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A randomized, controlled trial of positional therapy versus oral appliance therapy for position-dependent sleep apnea

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Abstract

Objective: To compare the effectiveness of positional therapy (PT) with the sleep position trainer (SPT) to oral appliance therapy (OAT) in patients with mild-to-moderate positional obstructive sleep apnea (POSA).

Methods: Multicenter, prospective, randomized, controlled trial. Patients with mild-to-moderate POSA (apnea-hypopnea index (AHI) $\geq 5 \leq 30$ /hour sleep) were randomized for PT or OAT. Polysomnography was repeated after 3 months. Efficacy, adherence, mean disease alleviation (MDA), quality of life, dropouts and adverse events were evaluated.

Results: A total of 177 patients were screened for the study; 99 underwent randomization and 81 completed the study. Intention-to-treat (ITT) analysis of median [IQR] AHI showed a reduction in the PT group from 13.0 [9.7-18.5] to 7.0 [3.8-12.8], $p < 0.001$ and in the OAT group from 11.7 [9.0-16.2] to 9.1 [4.9-11.7], $p < 0.001$. Mean adherence (≥ 4 hours/night, ≥ 5 days/week) was $89.3 \pm 22.4\%$ for SPT versus $81.3 \pm 30.0\%$ in OAT patients, $p = 0.208$.

Conclusions: Oral appliance therapy and positional therapy were equally effective in reducing the median AHI in patients with mild-to-moderate POSA. The results of this study have important implications for future OSA treatment guidelines and daily clinical practice.

ClinicalTrials.gov number NCT02045576

Keywords:

Obstructive sleep apnea

Positional obstructive sleep apnea

Positional therapy

Oral appliances

Randomized, controlled trial

Introduction

Obstructive sleep apnea (OSA) has an overall prevalence of 9-38% in the general adult population, which is higher in men and rises with increasing age [1]. Obstructive sleep apnea is associated with daytime sleepiness, snoring, poor sleep quality, increased risk of cardiovascular disease, and motor vehicle accidents [2-5].

Conservative treatment starts with lifestyle alterations, such as weight reduction and avoidance of alcohol near bedtime, if applicable. In the case of position dependency, avoidance of the supine sleeping position is recommended. More aggressive treatment options include continuous positive airway pressure (CPAP) [6], oral appliance therapy (OAT) [7], and surgery, including upper airway stimulation [8]. All treatment modalities have their own specific indications, contraindications and side effects. Oral appliance therapy (OAT) is an established treatment for patients with mild-to-moderate OSA, both as a primary therapy and secondary treatment after CPAP failure. Oral appliance therapy often decreases the apnea-hypopnea index (AHI), with clinically relevant improvement [9]. When compared to CPAP, OAT has a non-inferior efficacy based on symptomatic response, although CPAP is more effective in reducing the AHI [10,11]. Although CPAP and OAT have different efficacy and compliance profiles, the overall therapeutic effectiveness is similar. Oral appliance therapy has better usage rates, while CPAP therapy is more efficacious [12]. The use of mean disease alleviation (MDA) enables calculation of overall therapeutic effectiveness; MDA is the product of the percentages for sleep time-adjusted adherence and therapeutic efficacy measured by AHI reduction. Since MDA provides data that are a more comprehensive metric of clinical effectiveness, MDA has been preferred above reporting AHI alone for treatment evaluation in recent studies [13,14].

However, OAT might have various downsides. Petit et al. demonstrated that approximately one-third of patients screened for OAT had a contraindication that was mainly associated with insufficient tooth number and periodontopathy coupled with tooth mobility [15]. In addition, OAT may induce dry mouth, jaw discomfort and changes in teeth position and occlusion [9,16]. Self-reported compliance is high (75-100%), although compliance decreases over time [17]. In one previous study, estimated OAT use was 32% after 4 years [18]. Non-compliance is due to complications, side effects, or absence of beneficial effects [19].

