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Does restriction of mandibular movements during sleep influence jaw-muscle activity?

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ABSTRACT

AIM: To investigate the effect of restriction of mandibular movements during sleep on jaw-muscle activity. **MATERIALS AND METHODS:** Eleven healthy subjects (four men, seven women; mean age 25.9 ± 3.1 years) with self-reports and clinical indications of sleep-bruxism participated in three randomized sessions with three different types of oral appliances: 1) a full-arch maxillary and mandibular appliances which did not allow any mandibular movement, i.e., restrictive oral appliance (ROA), 2) full-arch maxillary and mandibular oral appliances (MMOA) with no restrictions of mandibular movements, and 3) a conventional full-arch flat stabilization appliance, i.e., maxillary oral appliance (MOA). Baseline recordings of jaw-muscle activity during sleep without any oral appliance were performed and followed by one week of nightly use of the oral appliances. After the baseline recording, subjects did three sessions with oral appliance during sleep. During the last night in each session, jaw-muscle activity was recorded and compared to baseline values. A detection threshold of 10 % of maximal voluntary clenching was used to analyze the electromyographic (EMG) activity from both sides of the masseter muscles and in accordance with published criteria (Lavigne et al. 1996).

RESULTS: All subjects completed the experimental protocol. Regarding to the average of left and right sides, jaw-muscle activity expressed as number of EMG episodes per hour sleep was significantly lower during MOA (5.2 ± 1.1 episodes/h) compared to baseline values (6.7 ± 1.2, $P < 0.01$). Furthermore, the number of EMG bursts per hour sleep was significantly lower for ROA (28.3 ± 5.0 bursts/h) and MOA (25.0 ± 6.8) compared to baseline values (40.9 ± 7.7, $P < 0.05$). The number of phasic EMG episodes and bursts (ROA: 1.5 ± 0.4 episodes/h and 14.8 ± 2.8 bursts/h, MMOA: 1.9 ± 0.3 and 17.7 ± 4.0, MOA: 1.5 ± 0.5 and 15.1 ± 4.7) especially decreased for all three types of appliances compared to baseline (3.0± 0.5 and 29.2 ± 5.8, $P < 0.05$). **CONCLUSION:** The results indicated that restriction of mandibular movements with oral appliances may not have major influence on jaw-muscle activity during sleep but rather that the immediate effect of any combination of oral appliances lead to a suppression of EMG bursts per hour of sleep.

INTRODUCTION

Sleep bruxism is defined as a sleep-related movement disorder characterized by grinding and/or clenching of the teeth during sleep and associated with excessive arousal responses [1]. It is often stated that sleep bruxism is associated with jaw-muscle problems such as tenderness, stiffness, and pain; attrition of tooth substance; fractures of dental restorations; osteohypertrophy; myopachynsis; locking of the temporomandibular joint (TMJ); and temporal headaches and cheek-biting [2-4]. The prevalence of self-reported sleep bruxism is 8 % in the normal adult population, approximately 14 % in childhood, and about 3 % in the elderly population with no apparent gender differences [5-8]. The cause of sleep bruxism is still controversial, however, a multifactorial etiology has been widely accepted [3, 9, 10] with a particular emphasis on central nervous system factors including autonomic function [11].

Oral appliances are commonly used to manage sleep bruxism because they are considered as reversible and non-invasive treatments [12]. The main advantage with oral appliances is the protection of tooth substances and perhaps a redistribution of forces to the dentition [13]. However, the efficacy of oral appliances to reduce jaw-muscle activity during sleep remains questionable. It has been reported that oral appliances such as flat stabilization splints inhibit the jaw-muscle activity [14-16]. On the other hand, several studies have shown no change in jaw-muscle activity [17, 18]. Recent studies on mandibular advancement devices for management of snoring and sleep apnea have reported that the devices also have a positive effect on sleep bruxism [19]. In fact, it appears the mandibular advancement devices (MAD) and clonidine have the lowest NNT (Number Needed to Treat) values in order to reduce jaw-muscle activity during sleep [20]. Thus, there are several reasons to reexamine the relations between jaw-muscle activity during sleep and oral appliances and there appears to be a need for further studies on jaw-muscle activity during various types of oral appliances and in particular if restriction of jaw-muscles per the design of the oral appliances could influence the recorded electromyographic (EMG) activity during sleep [21].

