspal position (ICP). Six occlusal conditions were subsequently tested in randomized order. Standardized cotton-rolls (17 mm in diameter) were used to modify the occlusal support and were positioned on the mandibular dentition on the right side, on the left side, or on both sides, and either in the molar region, covering the 1st molar and posterior regions, or in the premolar region, covering the 1st premolar and anterior regions. The long axes of the cotton-rolls were oriented in the buccal-lingual direction (Figure 1). During testing, the cotton-rolls were always intact, but were moistened with saliva during clenching. Care was taken to replace the cotton-rolls if they were penetrated. No occlusal contacts on the balancing side were reported by the subjects after the clenching tasks. The RMS-EMG values from the six cotton-roll modified occlusal contact conditions

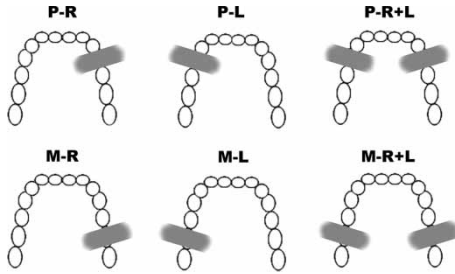


Figure 1. Schematic drawing illustrates the six different occlusal combinations of the cotton-roll modified occlusal support conditions. P = premolar, M = molar, R = right, L = left.

were normalized by the EMG activity obtained during MVC in the ICP and used for further statistical analysis. The reason for using the normalized data for comparison was that the MVC is influenced by many factors and is not always believed to be a suitable reference value for deriving the analytic EMG values. Using the normalized EMG values is to diminish the possible variations within subjects during MVC.

Statistics

The SPSS v. 11.0 package (SPSS Inc., Chicago, Ill., USA) was used to describe and analyze the data. First, the normalized EMG activity between right and left masseter and anterior temporalis muscles was compared with a paired t-test for possible side-to-side differences when they acted as working-side muscles or balancing-side muscles. There were no side-to-side differences between clenching on the left or right side, thus the working-side and balancing-side EMG activity were pooled. Second, paired t-tests were used for comparison of the normalized EMG values in the masseter and anterior temporalis muscles during each of the bilateral clenches, and between bilateral and unilateral clenching with the same occlusal conditions in each muscle. Third, mixed analyses of variance (ANOVA) models were used with muscles (2 levels: masseter and anterior temporalis muscles – within subjects), occlusal support conditions (2 pairs of modified conditions: premolar or molar supported clenching – within subject), sides (2 levels: working or balancing side), and sex (2 levels – between groups). The level of significance was set at $p < 0.05$ for all statistical tests.

Results

The normalized EMG values of the cotton-roll modified occlusal conditions are shown in Figure 2. Overall, there were no significant sex-related effects on the normalized EMG values (ANOVA: $F < 0.29$, $p = 0.588$). However, there were significant effects of the cotton-roll modified occlusal support (ANOVA: $F = 64.30$, $p < 0.001$), different muscles (ANOVA: $F = 21.86$, $p < 0.001$), and working versus