The majority of patients with mild-to-moderate OSA have more apneic events in the supine position, as compared to non-supine positions [20-23]. Positional OSA (POSA) is defined as an apnea-hypopnea index (AHI) that is at least twice as high in the supine position as compared to non-supine positions [20]. The prevalence of POSA is 56%, with an additional 30% having more apneic events in the supine position, although not twice as much [24]. Promising results have recently been reported for active positional therapy (PT) with new smart and adaptive devices [14,25-27]. The sleep position trainer (SPT) is a device that is worn around the chest with a strap that gives vibro-tactile feedback on supine positions at minimum intensity. The SPT aims to eliminate sleep time in the supine position without disturbing sleep quality [25]. Positional therapy with the SPT has improved sleep-related quality of life outcomes with an objectively measured adherence of 64.4% after 6 months of treatment [25,28].

It is well known that various patient factors have been associated with therapeutic outcome. For example, OAT has proven to be more effective in POSA patients compared to non-positional OSA patients [7,29,30]. It is believed that active PT has not directly been compared to OAT in the treatment of OSA. This multicenter, prospective, randomized study assessed the effectiveness of PT compared with OAT in mild-to-moderate POSA patients. The efficacy, adherence, MDA, quality of life and the side effects were evaluated after 3 months of therapy.

Material and methods

Patients

Patients were recruited at the departments of Otolaryngology and Clinical Neurophysiology at OLVG West Hospital, Amsterdam. Patients were eligible for inclusion if they met the following criteria: mild-to-moderate positional OSA, defined as an AHI in supine position at least twice as high as compared with the AHI in non-supine position, with 10-90% of total sleep time (TST) in the supine position, and aged ≥ 18 years. Exclusion criteria were: inadequate dental status for wearing oral appliances; central sleep apnea; night or rotating shift work; severe chronic heart disease; active psychiatric disease; seizure disorder; medication usage for sleeping disorders; muscular or joint problems in head, neck or back area; previous treatment with OAT or SPT; simultaneous other OSA treatments; reversible

morphological upper airway abnormalities (eg, enlarged tonsils); pregnancy; self-reported severe snoring in the lateral position as a primary complaint; and coexisting non-respiratory sleep disorders (eg, insomnia, periodic limb movement disorder, narcolepsy) that would influence functional sleep assessment.

Study design

In a multicenter, randomized, controlled trial, randomization was carried out centrally using a specialized computer system maintaining allocation concealment, stratified for BMI and, to a lesser extent, smoking. These two parameters were chosen as both factors could potentially contribute to sleep apnea. It was hypothesized that participants treated with PT would show equivalence in AHI compared with those treated with OAT. The physician and participant were not blinded to treatment arms. Primary outcome measures were assessed by overnight polysomnography (PSG) and scored manually by scorers blinded to therapy arm. The institutional Medical Ethics Committee of the OLVG West Hospital, Amsterdam and the Academic Medical Center Amsterdam approved the protocol. Written informed consent was obtained before enrollment. Independent monitors performed verification of documentation and source data.

Polysomnography

A digital PSG system (Embla A10, Broomfield, CO, USA) was used and recorded electroencephalogram (EEG) (FP2-C4/C4-O2), electro-oculogram (EOG), electrocardiogram (ECG) and submental and anterior tibial electromyogram (EMG). Nasal airflow was measured by a nasal pressure cannula, and blood oxygen saturation was measured by finger pulse oximetry. Straps containing piezoelectric transducers recorded thoracoabdominal motion, and a position sensor (Sleepsense, St Charles, IL, USA) attached to the midline of the abdominal wall was used to differentiate between supine, prone, right lateral, left lateral, and upright positions. The recorded data were analyzed using special software (Somnologica™ studio) and manually edited. Apnea was defined as the cessation of nasal airflow of more than 90% for a period of ≥ 10 seconds in the presence of respiratory efforts. In accordance with the prevailing definition from the American Academy of Sleep Medicine (AASM) at that time, a hypopnea was scored whenever there was a $>30\%$ reduced oronasal airflow for at least 10 seconds, accompanied by $\geq 4\%$ oxygen desaturation from pre-event baseline.

