Reduction of Sleep Bruxism Using a Mandibular Advancement Device: An Experimental Controlled Study

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Purpose: The objective of this experimental study was to compare the effect on sleep bruxism and tooth-grinding activity of a double-arch temporary custom-fit mandibular advancement device (MAD) and a single maxillary occlusal splint (MOS). ***Materials and Methods:*** Thirteen intense and frequent bruxors participated in this short-term randomized crossover controlled study. All polygraphic recordings and analyses were made in a sleep laboratory. The MOS was used as the active control condition and the MAD was used as the experimental treatment condition. Designed to temporarily manage snoring and sleep apnea, the MAD was used in 3 different configurations: *(1)* without the retention pin between the arches (full freedom of movement), *(2)* with the retention pin in a slightly advanced position (< 40%), and *(3)* with the retention pin in a more advanced position (> 75%) of the lower arch. Sleep variables, bruxism-related motor activity, and subjective reports (pain, comfort, oral salivation, and quality of sleep) were analyzed with analysis of variance and the Friedman test. ***Results:*** A significant reduction in the number of sleep bruxism episodes per hour (decrease of 42%, $P < .001$) was observed with the MOS. Compared to the MOS, active MADs (with advancement) also revealed a significant reduction in sleep bruxism motor activity. However, 8 of 13 patients reported pain (localized on mandibular gums and/or anterior teeth) with active MADs. ***Conclusions:*** Short-term use of a temporary custom-fit MAD is associated with a remarkable reduction in sleep bruxism motor activity. To a smaller extent, the MOS also reduces sleep bruxism. However, the exact mechanism supporting this reduction remains to be explained. Hypotheses are oriented toward the following: dimension and configuration of the appliance, presence of pain, reduced freedom of movement, or change in the upper airway patency. *Int J Prosthodont 2006;19:549–556.*

Sleep bruxism (SB) is defined as a stereotyped movement, characterized by grinding or clenching of the teeth, occurring in the subject's otherwise normal sleep.[1] Recent evidence suggests that SB occurs following a specific sequence of physiologic events related to sleep microarousals: *(1)* a transient brain and heart activation precedes *(2)* a rise in the activity of the jaw opener and *(3)* of the jaw closer muscles before *(4)* tooth grinding.[2–4] Although microarousals are observed approximately 10 to 14 times per hour of sleep in normal subjects and SB patients,[5] rhythmic masticatory muscle activity (RMMA) is 3 times more frequent and electromyogram (EMG) levels are 40% higher in SB subjects.[6,7] These observations suggest that SB is an exaggerated expression of a normal physiologic activity during sleep.[3,4,8]

Among the most popular management strategies used to prevent the consequences of SB and tooth grinding is the use of an occlusal splint. One rationale behind recommending these oral devices is to protect the tooth against damage (eg, wear, cracking, or fracture). In some cases, it can also help to reduce concomitant orofacial pain.[9,10] Moreover, a recent short-

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term randomized controlled study reported that SB motor activity index (episodes per hour of sleep) can be significantly reduced using a maxillary occlusal splint (MOS).[7] Similar results have been reported by others,[11–15] although contrary findings have also been published.[16–19] The exact mechanism behind SB reduction with the use of an occlusal splint still remains controversial, because of the studies' lack of standardization, short duration, and the difference in their outcome measurement.

During sleep, airway patency is known to be compromised as a result of the posterior displacement of the tongue and the soft tissues.[20] Since jaw opener muscles are activated before the onset of SB/tooth-grinding episodes,[6] it has been hypothesized that SB-RMMA may contribute to re-establishing airway patency during sleep.[8] However, no direct evidence supports this hypothesis. The objective of the present study was to assess the influence of a temporary custom-fit mandibular advancement device (MAD) used to manage sleep apnea and snoring on SB/tooth-grinding activity and respiratory and sleep variables.