The aim of the present study was to compare the jaw-muscle activity during sleep with three different types of oral appliances and in particular if a full-arch maxillary and mandibular appliance which does not allow any jaw movements could decrease EMG activity assessed in accordance with current guidelines.

MATERIALS AND METHODS

Subjects

Four healthy men (26.3 ± 3.2 year old) and seven women (25.9 ± 3.1) participated in this study. All subjects had self-reports of sleep bruxism during the last six months as indicated by s sleep partner [22]. The inclusion criteria were also a full dentition except third molars without any caries or serious periodontal problems. The absence of temporomandibular disorders was ascertained following the Research Diagnostic Criteria for Temporomandibular Disorders [23]. Informed consent was obtained from all subjects and the experimental protocol was conducted in accordance with the Helsinki guidelines and had been approved by a local ethics committee.

Experimental protocol

All subjects participated in a 30-nights protocol (Fig. 1). Jaw-muscle activity was recorded as EMG from both sides of the masseter muscles on the 1st, 2nd, 3rd, 16th, 23rd, and 30th experimental nights (night 1, 2, 3, 16, 23, and 30) in subject's own home. Night

1 was used as an adaptation to the experimental equipment and the average of night 2 and 3 were used to define the baseline activity. After the baseline recordings, subjects did not wear any oral appliances for six further nights (washout: night 4 to 9). From night 10 to 16 (Oral appliance 1), subjects slept with one of the three types of appliances (restricted oral appliance = ROA; maxillary and mandibular oral appliance = MMOA which allowed normal mandibular movements; and maxillary oral appliance = MOA). After one week of nightly use, subjects shifted the next type of oral appliance and slept for another week with that particular appliance (Oral appliance 2: night 17 to 23). During the last week, the subjects wore the last type of appliance (Oral appliance 3: night 24 to 30). On the last night in each of the 3 weeks (night 16, 23, and 30), recording of jaw-muscle activity was repeated in the subject’s home. The order of oral appliances was randomized between each subject. EMG data was off-line analyzed following the criteria described by Lavigne et al. (1996) [24].

Oral appliances

Three types of oral appliances (Fig. 2) were made on a set of maxillo-mandibular study casts (New-Plastone, GC, Tokyo, Japan) which were obtained from each subject by irreversible hydrocolloid impressions. The casts were mounted in centric relation in a mean value articulator. The detailed design of each oral appliance is described below. All adjustments of the appliances were performed with the subjects in a supine position.

Restricted oral appliance (ROA, Fig. 2-A)

This type of oral appliance was used in order to restrict mandibular movements and therefore share some of the same features as a MAD except that the mandible was not attempted to be advanced in the present study. Acrylic resin sheets (Exclusive Disk for Vacuum-Adapter®, Yamahachi Dental MFG. CO., Gamagori, Japan) were pressed on the maxillo-mandibular study casts by a vacuum adapter (Vacuum-Adapter I, Yamahachi Dental MFG. CO., Gamagori, Japan). The acrylic resin sheets were removed from the casts. The sheets were cut and shaped along the dentition. The maxillo-mandibular resin sheets were, then, fitted in the subjects' mouth. The self-curing resin was added to occlusal surface of the appliances, and the subjects bite with upper and lower appliances to fix each other. Then each appliances were fixed each other with a distance of approximately 2 mm between the upper and lower first molars.

Maxillary and mandibular oral appliance (MMOA, Fig. 2-B)

The procedure of these oral appliances was the same as described above, however, the maxillo-mandibular parts remained separated and were not fixed in order to allow free mandibular movements but with a similar increase in vertical bite height as the ROA.

Maxillary oral appliance (MOA, Fig. 2-C)

This type of oral appliance was a conventional flat, full-arch maxillary stabilization splint. The MOA was waxed up with canine guidance (Paraffin Wax, GC, Tokyo, Japan) in an articulator and fabricated according to standard procedures in heat curing resin. The MOA was approximately 2-mm thickness in the first molar region, i.e., the increase in vertical height was similar in all three types of oral appliances.