Study treatment

Participants were assigned either to the SPT or OAT after stratified randomization.

The SPT (SPT-DEV-PX-11.08) of NightBalance™ is a small lightweight device (72 x 35 x 10 mm; 25 g) worn across the chest using a neoprene strap (Fig. 1). The sensor contains a lithium polymer battery cell of 3.7 V and 180 mAh, a 3.2 G vibration motor and a protection circuit integrated in the printed circuit board. A three-dimensional digital accelerometer is used to determine body position. The SPT gives a soft vibration when supine position is detected, in order to urge a patient to change body position. Treatment is divided into three phases. During the first 2 nights, the SPT analyzes body position without giving active feedback. During the following 7 nights, the SPT trains the patient by vibrating in an increasing percentage of episodes while in the supine sleeping position. If the patient does not change position, the SPT will vibrate again after 2 minutes. At day 10, the full therapy phase begins, in which the SPT will vibrate every time the patient is in the supine sleeping position. The SPT has a USB port to recharge the internal battery and to upload data to an online self-monitoring system that can also be accessed by the patient and physician.

In the present study, OAT was carried out using a custom-made titratable device (SomnoDent flex, SomnoMed™) (Fig. 1). The device was worn intraorally and had a soft inner liner that supported comfort and maintained retention. The OAT was adjusted individually and advancement was titrated using a standard titration protocol [31]. After adequate assessment of the central relation and maximum protrusion using a construction bite with the George Gauche instrument, the OAT was set at 60% advancement at baseline. At each consecutive visit, the OAT was evaluated and advanced to 75%, or 90% if necessary. On the other hand, if side effects were not acceptable for the participant (eg, tooth pain or signs of temporomandibular dysfunction) the advancement was adjusted backwards to 75, 60 or 45%. Objective compliance was measured using a temperature-sensitive microsensor with on-chip integrated read-out electronics (Theramon®, Handels- und Entwicklungsgesellschaft, Handelsagentur Gschladt, Hargelsberg, Austria). Temperature was recorded by the microsensor at a sampling rate of 1 measurement per 15 minutes, allowing data acquisition on usage for a consecutive 100-day period. A recorded temperature of ≥ 30 °C indicated that the OAT was worn [32]. This microsensor was embedded in the OAT at the lower right side. Data were extracted at 3 months (± 2 weeks) using a dedicated reading station.

Study end points

The primary outcome measure was AHI. Secondary outcomes were other respiratory indices, including oxygen desaturation index (ODI) ($\geq 4\%$ decrease in oxygen saturation), and percentage of supine sleep time. Other outcome measures were subjective improvement in daytime sleepiness, measured with the Epworth Sleepiness Scale (ESS) (overall score between 0 and 24, a score < 10.0 is regarded as normal) [33], and the Functional Outcomes of Sleep Questionnaire (FOSQ) (global score ranging from 5-20, the lower the score the more dysfunctional the individual secondary to sleepiness) [34]. Furthermore, adherence and mean disease alleviation (MDA) were addressed. Adherence was defined as the percentage of daily use of ≥ 4 hours per night, during ≥ 5 days per week [35]. The MDA (%) was calculated by the product of the percentages for adjusted compliance and therapeutic efficacy, divided by 100. Within this definition, adjusted compliance was defined as the percentage of daily use (≥ 4 hours/night, ≥ 5 days/week) adjusted for sleep time (recorded by PSG) and limited to 100%. Therapeutic efficacy is defined as the AHI baseline minus AHI with therapy, expressed as a percentage [13].

Adverse events

Adverse events were reported in accordance with the International Conference of Harmonization ICH E2A guidelines (Good Clinical Practices) by the principal investigators and evaluated by clinical data monitors [36].