Materials and Methods

Population and SB/Tooth Grinding Diagnosis

Patients were recruited via advertisements posted at various universities and colleges in Montreal and letters to practitioners' offices. A total of 101 subjects with a history of frequent SB/tooth grinding responded and were interviewed via telephone. According to the results of this interview, 73 subjects were selected for a clinical examination. At this point, the main inclusion criterion was a tooth-grinding sound reported by a sleep partner or a family member occurring at least 3 times a week over the previous 6 months. The presence of occlusal tooth wear and masticatory muscle hypertrophy (temporalis, masseter) upon voluntary clenching were also considered.[1,21] Subjects presenting medical disorders (eg, psychiatric, physiologic, neurologic), reporting pain, or taking drugs, alcohol, or medication on a regular basis were excluded. Other exclusion criteria included the following: absence of 2 posterior teeth (third molars not considered) or more, use of a dental prosthesis, gross dentoskeletal malocclusion, or previous treatment with any type of oral appliance over the past 6 months.

Forty subjects corresponding to these criteria spent 2 nights in a sleep laboratory to confirm the diagnosis of intense and frequent SB. The first night was used for habituation to the sleep-recording environment and was therefore excluded from the statistical analysis. The second night (baseline) was used for SB diagnosis and to rule out other sleep disorders such as apnea ($>$ 5 events per hour of sleep), periodic limb movement ($>$ 10 events per hour of sleep), and epileptiform brain activity. Polysomnographic criteria for intense SB diagnosis were based on the following research criteria: more than 4 SB episodes per hour and more than 25 SB bursts per hour.[22]

From the initial population, 14 young adults (9 women and 5 men, mean age 24.6 $\pm$ 1.0 years, range 19 to 31 years) fulfilled all the criteria (from the telephone interview to the polysomnographic recording) and were selected to participate in the crossover randomized controlled study. All participants were able to understand and sign an informed consent form approved by the research ethics board at the Hôpital du Sacré-Coeur de Montréal. Financial compensation was given to all subjects for the inconvenience related to their participation. All subjects agreed to spend at least 6 consecutive nights in a sleep research laboratory and no dropouts occurred. However, 1 subject was excluded from the statistical analysis because he was unable to wear one of the appliances. The final statistical sample of subjects was reduced to 13.

Polygraphic Recordings

Polygraphic recordings were made in a sound-attenuated and temperature-controlled room from approximately 10:30 PM to 7:30 AM or until the subject awoke. Patients were asked to avoid caffeine for at least 1 day before the recordings. These recordings were used to confirm SB/tooth grinding, but also to rule out other sleep disorders such as insomnia, PLM, apnea, or other respiratory disturbances.

Polygraphic recordings and analysis were made using surface electrodes according to the standard technical protocol used in previous SB studies at the same laboratory.[4,7,22] The following signals were recorded: electroencephalograms (EEGs; C_3A_2, O_2A_1), bilateral electro-oculograms (EOGs), electrocardiogram (ECG), and EMGs (from bilateral temporalis, masseter, anterior tibialis, and unilateral chin/suprahyoid muscles). The reference point was on the earlobe and the middle of the forehead. Video recording, focused on head and neck, was carried out in parallel with audio signals to distinguish SB from nonspecific orofacial activities.[23,24] Chest movements and respiratory parameters were measured using an abdominal belt, a thermistance sensor placed beneath the nostrils to assess airflow, and a saturometer for the oxymetry (SaO_2). The number of swallowing events per hour was estimated using a piezoelectric sensor placed over the thyroid, along with the videotape.[25]

The physiologic sleep variables were computed using commercial software (Harmonie, Stellate) at an acquisition rate of 256 Hz, later transformed at 128 Hz.

