Effects of Occlusal Stabilization Splints on Obstructive Sleep Apnea: A Randomized Controlled Trial

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Aims: *To assess the influence of occlusal stabilization splints on sleep-related respiratory variables in obstructive sleep apnea (OSA) patients.* ***Methods:*** *Ten OSA patients (47.3 ± 11.7 years of age) received a stabilization splint in the maxilla. All patients underwent three polysomnographic recordings with their splint in situ, and three recordings without their splint in situ, using a randomized crossover design.* ***Results:*** *Repeated-measures ANOVAs did not yield statistically significant differences in the Apnea-Hypopnea Index (AHI) or in the Epworth Sleepiness Scale (ESS), neither between the three nights without the stabilization splint (AHI: F = 2.757,* P = *.090; ESS: F = 0.153,* P = *.860) nor between the nights with the splint in situ (AHI: F = 0.815,* P = *.458; ESS: F = 0.231,* P =. *796). However, independent ANOVAs revealed that the mean AHI of the three nights with the stabilization splint in situ (17.4 ± 7.0 events/hour) was significantly higher than that of the nights without the splint in situ (15.9 ± 6.4 events/hour) (F = 7.203,* P = *.025). The mean increase in AHI with the splint in situ was 1.4 ± 1.7 (95% confidence interval = –1.9–4.7). No difference in ESS was found when both conditions were compared (F = 1.000,* P = *.343).* ***Conclusion:*** *The use of an occlusal stabilization splint is associated with a risk of aggravation of OSA; however, the effect size was small, which reduces the clinical relevance of the study.* J OROFAC PAIN 2013;27: 199–205. doi: 10.11607/jop.967

Key words: crossover design, obstructive sleep apnea, occlusal stabilization splint, randomized controlled trial, vertical dimension

In dentistry, occlusal stabilization splints (ie, hard acrylic resin dental appliances that cover the occlusal surfaces of the maxillary dentition) are commonly used in the management of temporomandibular disorders (a number of clinical problems that involve the masticatory muscles, the temporomandibular joint, and the associated structures)[1] and of sleep bruxism (an oral parafunction characterized by grinding or clenching of the teeth during sleep).[2] They are also used in dental rehabilitation procedures for patients with occlusal tooth wear and to protect dental restorations. The possibility that a stabilization splint alters airway patency during sleep in patients with obstructive sleep apnea (OSA; a condition characterized by repetitive complete or partial obstruction of the upper airway during sleep)[3] has been investigated in two previous pilot studies.[4,5] One study found that the use of stabilization splints in OSA patients may be associated with a risk of aggravating these patients' respiratory disturbance. In the other study, a mandibular advancement device, which is a common treatment option for mild and moderate OSA,[6] was inserted in the 0% protrusion position (ie, without protruding the mandible), thereby only raising the bite

of the participating OSA patients.[5] In line with the finding of Gagnon et al,[4] the outcome of that study suggested that a bite rise without a protrusive component may be associated with a risk of aggravation of OSA for some but not for all OSA patients.

So far, however, no well-controlled prospective clinical trial has been performed on this topic, thus rendering the suggested association between stabilization splints and aggravation of OSA as inconclusive. The aim of the present study, therefore, was to assess the influence of occlusal stabilization splints on sleep-related respiratory variables in OSA patients. A crossover, randomized, controlled trial design was employed. The hypothesis was that insertion of a stabilization splint, resulting in an increase of the vertical dimension of occlusion, rotation of the mandible, and reduction of the tongue space would yield a significant worsening of the OSA condition.

Materials and Methods

Settings and Participants

Potential participants for the study were selected from among those being referred to the Center for Sleep-Wake Disorders of the Slotervaart Medical Center in Amsterdam by their family physician because of a possible OSA. All potential participants underwent a thorough medical examination, including a full-night polysomnographic (PSG) recording, using Siesta hardware and ProFusion software (Compumedics). A multidisciplinary OSA team—consisting of neurologists; ear, nose, and throat specialists; pulmonologists; dentists; psychologists; and technicians especially trained in sleep medicine—discussed all PSG recordings. All consecutive and eligible OSA patients for whom a mandibular advancement device was indicated were invited to participate in the study, provided that they also fulfilled the other inclusion and exclusion criteria (see below).