Statistical analysis

Descriptive statistics and inferential statistics were used. A Kolmogorov-Smirnov test, Q-Q plot and Levene's test first tested all data for normality. Categorical and dichotomous variables were expressed as n (%). Normally distributed continuous variables were expressed by their mean and standard deviation (SD) and tested with the independent samples Student's t -test. Skewed distributed data were expressed by their median and interquartile range [IQR] and tested with the independent samples Mann-Whitney U test or Wilcoxon signed-rank test. Significance level for baseline variables was set at $p < 0.05$. Statistical analysis was performed using SPSS Statistical software (version 21.0, SPSS Inc., Chicago, IL). Both intention-to-treat (ITT) ($n = 99$) and per-protocol (PP) ($n = 81$) analyses were executed for the main outcome parameters. For ITT analyses, none of the patients could be excluded, and patients were analyzed according to the original randomization. Therefore, missing data, in case of dropout, were imputed from baseline to the 3-month values.

Results

Characteristics

A total of 177 patients were screened (70.7% men, age 48.3 ± 10.1 years; BMI 27.6 ± 3.8 kg/m²), of whom 99 underwent randomization (Fig. 2). Participant characteristics are shown in Table 1. Both groups were similar in the baseline characteristics of age, gender, BMI, AHI, percentage supine time and TST. A total of 81 participants (81.8%) completed the 3-month follow-up. Most dropouts, including withdrawal, were seen in the OAT group (15 versus 3) (Fig. 2).

Primary outcome

Intention-to-treat

In an ITT analysis, including dropouts, the median AHI in OAT decreased from 11.7 [9.0-16.2] to 9.1 [4.9-11.7], $p < 0.001$, and in SPT patients from 13.0 [9.7-18.5] to 7.0 [3.8-12.8], $p < 0.001$. These results are graphically illustrated in Fig. 3. No significant between-group difference was seen at 3 months, $p = 0.535$ (Table 2).

Per-protocol analysis

The PP analysis showed that the AHI dropped from 12.4 [9.1-17.2] to 6.8/hour sleep [3.7-10.8], $p < 0.001$. No significant between-group differences were seen in AHI reduction, $p = 0.875$. The median AHI in the SPT group dropped from 12.7 [9.8-18.4] to 6.8/hour sleep [3.7-11.5] (46.5%, $p < 0.001$) and in the OAT group from 12.9 [9.1-16.7] to 6.9/hour sleep [3.7-10.3] (46.5%, $p < 0.001$). For the 3-month PSG, 13 participants were titrated at 60% and 23 at 75%. Objective outcome measures for PP analysis, as well as other sleep parameters, are shown in Table 2.

Secondary outcomes

Respiratory indices

The ODI was lower in both groups at 3 months than at baseline, $p = 0.689$, with an equal improvement. Both percentage of supine sleep and the AHI in supine position dropped in the total sample from 41.0 [26.0-54.0] to 19.0% [8.0-35.5] ($p < 0.001$) and 26.0 [17.8-40.1] to 13.0/hour sleep [4.6-27.5] ($p < 0.001$), respectively. Sleep efficiency did not change: 92.0 [86.0-95.0] to 91.0% [85.3-95.0], $p = 0.928$. Median percentage of supine sleep time, as recorded by PSG, decreased significantly in the SPT group from 43.0 [30.0-54.0] to 11.0%

[1.0-22.5], $p < 0.001$. For OAT, median percentage supine sleep time remained unchanged from 34.0 [25.0-56.3] to 32.0% [16.8-57.8], $p = 0.922$. The median percentage of supine sleep time per night over the 3-month period, as recorded by the SPT, is depicted in Fig. 4.