EMG recordings

Jaw-muscle activity during sleep was recorded from both masseter muscles with the use of a portable EMG device (DR-C2, TEAC, Tokyo, Japan) in the subject's own home. The skin above the masseter muscle was cleaned with absolute alcohol and abrasive gel (Skinpure, NIHON KOHDEN, Tokyo, Japan) and bipolar surface electrodes (Duo-Trode, Myotronics, Washington, USA) were placed on the central part of the masseter muscles parallel to the main direction of the muscle fibers based on the palpation during a maximal contraction [25]. The distance between the EMG electrodes was 1 cm. After the placement of the EMG electrodes, subjects started EMG recording and performed a maximal voluntary clenching (MVC) for five sec and repeated three times. The MVC procedure was also performed in the mornings upon awakening. The subjects were instructed to place the EMG electrodes at the same site in a similar manner. Adequate training was performed to ensure that the subjects were able to reliably mount the EMG electrodes. As an additional help, a custom-made instruction brochure was provided with step-by-step illustration of the procedure. EMG signals were amplified and filtered (0.53 - 250 Hz) by a processor box (DR-C2, TEAC, Tokyo, Japan) and A/D converted with a sample frequency of 500 Hz. The EMG data were stored in a PC card and transferred to a PC for the off-line analysis.

Data analysis

The first and last 30 min of the collected EMG data per night was discarded from the analysis. The EMG activity from the masseter muscle was analyzed with a custom made EMG software (JAWs version 1.441+, Aalborg University, Aalborg, Denmark) [26]. This program applies a similar algorithm for EMG analysis as described by Lavigne et al. (1996) [24]. The threshold of EMG detection was set to 10 % MVC. An EMG burst lasting longer than 0.25 sec but less than 2.0 sec was classified as a phasic burst (P-burst, Fig. 3-A). An EMG burst lasting longer than 2.0 sec was defined as a tonic burst (T-burst Fig. 3-B). In case the interval of EMG bursts was less than 2.0 sec, these bursts were considered to be one episode. The episodes were classified as three types (phasic episode, tonic episode, and mixed episode). A phasic episode (P-episode, Fig. 3-C) consists of more than 3 P-bursts. An episode with a burst lasting longer than 2.0 sec was classified as a tonic episode (T-episode, Fig. 3-B). A mixed episode (M-episode, Fig. 3-D) was a mixed type of P- and T-bursts. The total number of episodes and bursts per hour sleep were calculated for the left and right side masseter muscle and compared between the different experimental sessions.

Statistical analysis

One way analysis of variance with repeated measures (1-way rm ANOVA) was used to compare the total number of episodes and bursts between sessions. Tukey post-hoc tests were used to compensate for multiple comparisons. The level of significance was set to $P < 0.05$.

RESULTS

The total number of episodes or bursts per hour sleep at baseline from the left side (6.5 ± 1.1 episodes/h, 40.5 ± 7.4 bursts/h) and right side masseter muscles (6.8 ± 1.3 episodes/h, 41.3 ± 8.7 bursts/h) did not differ (ANOVA, $F < 0.30$, $P > 0.75$). Therefore, the average of the left and right side muscle activity was used in the subsequent analyses.

Number of episodes per hour sleep

There was a significant difference between the total number of episodes at baseline (6.7 ± 1.2 episodes/h) and after the use of the different oral appliances (ROA: 5.2 ± 1.1, MMOA: 5.0 ± 1.2, MOA: 4.3 ± 1.0, ANOVA, $F = 4.36$, $P = 0.01$, Fig. 4-A). Post-hoc tests showed that the total number of episodes after the MOA was significantly lower than at baseline (Tukey, $P < 0.01$, Fig. 4-A).