Sleep stages were scored according to criteria proposed by Rechtschaffen and Kales[26] and quantitative assessment of the following variables was carried out: sleep efficiency, duration, microarousals, awakenings, SB episodes per hour (bruxism index), and the number of orofacial movements. The bruxism time index, which is defined as the percentage of the total sleep time spent bruxing,[19] was also assessed. For each SB burst, the duration (sum and mean), amplitude, and interval between each event were measured. Subjective self-reports of sleep quality, pain, comfort, oral salivation, and appliance preference were also collected. One technician scored all the data, blind to the treatment assignation from nights 3 to 6.

Experimental Sequence

This crossover study evaluated 2 oral devices: a "classic" hard acrylic resin (Lucitone 199, Dentsply) U-shaped MOS (Fig 1) and a double-arch temporary custom-fit MAD (The Silencer Custom II, Silencer Products) (Fig 2). The MAD was used as the active treatment in 3 different configurations, as shown below.

Dental impressions were made with irreversible hydrocolloid, and the working casts were poured with artificial stone (type III). A facebow was used to mount the models on a semiadjustable articulator. The centric relation was registered with a rigid blue-wax

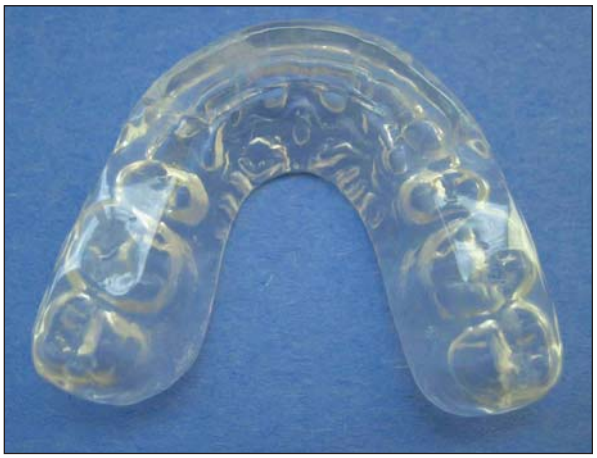
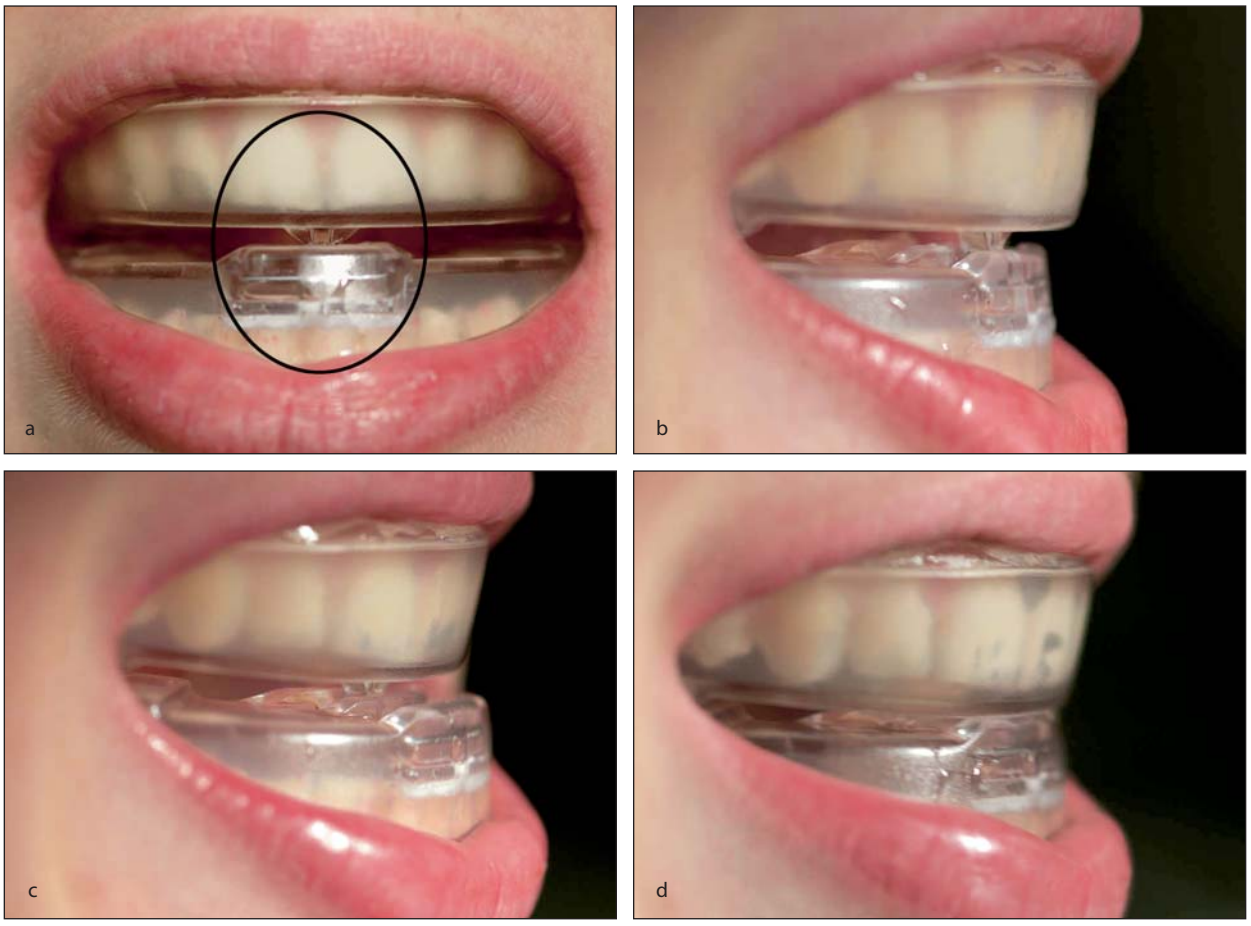