Adherence and mean disease alleviation

Mean adherence (≥ 4 hours/night, ≥ 5 days/week) for PP analysis over 3 months was similar in both groups, $89.3 \pm 22.4\%$ for SPT versus $81.3 \pm 30.0\%$ in OAT patients, $p = 0.208$ (Table 3). Mean adjusted compliance for ITT analysis was 88.4% and 60.5% for SPT and OAT, respectively, with an efficacy of 36.3% vs 28.0%. Combining these numbers gives a calculated MDA of 33.2% for SPT and 23.6% for OAT, $p = 0.215$. For the PP analysis, mean adjusted compliance for SPT was 96.0% and for OAT 88.8%, the efficacy 38.7% (SPT) vs 39.6% (OAT) and, hence, MDA 36.1% for SPT and 34.7% for OAT in the continuing users. This difference in MDA was not significant, $p = 0.879$.

Questionnaires

Questionnaires were collected at baseline and 3 months. In the OAT group, fully completed questionnaires at 3 months were collected in 80.6% ($n = 21/36$) for the ESS and in 58.3% ($n = 29/36$) for the FOSQ. For SPT these percentages were 88.9 ($n = 40/45$) and 64.4 ($n = 29/45$) for the ESS and FOSQ, respectively. In both treatment groups, no clinically relevant change in quality of life, as measured with the FOSQ, was found. A minimal increase in mean FOSQ score was seen in the SPT arm (15.2 ± 3.8 to 15.3 ± 4.2). For OAT the mean FOSQ score dropped minimally from 15.5 ± 3.50 to 15.2 ± 3.7 . A significant between-group difference was observed in mean ESS score at 3 months (8.1 ± 4.8 vs 6.0 ± 4.6 , $p = 0.035$) for SPT and OAT, respectively.

Adverse events

In total, 97 adverse events (AEs) were reported; 40.2% were device-related. In OAT, AEs (eg, pain/sensitive teeth, dry mouth, occlusion problems) occurred in 26.8% ($n = 26$). In the SPT group, 13.4% ($n = 13$) reported AEs (eg, vibro-tactile feedback disturbs sleep quality or wakes up partner, discomfort). Other AEs were: persistent snoring (22.7%; 12 SPT, 10 OAT); persistent tiredness (21.6%; 10 SPT, 11 OAT); other sleeping disorder (5.2%; 3 SPT, 2 OAT); and shoulder/joint complaints (3.1%; 3 SPT).

Discussion

It is believed that this is the first article on 3-month results of an effectiveness and efficacy comparison of SPT with OAT in patients with mild-to-moderate positional OSA. The SPT and OAT were equally effective in reducing the AHI and ODI. In the samples, higher adherence and MDA (efficacy x adherence) values were observed for the ITT analysis in the SPT group compared to OAT.

Earlier studies on short-term results (1 month) of the SPT showed a reduction in AHI from 39% to 68% [14,25,27]. The SPT results in the present study were in agreement with this, although the follow-up period in the present study (3 months) was longer. OAT has been extensively investigated, being effective in improving respiratory indices [11]. In the current study, the AHI in OAT dropped 46.5%; this is in line with the earlier literature [7].

In reporting treatment outcomes in OSA, there is an essential difference in efficacy and effectiveness [12,37,38]. Efficacy reflects the reduction in apneic events when a device is actually used. Effectiveness also takes adherence into account and is a better reflection of the real success of the treatment. Suboptimal adherence results in less effectiveness. Continuous positive airway pressure, for example, is highly efficacious when used, but the majority of patients have adherence problems that result in poor usage [35,39,40]. In fact, 29-83% of patients using CPAP are non-adherent [2,41-43]. In general, OAT has higher usage rates than CPAP treatment, but is less effective [12,13]. Objective adherence monitoring of OAT is possible by using microsensors thermometers embedded in the OA [7]. In a prospective trial, an objective adherence (≥ 4 hours/night, ≥ 5 days/week) of 84% was measured in 51 patients with OSA using OAT over a 3-month period [13]. These results are in line with the findings in the present study, where the mean adherence (≥ 4 hours/night, ≥ 5 days/week) was $81.3 \pm 30\%$ for OAT participants.