In terms of P-episodes per hour sleep, there was a significant decrease (ANOVA, $F = 7.41$, $P < 0.001$) for all three types of appliances compared to baseline values (baseline: 3.0 ± 0.5 episodes/h, ROA: 1.5 ± 0.4, MMOA: 1.9 ± 0.3, and MOA: 1.5 ± 1.0, Tukey, ROA: $P < 0.01$, MMOA: $P < 0.05$, and MOA; $P < 0.01$, Fig. 4-B). However, for the T- and M-episodes, there were no significant differences between baseline and any of the three types of appliances (T-episodes, baseline: 0.7 ± 0.2 episodes/h, ROA: 1.2 ± 0.6, MMOA: 0.6 ± 0.2, and MOA: 0.8 ± 0.2, M-episodes, baseline: 3.0 ± 0.5 episodes/h, ROA: 2.5 ± 0.6, MMOA: 2.6 ± 0.8,and MOA: 1.9 ± 0.5) (ANOVA, $F < 2.47$, $P > 0.05$, Fig. 4-C, D).

Number of bursts per hour sleep

The total number of bursts per hour sleep varied between baseline (40.9 ± 7.7 bursts/h) and the different oral appliances (ROA: 28.3 ± 5.0, MMOA: 28.6 ± 6.6, and MOA: 25.0 ± 6.8, ANOVA: $F = 4.89$, $P = 0.007$, Fig. 5-A). There was a significant decrease for all three types of appliances compared to baseline values (Tukey, $P < 0.05$).

There were significant decreases (ANOVA, $F = 7.10$, $P < 0.001$) for all three types of appliances compared to baseline values (29.2 ± 5.8 bursts/h) for the number of

P-bursts per hour sleep (ROA: 14.8 ± 2.8, MMOA: 17.7 ± 4.0, and MOA: 15.1 ± 4.7, Tukey, $P < 0.05$, Fig. 5-B). The number of T-bursts per hour sleep did not vary between baseline (4.9 ± 1.0 bursts/h) and the treatments (ROA: 5.6 ± 1.5, MMOA: 4.9 ± 1.7, and MOA: 3.4 ± 0.8, ANOVA, $F = 1.91$, $P = 0.15$, Fig. 5-C).

DISCUSSION

The present study has shown that oral appliances can decrease the EMG activity from the jaw-muscles during sleep but not specifically related to a restriction of mandibular movements. An interesting and novel finding was that there appears to be more specific effects of this immediate suppression of jaw-muscle activity on the phasic EMG bursts and episodes.

Traditionally, oral appliances are used to manage sleep bruxism [13]. The features of MAD are similar to the present restriction oral appliance (ROA), and MADs are generally used for the management of snoring and sleep apnoea [27]. Many studies have reported highly effective outcome in the reduction of sleep bruxism but with undesirable side effects [19, 28, 29]. One study compared the effectiveness of a MAD and a flat stabilization splint [28]. A moderate reduction in sleep bruxism was found with the stabilization splint but a large reduction in bruxism activity with the MAD. The authors suggested that because two thirds of the study sample (n = 13) reported pain during the use of the MAD it could be that pain inhibited the jaw muscle activity during sleep. On the other hand, the efficacy of a flat oral appliance and a placebo device (palatal control device) was compared, and there was a statistically significant reduction of the masseter EMG activity immediately after the insertion of appliances, although there was no statistical difference between the two devices [21]. Therefore, the efficacy of oral appliances to reduce jaw-muscle activity during sleep remains questionable. Recently the role of oral appliances is considered to be the protection of tooth substances and perhaps a redistribution of forces to the dentition [13, 30].

In this study, we analyzed the EMG activity during sleep with different types of oral appliances. Overall, we noted no differences between the right and left side masseter muscle activity in response to treatments. There was a significant difference between total episodes per hour sleep at baseline and MOA, but perhaps surprisingly there was not a significant difference between baseline and ROA. This result suggested that the restriction of mandibular movement does not decrease jaw-muscle activity during sleep. The difference between the MAD design and our ROA is primarily that the ROA did not advance the mandible in a forward position. In terms of of the T-episode, T-bursts, and M-episodes, there were not differences between baseline and any types of oral appliances. Therefore, this result suggests that oral appliances may have a specific or predominant effect on P-episodes and bursts.