Fig 1 The MOS.



Figs 2a to 2d The MAD: **(a)** the vertical retention pin, **(b)** MAD min, **(c)** MAD max, **(d)** MAD free.

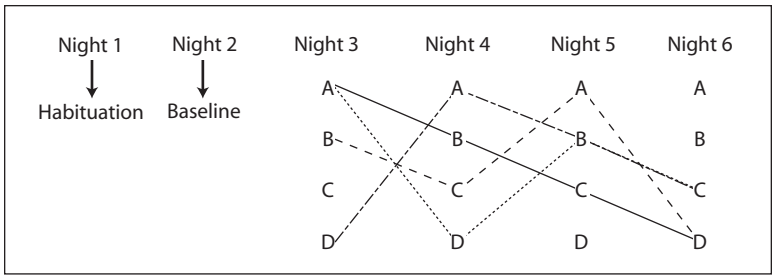


Fig 3 The study design. A = MOS; B = MAD min, C = MAD max; D = MAD free.

waffle (Delar Bite Wafers, Great Lakes Orthodontics). All MOSs were made 2.5 mm thick in the first molar region by the same laboratory technician and were adjusted by a single operator.

Once received, each MOS was adjusted to fit on the teeth without any discomfort. Centric occlusion contacts, corresponding to the contact between the lower buccal cusps and the flat occlusal table of the splint, were adjusted and preserved. Occlusal contacts other than the canines in lateral excursion and the incisors in protrusion movements were eliminated, and modifications were made with a double-thickness 17 µm articulation paper (AccuFilm II, Parkell), an acrylic resin bur, and a handpiece.

The MAD is a thermoplastic, heat-molded, double-arch oral device that can be easily fitted at chairside in a single appointment. It was created to serve as an inexpensive short-term therapy in the temporary management of snoring and apnea. The upper part is provided with a fixed vertical retention pin, while the lower part has 2 slots (accommodating 2 different positions) (see Fig 2). In the present study, 2 upper devices were made for each patient: one with the vertical retention pin and the other with the vertical retention pin cut off. Removing the vertical retention pin gave the patients full freedom in their mandibular movements while sleeping. When appropriate, the George Gauge (Great Lakes Orthodontics) was used to appraise the amount of advancement with the MAD.