New-generation PT, with chest-worn devices providing vibro-tactile feedback if the supine position is adopted, is gaining renewed interest. Short-term [14,25] and long-term [28] objective adherence with SPT have been previously described. Van Maanen et al. reported a median adherence (≥ 4 hours/night, 7 days/week) after 1 month and 6 months of 92.7% and 64.4%, respectively. Another study looked at adherence of SPT in comparison with the tennis ball technique and demonstrated that after 1 month, the reduction in AHI was similar, but adherence (≥ 4 hours/night, ≥ 5 days/week) was significantly better in the SPT group, 75.9% vs 42.3%, $p=0.01$ [14]. The present study observed higher mean objective adherence (≥ 4 hours/night, ≥ 5 /week) over the study period

of 3 months in SPT participants as compared with the OAT group (89.3% vs 81.3%, $p=0.208$).

Objective measurement of therapy adherence is becoming standard clinical practice. A combination of adherence with efficacy results in the calculation of MDA as a measure of effectiveness. An MDA for OAT of 51.1% and 54.9%, respectively, were reported in two studies [13,44]. Another study reported an MDA for the SPT of 70.5% [14]; MDA has also been reported for OAT and CPAP. Although in general OAT is inferior to CPAP in reducing respiratory indices, adherence on the other hand is higher, resulting in similar overall MDA [10,12]. Recently, Dieltjens et al. identified that a more pronounced decrease in reports of snoring and the presence of dry mouth were the two parameters that were correlated with higher objective compliance during OAT [45]. In the present study, ITT analysis showed higher MDA at 3 months in the PT group (37.2% for SPT vs 28.9% for OAT); while per-protocol analysis numbers were similar (40.3% for SPT and 42.5% OAT). Both results, however, were not significantly different between the groups.

When comparing SPT with OAT, SPT seems to have several advantages: it is well tolerated and reversible [28], and a daily readout of number of corrections and remaining percentage of supine position is available online for patients. A disadvantage may sometimes be continued snoring in the lateral position. Advantages of OAT are its efficacy and preference. Disadvantages of OAT are more reported side effects [7] and also limited inclusion because of dental status. In the case of insufficient effect, the custom-made OAT cannot be returned and used by someone else. The devices can be combined with each other or with other treatments, if needed.

For POSA patients with a partial response to OAT, combination therapy (adding PT to OAT) has already been shown to further decrease OSA severity in an earlier study; here, OAT and SPT were equally effective in reducing the AHI. The combination of OAT and PT gave an additional statistically significant AHI reduction [27]. In the present study population, adding PT to the OAT group could have potentially improved the AHI by eliminating the non-supine AHI. For patients using SPT, the AHI will likely decrease in all sleeping positions when OAT is added. Follow-up studies are needed to evaluate the effect of combination therapy. Vanderveken also recently highlighted the importance of combining different treatment options for OSA [46]. Additional effects of PT after partial effective surgery have also been recently reported [47].

The results of this study have important implications for future OSA treatment guidelines and daily clinical practice, where the potential of PT is still undervalued [23].

According to the findings, mild and moderate POSA patients with similar characteristics could benefit from both PT and OAT.

Limitations

Several limitations for this study should be considered. Eighteen of the 99 participants dropped out. Nonetheless, power analysis suggested a minimum sample size of 36 participants per therapy arm (to reach a power of 90%), which was achieved despite the dropouts. Orthopantomography was not routinely performed before randomization to identify unsuitable patients for OAT. One third of the OAT dropouts were lost to follow-up, perhaps due to the fact that the custom-made titratable device had to be fitted and manufactured at the next visit, and titrated afterwards elsewhere, which might have caused a delay in patient intake and diminished patient commitment.

While the study participants, on average, had mild POSA with limited self-reported sleepiness, it is believed that the results of this study could be generalized to patients with mild-to-moderate POSA in Western populations. Future studies will need to look more closely at general quality of life and cost-effectiveness to achieve a more stepped care approach for each individual patient.