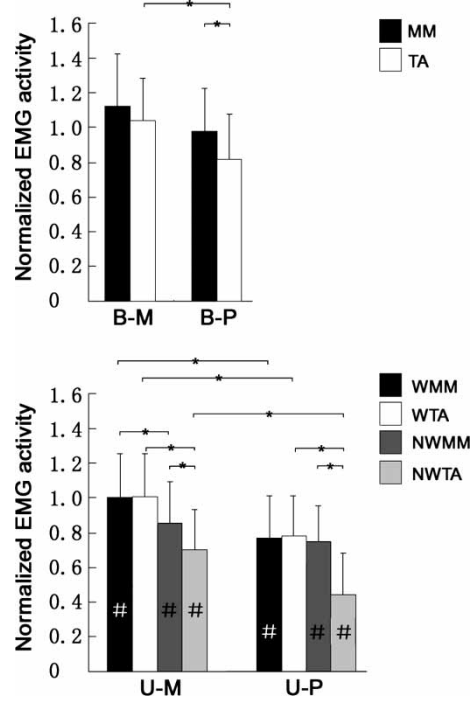


Figure 2. Mean (SD) of the normalized EMG activity ($n = 47$) when subjects clenched maximally at the cotton-roll modified occlusal relations. * indicates significant difference ($p < 0.05$) between the corresponding muscles. # indicates the difference ($p < 0.05$) between the corresponding bilateral clenching and unilateral clenching. This figure shows that the normalized EMG activity is higher on the working side than on the balancing side in both masseter and anterior temporalis muscles during unilateral clenching on molar support, but only in anterior temporalis muscle during unilateral clenching on premolar support. The activity is higher in masseter than in anterior temporalis muscle only on the balancing side but not on working side during unilateral clenching on molar or premolar support. The activity is higher during clenching on molar than on premolar support except balancing side masseter. The activity is higher during clenching on bilateral occlusal support than on unilateral occlusal support except working side anterior temporalis. P = premolar, M = molar, B = bilateral clenching, U = unilateral clenching, MM = masseter, TA = anterior.

balancing side (ANOVA: $F = 64.86$, $p < 0.001$) on the normalized EMG values. There were significant interactions between muscles and balancing versus working sides ($F = 21.78$, $p < 0.001$). The results are described in detail below.

Masseter versus anterior temporalis

In the clenching conditions with bilateral molar support there were no significant differences between the normalized EMG activity in the masseter and anterior temporalis muscles ($p = 0.157$). However, in the conditions with clenching on the premolars, the normalized EMG activity in masseter muscle was higher than in the anterior temporalis muscle ($p = 0.002$).

During unilateral clenching, the normalized EMG activity in the anterior temporalis muscle was always lower than in the masseter muscle on the balancing

side ($p < 0.05$), but not on the working side ($p > 0.05$).

Working-side versus balancing-side

A consistent finding was that clenching in both the molar and premolar conditions was associated with significantly lower normalized EMG activity on the balancing side compared with the working side in the anterior temporalis muscle ($p < 0.05$). However, for normalized EMG activity in the masseter muscle, the balancing-side values were lower than the working-side values in the molar support condition ($p < 0.05$), but not in the premolar support conditions ($p > 0.05$).

Premolar versus molar support

Normalized EMG activity in the conditions with clenching on the premolars was significantly lower than in the conditions with clenching on the molars for both the masseter and anterior temporalis muscles, and was found during both unilateral and bilateral clenching ($p < 0.05$). Two exceptions to this pattern were found for the masseter muscle during clenching on bilateral premolar versus molar support, and for the balancing masseter muscle during clenching on unilateral premolar versus molar support ($p > 0.05$).

Unilateral versus bilateral

Unilateral clenching was consistently associated with significantly lower normalized EMG activity than bilateral clenching on the balancing side for both the masseter and anterior temporalis muscles ($p < 0.05$) and on the working side for the masseter muscle ($p < 0.05$), but not for the anterior temporalis muscle ($p > 0.05$).

Discussion

Our results show that during vertically directed maximal voluntary clenching in healthy men and women the masseter and anterior temporalis muscles respond differently to changes in occlusal support. We observed no sex-related influence on EMG activity. Generally, both bilateral and unilateral premolar support was associated with lower EMG activity in anterior temporalis muscles. Furthermore, similar to results reported by Bilt et al. [28], balancing-side anterior temporalis muscles always have lower EMG activity than those on the working side. However, normalized EMG activity in the masseter muscle was lower during premolar-supported clenching than during molar-supported clenching only on the working side during unilateral-supported clenching. In the bilateral premolar-supported clenching and the balancing side during unilateral premolar-supported clenching, masseter

muscle activity was similar to the level during molar-supported clenching. Moreover, the working-side masseter activity during clenching on unilateral premolar support was similar to that on the balancing side, although it was higher than on the balancing side during clenching on unilateral molar support. Variations in thresholds and density of periodontal mechanoreceptors are unlikely to be the cause of decreased EMG activity in the premolar contact conditions because the feedback effect from periodontal mechanoreceptors can be overridden by maximum voluntary acts [29].