The same operator instructed each patient concerning the use of each device. To prevent bias, subjects were told that the MAD offers tooth protection just like the MOS. They were also told that one of the study's goals was to compare the efficacy and comfort of both devices. This point was reinforced with questionnaires assessing sleep quality, comfort, preference, and efficacy. The patients completed the questionnaires after each night they spent at the sleep laboratory with an appliance.

Study Design

The study design was a short-term randomized crossover controlled experimental study (Fig 3). The 4 devices to be worn were: *(1)* MOS, *(2)* MAD with the vertical retention pin in the minimum advancement position (MAD min), *(3)* MAD with the vertical retention pin in the maximum advancement position (MAD max), and finally *(4)* MAD without the vertical retention pin (MAD free) (see Fig 2). Because of budget constraints, there were no washout periods, and the EMG levels were not reassessed during the periods in between appliances.

The sequence of the devices to be worn was randomly assigned using a computer and then modified, if needed, to have balanced blocks (Fig 3). For example, modification was made if the computer selected the MAD max first. Because of its forced position (advancement $>$ 75% of maximum protrusion), it was decided that patients should sleep only 1 night with MAD max, without any habituation, and that it should always follow the MAD min. If morning orofacial pain or stiffness was felt in the first 2 days following the use of MAD max, 2 caplets of pain reliever/muscle relaxant containing methocarbamol 400 mg and acetaminophen 500 mg (Robaxacet, Wyeth Health Care) were offered to the patients. Only 3 patients used the medication and none was taken 5 days prior to polygraphic recordings.

The MOS was worn for 2 weeks, before recording, for habituation. The first MAD to arrive in the sequence (MAD min or MAD free) was also worn for 2 weeks, whereas the second MAD was worn for 1 week, with the assumption that the subject was already used to this kind of appliance. During the period of habituation, several phone calls were made on an irregular basis to ensure compliance. Subjects were told to contact one of the group members if they had any questions or problems. At the end of the sequence, all MADs were returned to the operator and an MOS was given to the patient as further compensation for their participation.

Statistical Analysis

Repeated measures analysis of variance (ANOVA) was used to evaluate the treatment effect. The baseline night was compared to the MOS and then to each MAD using paired comparison. Friedman 2-way ANOVA followed by Wilcoxon signed ranks tests for paired comparisons were used when the data distribution was not normal.

Table 1 Sleep Variables Data

Sleep variables	Baseline	MOS	MAD free	MAD min	MAD max
Sleep latency	7.8 ± 1.6	5.8 ± 1.2	7.9 ± 1.6	8.8 ± 1.6	9.2 ± 2.0
Total sleep time	458.7 ± 8.3	464.4 ± 9.2	460.8 ± 8.8	455.4 ± 7.2	437.3 ± 7.9
Sleep efficiency (%)	95.5 ± 0.6	96.7 ± 0.7	96.4 ± 0.6	96.0 ± 0.6	95.7 ± 0.8
Stage 2 (%)	66.6 ± 2.0	65.2 ± 2.3	64.7 ± 2.0	64.7 ± 1.6	63.1 ± 2.0
REM (%)	21.2 ± 1.2	22.0 ± 1.0	21.8 ± 1.0	19.7 ± 0.9	21.6 ± 0.8
Awakenings	29.0 ± 3.0	21.1 ± 3.0	25.3 ± 3.7	27.0 ± 3.6	25.1 ± 3.5
Microarousals (per hour)	6.7 ± 0.8	6.4 ± 0.7	7.4 ± 1.3	6.2 ± 0.6	6.9 ± 0.6
Apnea-hypopnea (per hour)	0.5 ± 0.1	0.8 ± 0.2	1.2 ± 0.5	0.8 ± 0.2	1.0 ± 0.3