Conclusions

Results of this first RCT comparing respiratory indices and MDA between OAT and SPT indicate that after 3 months, OAT and PT are equally effective in reducing the AHI in mild-to-moderate POSA patients. It is believed that the results of this study have important implications for future OSA treatment guidelines and daily clinical practice. Additionally, long-term results still have to be determined.

Disclosure statement: L. B. L. Benoist, M. H. T. de Ruyter and Prof. Dr. J. de Lange declare no conflict of interest. Prof. Dr. N. de Vries is a member of the Medical Advisory Board of NightBalance, consultant of Philips Healthcare and Olympus, researcher for Inspire Medical Systems, member of ReVent's Medical Advisory Board, and has shares in NightBalance and ReVent.

Conflict of interest: None for all authors.

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Contributorship statement: All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in Sleep Medicine.

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Fig. legends

Fig. 1. Sleep position trainer (SPT) SPT-DEV-PX-11.08 of NightBalance™ (left panel) and Oral appliance, type SomnoDent flex, SomnoMed, with Orthosmart, TheraMon chip in blue (right panel).

Fig. 2. Study enrollment.

Overview of screening (enrollment), randomization and 3-month follow-up

*Although insufficient dental status was an exclusion criterion, a dentist checked this through regular physical examination. Some dental problems were only visualized after the orthopantomography was made.

** Adherence data for the OAT was retrieved in 32 participants, since there was a technical error with the chip in four participants.

*** Adherence data for the SPT was retrieved in 43 participants, since one patient did not show up at his follow-up visit after his 3-month PSG, for exporting the data. The other participant did not use the SPT during the 3-month PSG.

Fig. 3 a and b. Intention-to-treat and per-protocol analysis for primary outcome AHI reduction.

Overall apnea-hypopnea index (AHI) for OAT and SPT. The different gray scales represent the levels of sleep apnea severity, ranging from normal nocturnal breathing (AHI <5/hour sleep), mild OSA (AHI 5–15/hour), moderate OSA (AHI 15–30/hour), to severe OSA (AHI >30/hour). Box plots are displayed for the two different study nights subdivided for OAT (spotted fill) and SPT (blanc fill). The 25th and 75th percentiles are represented by the upper and lower margins, the mean values by the cross, and the median values by the horizontal line. Whiskers represent the maximum value (top) and the minimum value (bottom) of the dataset. Outliers are represented by a closed dot.

Fig. 4. Median percentage of sleep time in the supine position per night.

The first 9 days of the SPT therapy are part of the training program in which the SPT gradually decreases the number of times in which patients can sleep on their backs

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Table 1. Characteristics of the study population at baseline ($n = 99$)			
	SPT $N = 48$	OAT $N = 51$	$p^{a,b}$
Male, n (%)	34 (70.8)	36 (70.6)	0.979
Age, years	47.3 \pm 10.1	49.2 \pm 10.2	0.347
BMI, kg/m ²	27.5 \pm 2.9	27.7 \pm 4.5	0.797
Neck circumference, cm	38.0 \pm 3.6	37.7 \pm 3.2	0.624
Smoking, n (%)	11 (22.9)	12 (23.5)	0.943
Alcohol			
≤ 2 drinks/day, n (%)	45 (93.7)	48 (94.1)	0.499
> 2 drinks/day, n (%)	3 (6.3)	3 (5.9)	
Blood pressure, mmHg			
Systolic	135.0 [125.0-150.0]	130.0 [120.0-140.0]	0.032
Diastolic	90.0 [80.0-97.5]	85.0 [80.0-90.0]	0.033
Pulse, bpm	69.0 [64.0-78.0]	72.0 [66.0-80.0]	0.530
AHI, events/hour	13.0 [9.7-18.5]	11.7 [9.0-16.2]	0.318
AHI supine, events/hour	27.0 [18.7-43.1]	25.8 [17.4-35.0]	0.687
Percentage supine sleep	44.5 [30.0-55.5]	39.0 [26.0-54.0]	0.575

Mean \pm SD standard deviation

Median [Q1-Q3]

AHI, apnea hypopnea index; BMI, body mass index; OAT, oral appliance therapy; SPT, sleep position trainer

^a Independent t -test

^b Mann-Whitney test

Table 2. Primary and secondary outcome measures represented as mean \pm standard deviation or median with interquartile range.