OSA was quantified and classified using the Apnea-Hypopnea Index (AHI),[3] which was used as this study's primary outcome measure. According to the American Academy of Sleep Medicine Task Force,[3] an apnea is defined as a cessation of airflow for at least 10 seconds. A hypopnea is defined as a decrease in nasal-oral airflow of more than 50% for at least 10 seconds, or a substantial decrease of less than 50% in nasal-oral airflow if associated with an arousal and/or an oxygen desaturation of greater than 3%. The AHI is the number of apneas and hypopneas per hour of sleep. Based on the report of the American Academy of Sleep Medicine Task Force,[3] an AHI of at least 5 events/hour and the presence of excessive daytime sleepiness (measured objectively or subjectively), which is not explained by other factors, are commonly used for an OSA diagnosis. When excessive daytime sleepiness is absent, at least two symptoms, eg, recurrent complaints of unrefreshing sleep and daytime fatigue, should be present.[3]

To be included in this study, participants had to be at least 18 years of age, and their AHI should have a value between 5 and 30 events/hour of sleep,[7] combined with an Epworth Sleepiness Scale (ESS) score of 6 to 10 (higher values were excluded for ethical reasons)[8] or with at least two of the symptoms suggested by the American Academy of Sleep Medicine Task Force[3] (see above). Further, the participants had to have adequate retention possibilities in their dentition for an occlusal stabilization splint (ie, not missing more than two posterior teeth and not wearing a removable dental prosthesis), which was determined during a thorough dental examination at the Department of Oral Kinesiology of the Academic Centre for Dentistry Amsterdam (ACTA). Exclusion criteria were medicine usage that influences sleep (eg, selective serotonin reuptake inhibitors, benzodiazepines), a body mass index (BMI) of more than 40, and/or sleep bruxism (ie, diagnosed by a PSG recording following the criteria of Lavigne et al[9]). Patients with temporomandibular disorders (diagnosis based on a functional examination of the masticatory system),[10] an unhealthy periodontium (ie, periodontal diseases), and/or dental pain (eg, chronic pulpitis) were excluded as well.

Following the above-outlined selection procedure, a total 16 OSA patients were asked to participate in the present study. Six of them (3 men and 3 women) declined participation because of time constraints. Thus, a total of 10 mild/moderate OSA patients with an AHI between 5 and 30 events/hour participated in the study. There were 3 men and 7 women, with a mean (± SD, range) age of 47.3 (± 11.7, 23 to 62) years.

The scientific and ethical aspects of the protocol were reviewed and approved by the Medical Ethics Committee of the Slotervaart Medical Center (NL23988.048.08). The protocol was also registered at ClinicalTrials.gov under number NCT01004692.

Randomization and Allocation

The participants were randomly allocated to one of two investigative groups (see Study Protocol). To ensure that the groups were of approximately the same size, block randomization was used. The allocation sequence was automatically generated and subse-

quently concealed by an independent coworker, who kept a paper copy in a lockable drawer. Sealed opaque envelopes were used to conceal the allocation from the principal investigator.

Occlusal Stabilization Splint and Blinding

An occlusal stabilization splint was constructed for each participant. The splint was a hard acrylic resin appliance with no palatal coverage, to be worn in the maxilla. It caused a bite rise of about 1.0 mm at the level of the first molar (for a detailed description, see van der Zaag et al[11]). The intermaxillary relationship of choice was the retruded contact position, ie, the point of initial contact between the mandibular dentition and the splint when the mandibular condyles are guided along the posterior slope of the articular eminence into their most superior position on jaw closure.[1] Canine guidance and anterior guidance were built in so as to enable contralateral and posterior disclusion during articulation movements. The splint did not come into contact with the participant's soft tissues, nor did it act as an orthodontic device. The splints were fabricated at the Department of Oral Kinesiology of ACTA, in collaboration with a dental laboratory (Excent Tandtechniek Amsterdam).

The participants were blinded to the a priori hypothesis regarding the effect of the splint on their OSA condition. After using the splint, all the patients were asked if they experienced a change in their sleep apnea symptoms with the splint in situ. Analyst blinding was ascertained by assigning codes to data sets and by analyzing these sets in random blocks.

Study Protocol

After written informed consent was obtained, all participants underwent two sets of three consecutive ambulatory PSG home recordings, with 2 weeks between both sets, using a crossover design. In the first randomly composed group (see Randomization and Allocation), the participants (2 men, 4 women) who had a mean (± SD, range) age of 50.2 (± 8.7, 39 to 60) years first underwent the three nights of PSG recordings without the stabilization splint in situ. After the 2-week wash-out period, they underwent the three nights of recordings with the splint in situ. In the second group, the participants (1 man, 3 women) with a mean (± SD, range) age of 43.0 (± 15.7, 23 to 62) years first underwent the three PSG recordings with the splint in situ, and 2 weeks later they underwent the three PSG recordings without the splint in situ. All participants used the splint in situ 10 nights before the recordings as a habituation period.