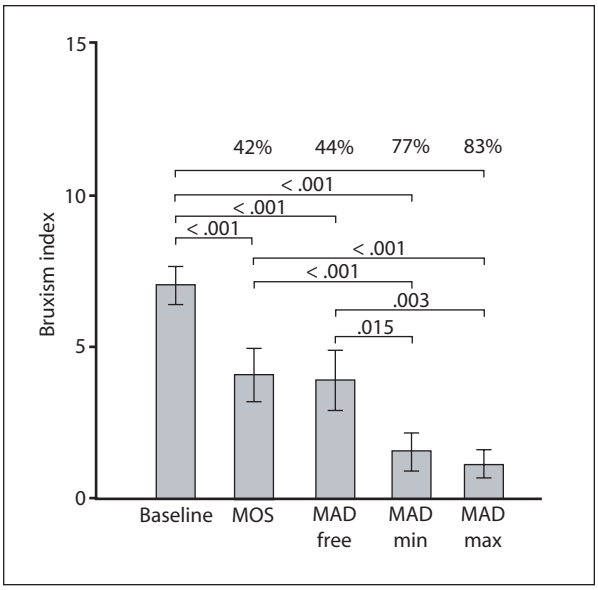


Fig 4 Results for all devices regarding the bruxism index.

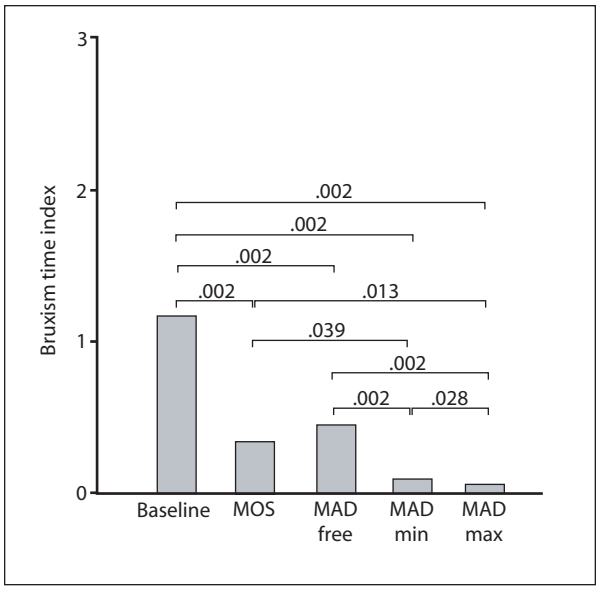


Fig 5 Results for all devices regarding the bruxism time index.

Results

Compared to baseline nights, most of the sleep variables (sleep latency, efficiency, incidence of microarousals, awakenings) did not differ with the use of any of the oral devices (Table 1). The respiratory variables (apnea and hypopnea) remained well below the pathologic range (5 to 15 per hour of sleep)[27] whether or not an appliance was worn (Table 1).

The mean bruxism index (number of episodes per hour) was significantly reduced ($P < .001$) with the MAD min and the MAD max compared to baseline (Fig 4). A 42% reduction was noted with the MOS, 44% with the MAD free, 77% with the MAD min, and 83% with the MAD max. The bruxism index values reached with MAD min (1.6 ± 0.6) and MAD max (1.2 ± 0.4) were far below the research cutoff criteria previously published.[22] The percentage of time spent bruxing (bruxism time index) was also significantly lower with all the oral appliances compared to baseline ($P < .002$) (Fig 5). Finally, compared to baseline, the total number of orofacial movements was significantly lower with all oral devices except the MAD free ($P < .03$) (Fig 6)