In this study, there are two concerns to consider. One is the vertical height of oral appliances, and the other is the duration of the study. There is some evidence that the vertical height may be important to consider in terms of the effects on jaw-muscle activity during sleep. The studies that compared a normal oral appliance with a palatal control device did not indicate any major differences in the magnitude of inhibitory effects [16, 21], however, another study tested different thicknesses of a palatal device and noted the largest inhibition of the jaw-muscle activity with the thickest palatal device [31]. In addition some reports have suggested that the change of oral sensory stimulation, for example, due to changes in oral volume and space for the tongue could influence the jaw-muscle activity during sleep [16, 32, 33]. The oral appliances used in this study increased the occlusal vertical dimension, but to a similar extent. Thus, even though the changes in vertical height may have influenced the afferent inputs from muscle spindles and oral proprioceptors, this may not easily explained the observed differences between the three types of oral appliances. The duration of treatment may also be important to consider. In the study by Harada et al. [21], subjects used a flat stabilization appliance or palatal control device for 6 continuous weeks, and the effects on jaw-muscle activity during sleep was assessed after the first day, 2 weeks, 4 weeks, and 6 weeks. Interestingly, inhibitory effects on jaw-muscle activity were only observed immediately after the insertion of the two different types of appliances with no long-lasting effects. This finding may be in line with the clinical observation that oral appliances do get worn and therefore may not interact with the central regulation of jaw-muscle activity, i.e., sleep bruxism is primarily determined and influenced by central nervous system factors [34]. On balance, there are a few reports employed Randomized Controlled Trial/ Open-Label Study that a flat stabilization appliance and a palatal control device can decrease jaw-muscle activity during sleep for several weeks after the administration of the devices [14, 16, 21]. A final caveat of the present study should be discussed. The subjects had used the oral appliances for 6 nights before the EMG recordings, and the sequence was randomized. Thus, the duration of the treatment phases was short and there were no wash-out phases between the different sessions. However, the observed inhibitory effects are unlikely to be due to mere time effects because of the randomization procedure. Further studies will be needed to test the long-term effects of oral appliances, perhaps with the use of single channel ambulatory EMG devices.

Conclusions

This study has demonstrated that restriction of mandibular movement does not play a major role for the short-term inhibitory effects on jaw-muscle activity during sleep. An interesting finding was that there appears to be more specific effects of this immediate suppression of jaw-muscle activity on the phasic EMG bursts and episodes.

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Figure legends

Fig. 1. Schematic presentation of experimental design. Night 1 was used as an adaptation to the experimental equipment. The average of night 2 and 3 were used to define the baseline activity. Night 1, 2, 3, 16, 23, and 30 were experimental nights to record EMG from the masseter muscles.

Fig. 2. Design of oral appliances. A: Restriction oral appliance (ROA). Maxilla-mandibular resin sheets were fixed to each other and did not allow any movements. B: Mandiblar-maxillary oral appliance (MMOA). Subjects wore both a maxilla resin sheet and a mandibular resin sheet. There were no restrictions of jaw movements. C: Maxillary oral appliance (MOA). This type of oral appliance was a conventional flat, full-arch maxillary stabilization splint.

Fig. 3. Typical types of electromyographic (EMG) activity from the masseter muscles. P = phasic, T = tonic, M = mixed. Definitions according to Lavigne et al. (1996) [24], and original source of this figure is Ph.D. Thesis by Arima [35].

Fig. 4. Number of episodes per hour sleep. Mean and SD (n = 11). A. Total number of episodes at baseline (baseline) and after the three different types of oral appliances. Graphs B, C and D details the findings for phasic (P), tonic (T) and mixed (M) episodes. * indicate significant different from baseline (Tukey, $P < 0.05$).

Fig. 5. Number of bursts per hour sleep. Mean and SD (n = 11). A. Total number of bursts at baseline and after the three different types of oral appliances. Graphs B, C, and D detail the findings for phasic (P) and tonic (T) bursts. * indicate significant different from baseline (Tukey, $P < 0.05$).