Monet hardware (Medcare) was used for the ambulatory recordings, and Rembrandt software (Medcare) was used for the analyses. All PSG recordings consisted of two electroencephalographic leads (C3-A2 and O2-A1), two electro-oculographic leads, mental surface electromyography, nasal-oral airflow using a thermistor, oximetry, abdominal and thoracic respiratory effort, body position, electrocardiography, leg movements (m tibialis anterior), and a piezoelectric lead for the detection of snoring. A trained coworker performed the montage of the recording devices at the Slotervaart Medical Center.

After each PSG recording, values of BMI and ESS were obtained.

Data Analysis

All PSG recordings were coded, randomized, and analyzed under blind conditions by a specialized sleep medicine technician. This examiner's intraobserver reliability of AHI scoring was excellent, with an intraclass correlation coefficient (ICC) of 0.96; that of sleep scoring could be qualified as good to excellent, with ICC values ranging from 0.64 to 0.96. Sleep stages were scored manually in 30-second epochs according to Rechtschaffen and Kales,[12] and standard sleep variables and respiratory variables were obtained. After the completion of the analyses, the recordings were decoded again.

Statistical Analysis

To enable the use of within-subject factors, analyses of variance (ANOVAs) for repeated measures were performed. Based on current insights into the etiology and mechanisms of OSA,[8,13] BMI was introduced as between-subject (co-)factor in case of a significant interaction of BMI with the variable of interest (ie, AHI or ESS). Repeated-measures ANOVA was used to assess possible statistical differences in the AHI (the primary outcome measure) and ESS between the consecutive nights. Second, the AHI and ESS values of the three non-splint nights and of the three splint nights were averaged, followed by independent ANOVA to check if there was a statistically significant difference in AHI and in ESS between the mean values of the non-splint nights and the mean values of the splint nights. Finally, the standard sleep variables, averaged over the three nights for each condition, were compared between the splint and non-splint conditions by using two-independent-samples *t* tests and Bonferroni adjustment for multiple comparisons.

Table 1 Mean Values ± SD of the Standard Sleep Variables of the 10 Participants, Averaged over the Three Nights* for Both Experimental Conditions (ie, without and with the stabilization splint in situ)

	No splint	Splint	T	*P*
Total sleep time (min)	428.9 ± 64.9	437.1 ± 85.9	–0.315	.757
Stage 1 and 2 (%)	6.07 ± 11.4	60.4 ± 14.8	1.990	.065
Stage 3 and 4 (%)	14.7 ± 12.8	17.5 ± 7.2	–0.994	.330
Stage REM (%)	19.9 ± 6.5	20.3 ± 5.2	–0.933	.362
Sleep in supine position (%)	51.0 ± 23.9	42.1 ± 22.8	1.120	.279
Sleep efficiency (%)	83.3 ± 7.3	87.9 ± 4.1	–2.61	.042

*For one participant, the mean values of the splint condition were based on two PSG recordings. T = test statistic for two-independent-samples *t* tests.

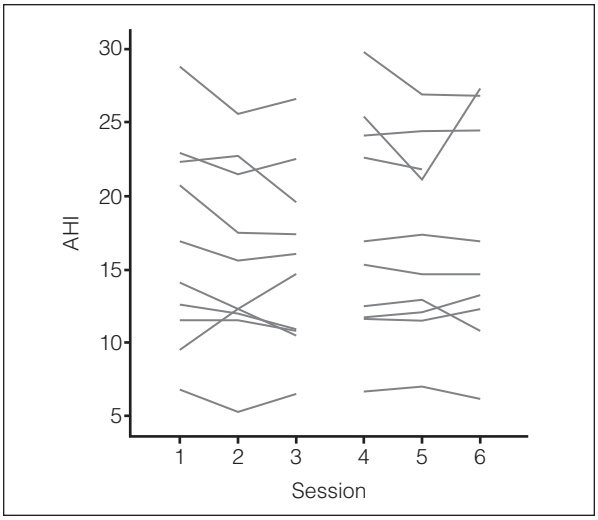

Fig 1 AHI values obtained with the six PSG recordings per participant. Note that for one participant, the AHI from the sixth PSG recording is missing.