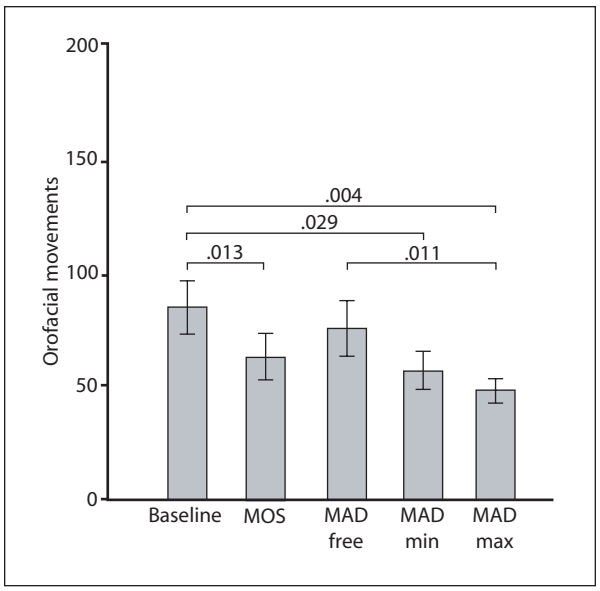


Fig 6 Results for all devices regarding orofacial movements.

Each morning following a night spent sleeping in the laboratory with an oral device, subjects filled out a questionnaire about their feelings and appreciation of the device. Pain was reported by 8 of 13 subjects (score 3 or more on a 0 to 5 scale) with both the MAD min and the MAD max. On a visual analogue scale (VAS) from 0 to 100, the median reported level of comfort was 79 for the MOS, 41 for the MAD free, 15 for the MAD min, and 12 for the MAD max. Oral dryness (score 3 or more on a 0 to 5 scale) was a complaint in 7 of 13 subjects with the MAD min, and this was significantly greater than baseline nights (2 of 13, $P = .03$) and the MOS (1 of 13, $P = .03$). At the end of the study, subjects were asked which appliance they preferred: 12 chose the MOS and 1 chose the MAD free. Interestingly, the MOS was also rated as the most efficient by 10 subjects.

Discussion

To the authors' knowledge, this is the first experimental controlled polygraphic study to compare a MAD with an MOS in regard to SB motor activity. This study also gives further support for the short-term use (2 weeks) of an MOS to reduce SB motor activity by 40%.[7] Moreover, it suggests that active MADs (min and max) are able to further reduce the number and magnitude of SB episodes. Sleep variables showed only marginal changes for both appliances in every configuration. Throughout the study, respiratory disturbances (apnea and hypopnea) remained far below the pathologic levels reported in the literature (5 to 15 episodes per hour of sleep).[27]

The interpretation of these results requires caution, because this study does have several limitations.

First, the sample size was limited, although it was sufficient enough to find significant differences in the main outcome, which was SB oromotor activity.

Second, subjects in the study were young and presented intense and frequent SB/tooth grinding without any pain or temporomandibular disorders. This may not represent the general SB population, but at least allowed a certain control on confounding variables in data interpretation.

Third, a disappointment bias toward the MADs was observed, because they were cumbersome, uncomfortable, and unesthetic compared to the MOS. It can be assumed that even if the MADs performed well in reducing SB occurrence and protecting the teeth, those negative elements may dissuade the patients from wearing this type of appliance on a long-term basis.[28] The fact that most of the patients still preferred the occlusal splint at the end of the study was therefore not unexpected. In addition, 8 of 13 subjects reported pain, mainly to the mandibular teeth and gums, with MAD min and the MAD max. It may be possible that pain contributed to the reduced oromotor activity related to SB. As previously reported in the literature, it seems that pain interferes with the sequence of SB genesis, and, as a result, can reduce the number of episodes per hour of sleep by up to 40%.[29,30] Certain studies have also reported some oro-dento-skeletal modifications with the use of a MAD.[28,31–34] Although the importance of those side effects is questionable, it should be considered when using this device as a long-term management therapy. On the other hand, subjects were very motivated to participate in the study, because once it was completed, they were given an MOS to protect their teeth against damage and attenuate the grinding sound. The majority of patients were already familiar the MOS through their dental practitioner, which may have influenced their opinion toward this appliance from the very beginning of the study, although the persistence of this motivation during sleep is very doubtful.