The cotton-rolls were assumed to provide similar occlusal contact relations in the premolar and molar areas and thereby to limit the influence from occlusal morphology. This explains the difference between our present result and that reported by Pröschel & Raum [30], who tested the EMG activity in masseter and anterior temporalis muscles during unilateral clenching on a bite fork and found that the working:balancing ratio amounted to 0.92 in the masseters but to 1.8 in the temporalis [30]. The good adaptability of cotton-roll(s) in the present study is believed to help the working-side masseter to act at a higher level. Thus, by placing the cotton-rolls in different positions in the mandibular dentition, parallel occlusal contact conditions were created and the influence of the occlusion morphology on the EMG activity could be diminished. In this way, the effect of bilateral versus unilateral, and premolar versus molar, support could be systematically examined during MVC.

It was assumed that balanced occlusal support would provide a more stable condition of the mandible during MVC and that the differences in location and extent of local occlusal support would have different effects on this stability. It can then be argued that the cotton-roll-modified occlusion support conditions allowed estimation of the contribution from the masseter and anterior temporalis muscles to the associated mandibular stability. Kozawa et al. have pointed out that posterior occlusal support may be more important than anterior occlusal support for keeping the mandible in balance and that reduced posterior occlusal support may cause displacement of the condyle [2]. In resisting such displacement, the elevator muscles have been found to have a lower degree of contraction [2,31,32]. The present results are in support, because when the mandible was less stabilized in the sagittal plane – it has been pointed out by Baba et al. [1] that clenching on bilateral premolars is less stable than on bilateral molars – the EMG activity in the anterior temporalis muscle decreased and the masseter muscle activity was more pronounced. Whereas, when the mandible was less stabilized in the coronal plane, i.e. during clenching on unilateral compared to bilateral molar support, the EMG activity in bilateral masseter

muscles, as well as in the balancing-side anterior temporalis muscle, decreased and the working side of the two muscles was higher than the balancing side. Furthermore, when the mandible was in a condition with reduced mandibular stability in both coronal and sagittal plane, i.e. during clenching on unilateral premolar support, the working-side masseter muscle responded primarily with a further decrease in EMG activity so that it was no longer higher than on the balancing side. This kind of bilateral balanced EMG activity in the masseter muscle is believed to be advantageous in compensating for instability of the mandible during maximal voluntary clenching. In contrast to the masseter muscle, the working-side anterior temporalis muscle during clenching on unilateral premolar support did not decrease compared to bilateral clenching.

The limitations of the present study need to be mentioned. First, same-sized cotton-rolls may not completely mimic the occlusion support in the molar and premolar areas. Placement of the cotton-rolls between the premolars will stretch the jaw-closing muscles less than between the molars, and there is a possible minor variation in vertical dimension. Thus, the angle of the jaw opening might also be slightly different during the different conditions. Moreover, the cotton-rolls were soft and adaptive, which made it difficult to control the jaw gapes precisely, and the exact jaw relations could be slightly different from test to test. Second, the study was designed to investigate the functional differences of jaw-closing muscles in response to the changes in occlusal support with a likely impact on mandibular stability. Direct measures of mandibular position, e.g. by jaw-tracking devices [33], might therefore add further information and should be employed in future studies. Finally, the influence of variations in craniofacial morphology [18,34,35] or in the internal organization [36] of the masseter and anterior temporalis muscle on the changes in EMG activity during different occlusal support conditions needs further investigation.

In summary, this experimental study in healthy human subjects has demonstrated that the masseter and anterior temporalis muscles respond differently to systematic changes in occlusal support, which may have implications for the stability of the mandible during intense clenching. The normalized EMG activity did not differ between men and women, suggesting a common motor strategy and influence of occlusal support.

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