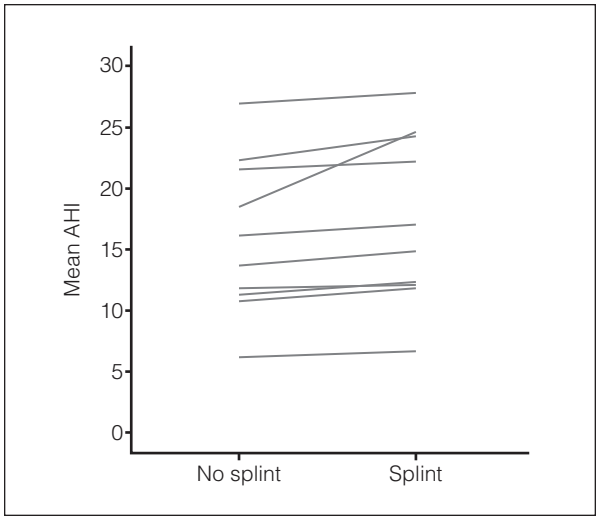

Fig 2 Mean AHI values of the three PSG recordings per experimental condition (ie, without and with the stabilization splint in situ) for all 10 participants individually. Note that for 1 participant, the mean value of the splint condition was based on two PSG recordings.

All analyses were performed with the SPSS package for Windows, version 16.0 (SPSS Inc). $P < .05$ was considered statistically significant.

Results

All but one participant completed the entire study protocol, even though two of them felt that the stabilization splint caused dry lips and increased their snoring. The patient who did not complete the entire protocol failed to do the last recording of the splint condition because of severe allergy to the glue and stickers used for the recordings. All PSG recordings were judged to have normal structures by the medically responsible sleep medicine specialist (HLH). The standard sleep variables are shown in Table 1. None of them differed significantly between the splint and non-splint conditions after Bonferroni adjustment (ie, statistically significant when $P < .0083$).

Since no significant interactions between BMI and any of the outcome measures were present, the ANOVAs for repeated measures were performed without using BMI as a cofactor. There was no statistically significant difference in AHI or in ESS between the three nights without the stabilization splint (AHI: $F = 2.757$, $P = .090$; ESS: $F = 0.153$, $P = .860$). Similarly, there was no statistically significant difference in AHI or in ESS between the three nights with the splint in situ (AHI: $F = 0.815$, $P = .458$; ESS: $F = 0.231$, $P = .796$). To illustrate the night-to-night variability in AHI, Fig 1 shows the results of the six PSG recordings for each individual.

Figure 2 shows the mean AHI values of the three PSG recordings per experimental condition (ie,

without and with the stabilization splint in situ) for all 10 participants individually. The mean AHI of the three nights with the stabilization splint in situ was significantly higher than that of the three nights without the splint in situ (with splint: mean ± SD = 17.4 ± 7.0 events/hour; without splint: mean ± SD = 15.9 ± 6.4 events/hour; F = 7.203, P = .025). The mean (± SD) increase in AHI with the splint in situ was 1.4 ± 1.7 events/hour; its 95% confidence interval (1.4 ± 1.96 × 1.7) was –1.9 to 4.7. Even when the patient with the largest effect size (a 62-year-old male; BMI = 20.9; neck circumference = 44.2 cm) was removed from the analyses, the mean (± SD) increase in AHI (0.9 ± 0.5) remained statistically significant (F = 29.033; P = .001). No significant difference in ESS was found when both experimental conditions were compared (with splint: mean ± SD = 9.5 ± 5.3; without splint: mean ± SD = 9.6 ± 5.2; F = 1.00, P = .343). An interaction with randomization order was not present for AHI or for ESS (AHI: F = 2.65, P = .142; ESS: F = 0.812, P = .394).

Discussion

The hypothesis tested in this study was that an occlusal stabilization splint is associated with aggravating the respiratory disturbance in OSA patients. The use of stabilization splints indeed raised the AHI significantly. The increase in the AHI was small, but it occurred in all 10 OSA patients who participated in the study (see Fig 2). Even when the patient with the largest effect size was removed from the analyses, the mean increase in AHI remained statistically significant. If one considers the mean difference plus or minus its 95% confidence interval, however, it turns out that zero is included in the interval, suggesting that both experimental conditions could be considered equivalent. Hence, whether the small increase in the AHI is actually clinically relevant remains to be studied. Also the long-term effects of stabilization splints on OSA need to be captured in future longitudinal trials, although such studies may be difficult to perform because most patients will have received treatment for their OSA condition in the meantime.