Fourth, the use of a mandibular occlusal splint may have given different results. This issue is currently under investigation in a separate study by the same authors.

Fifth, EMG levels were not periodically reassessed and there were no washout periods between the appliances to control the SB activity level. Washout periods would have excluded possible carry-over benefits. However, since a minimum of 7 days was left between treatment arms, it was expected that such an effect would be minimal. Nevertheless, knowing that SB can itself fluctuate from night to night,[35] one can argue that this variability may have modified the values of the oromotor outcomes. However, this issue may not be valid, considering that the study used a crossover design with quantitative variables for statistical analysis.

Finally, this study occurred over a short-term period, which limits the extrapolation of the results to a longer term. Nevertheless, previous studies have suggested that, in some cases, a reduction in SB oromotor activity can persist up to 6 months.[13]

Another interesting finding of this study is that the presence of an oral device did not seem to influence sleep efficiency or the number of microarousals or awakenings. These variables remained well within the normal limits.[5,6,36] Another noteworthy element is that 1 patient showed a clear exacerbation of SB/tooth grinding activity with the appliances. This phenomenon was anticipated, since it has occurred in previous studies.[7,19] Clinicians should always remain alert to the signs and symptoms reported by the patient when using an oral device for the management of SB.

In the authors' opinion, the occlusal splint still remains the oral device of choice, since it is reversible, protects the teeth against damage, and more importantly, is well tolerated by the patient. The study's hypotheses to explain the differences observed between

the MADs and MOSs were oriented toward the following: limitation of movement with the active MADs, dimensions and configuration of the appliances, pain/discomfort, and change in the airway patency.

Conclusions

This short-term controlled study showed the following results:

1. As previously published, the short-term use of an MOS can reduce the frequency of SB-related events by 42%.[7]
2. The use of a double-arch device (MAD free) produces a similar pattern of reduction (44%).
3. An active MAD (min and max) can nearly double the amount of reduction (77% and 83%, respectively).

The limitations inherent in the study, as previously described, should be considered in the interpretation and extrapolation of the results. Since the relation between respiratory disturbances and SB genesis remains to be elucidated, future studies should, in part, be oriented toward a smaller and less cumbersome MAD to exclude the influence of gum and tooth pain on SB activity. In this context, the effect of a mandibular occlusal splint should also be investigated.

Acknowledgments

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Literature Abstract

Influence of cavity preparation design on fracture resistance of posterior leucite-reinforced ceramic restorations

This study aimed to evaluate the fracture resistance of leucite-reinforced ceramic restorations placed on molars with various cavity preparation designs. Ninety sound molars were divided into 9 groups (n = 10): *(1)* intact teeth, *(2)* conservative inlay, *(3)* extensive inlay, *(4)* conservative onlay with mesio-buccal cusp coverage, *(5)* extensive onlay with mesio-buccal cusp coverage, *(6)* conservative onlay with buccal cusp coverage, *(7)* extensive onlay with buccal cusp coverage, *(8)* conservative onlay with total cusp coverage, *(9)* extensive onlay with total cusp coverage. The prepared teeth were restored with a leucite-reinforced ceramic (Cergogold, Cergo). The ceramic restorations were etched with 10% hydrofluoric acid and treated with silane. The preparations were etched using 37% phosphoric acid followed by 2 coats of adhesive. The restorations were luted in RelyX ARC (3M ESPE) and polymerized with a halogen light. The fracture resistance was measured under compressive load in a universal testing machine. The collected data were analyzed with 1-way and 2-way analysis of variance (ANOVA), followed by the Tukey test. Modes of fracture were also recorded. The result showed that: *(1)* intact teeth had the highest fracture resistance values, *(2)* two-way ANOVA showed a significant difference for the preparation design, *(3)* modes of failure all tended to involve the restorations alone. The studied cavity preparation design did not improve their resistance to fracture under load. Cuspal coverage did not increase fracture resistance in this study.

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