Previous studies[4,5] found no significant group change of the AHI when the bite was raised in OSA patients. Increases were observed only at the individual level. In both previous studies, however, it was noted that the observed differences between the two conditions (ie, no increased jaw gape versus increased vertical dimension) did not necessarily reflect a true effect of the intervention, because these were not randomized controlled trials (RCTs). In contrast, the present study was a RCT. The employed crossover design allowed each patient to be his or her own control. The design included a 2-week wash-out period between both conditions (ie, no splint versus splint). Furthermore, multiple PSG recordings were obtained for both conditions and for each participant to take into account the night-to-night variability in AHI.[14–16] Hence, the present study yielded conclusive data.

Apart from the dissimilarities in study design, variation in the design of the intraoral devices could have influenced the differences between both previous studies[4,5] and the present one as well. Indeed, the magnitude of the bite rise in the present study (viz, about 1.0 mm at the level of the first molar) differed from that in the studies by Gagnon et al[4] and Nikolopoulou et al.[5] Gagnon et al[4] used an occlusal stabilization splint with a slightly larger thickness of approximately 1.5 mm at the molar level and of maximally 4.5 mm at the incisor level, while Nikolopoulou et al[5] used an intraoral device (viz, a mandibular advancement device with 0% protrusion) with a bite rise of 6 mm at the incisor level. Whereas the small difference in thickness of only about 0.5 mm between the splints used in the present study and those used by Gagnon et al[4] is unlikely to have contributed to the different findings between both studies, the considerable difference in thickness between the devices used in the authors' previous study[5] and in the present one may have contributed to the differences in findings.

The exact mechanism that may have caused the above-discussed effect of increased thickness is as yet unknown. Possibly, it is related to the fact that occlusal stabilization splints not only modify the space between the dental arches, but also reduce the space for the tongue and rotate and anteriorly translate the condyles,[17–19] thus compromising the upper airway lumen.

Another aspect related to the design of the intraoral devices used in the various studies so far is the fact that in the study by Nikolopoulou et al,[5] the mandible was fixed to the maxilla with the intraoral device in situ, while both in the study by Gagnon et al[4] and in the present study the mandible could move freely in all directions. Hence, the above-discussed lumen-narrowing effect of intraoral devices is likely to have been stronger in the study by Nikolopoulou et al,[5] because the mandible was prevented from moving anteriorly and thus from widening the upper airway lumen.

The 62-year-old male participant who showed the largest increase in the AHI with the occlusal stabilization splint in situ was also one of the two

patients who complained of increased snoring with the splint in situ. Interestingly, when this patient was compared to the other participants, he turned out to have a relatively low BMI but a relatively large neck circumference. Obesity is known to be the main risk factor of OSA.[20,21] However, in this case, the participant was of normal weight, even tending towards underweight. On the other hand, fat deposition around the upper airway, as suggested in this participant by his neck circumference, may narrow the airway lumen and increase the collapsibility of the pharynx.[22] Furthermore, the older the age (and this was the oldest participant), the more this factor is considered a risk for developing OSA.[23] Mechanisms proposed in the literature for the age-related increase in OSA include increased deposition of fat in the parapharyngeal area and lengthening of the soft palate, which both result in a narrowed upper airway and a worsening of the upper airway neuromuscular reflexes.[24,25] This participant's fat deposition around the neck in combination with his relatively high age could thus explain the considerable rise of the AHI with the splint in situ.

ESS did not differ between the two conditions studied. This was to be expected, because already in the study by Nikolopoulou et al,[5] where a much higher bite raise was used in a comparable time frame, there was no change in ESS between both conditions either. Further, a change of lifestyle, which could lead to an improvement in ESS, was not possible within the short time frame of the present study. In a long-term follow-up study, Aarab et al[26] observed a delayed improvement of both continuous positive airway pressure and mandibular advancement devices on ESS as compared to the effects of these interventions on the AHI. Hence, long-term studies are needed to reveal the possible effects of occlusal stabilization splints on ESS.

Conclusions

This study revealed a small but statistically significant increase in the AHI of OSA patients with an occlusal stabilization splint in situ as compared to the condition without an occlusal splint. The use of an occlusal stabilization splint may thus be associated with a risk of aggravation of OSA, although the clinical relevance of this finding may be questioned given the small effect size and the fact that the ESS did not change. Nevertheless, a stabilization splint may lead to an apparent increase in the AHI in individual patients, so dental practitioners should be aware of a possible OSA in their patients' oral history.

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