ITT analysis (<i>n</i> = 99)	Sleep position trainer <i>n</i> = 48				Oral appliance therapy <i>n</i> = 51				
Primary outcome	Baseline	3 months	Change	<i>p</i> ^a	Baseline	3 months	Change	<i>p</i> ^a	<i>p</i> ^b
Total AHI, events/hour	13.9 \pm 5.9 13.0 [9.7-18.5]	9.0 \pm 7.3 7.0 [3.8-12.8]	-5.0 \pm 6.3 -5.2 [-9.7- -1.1]	<0.001	12.8 \pm 5.6 11.7 [9.0-16.2]	9.2 \pm 5.8 9.1 [4.9-11.7]	-3.7 \pm 5.4 -2.8 [-7.3-0.0]	<0.001	0.535
PP analysis (<i>n</i> = 81)	Sleep position trainer <i>n</i> = 45				Oral appliance therapy <i>n</i> = 36				
Primary outcome	Baseline	3 months	Change	<i>p</i> ^a	Baseline	3 months	Change	<i>p</i> ^a	<i>p</i> ^b
Total AHI, events/hour	13.9 \pm 5.9 12.7 [9.8-18.4]	8.7 \pm 7.4 6.8 [3.7-11.5]	-5.3 \pm 6.4 -5.4 [-9.8- -1.5]	<0.001	13.2 \pm 6.0 12.9 [9.1-16.7]	8.1 \pm 5.9 6.9 [3.7-10.3]	-5.2 \pm 5.8 -5.1 [-7.9 - -2.4]	<0.001	0.875
Secondary outcomes									
AHI supine, events/hour	31.0 \pm 17.2 26.0 [18.8-42.1]	19.6 \pm 22.5 12.3 [0.1-32.8]	-11.4 \pm 18.2 -14.3 [-23.4- -2.3]	<0.001	32.3 \pm 19.3 27.7 [16.5-42.4]	17.7 \pm 13.4 15.0 [6.0-27.0]	-14.5 \pm 18.1 -10.6 [-23.7 - -4.4]	<0.001	0.394
AHI <i>non</i> -supine, events/hour	4.0 \pm 3.3 3.4 [1.7-5.6]	6.2 \pm 6.0 4.3 [1.9-9.2]	2.2 \pm 6.2 1.3 [-1.3-4.1]	0.016	3.7 \pm 3.0 3.2 [0.9-5.3]	4.0 \pm 5.7 1.9 [0.8-4.7]	0.2 \pm 5.6 -0.5 [-3.1- 1.8]	0.402	0.005

ODI, oxygen desaturation Index	11.6 ± 5.8 10.0 [7.0-15.5]	7.5 ± 6.6 5.0 [3.0-10.0]	-4.3 ± 6.0 -3.0 [-7.0- -1.0]	<0.001	10.4 ± 6.0 10.0 [6.0-13.8]	7.3 ± 5.4 6.5 [4.0-9.0]	-3.1 ± 5.4 -3.0 [-6.0 - -1.0]	0.001	0.689
Percentage supine sleep	42.4 ± 17.4 43.0 [30.0-54.0]	14.4 ± 14.7 11.0 [1.0-22.5]	-28.0 ± 20.0 -31.0 [-41.0- -16.0]	<0.001	39.9 ± 20.3 34.0 [25.0-56.3]	38.9 ± 25.7 32.0 [16.8-57.8]	-0.9 ± 19.6 -1.0 [-9.8-8.0]	0.922	<0.001
Sleep efficiency	89.6 ± 8.2 92.0 [85.0-95.5]	89.8 ± 7.1 91.0 [86.0-95.0]	0.36 ± 9.2 0.5 [-0.5-6.0]	0.617	88.9 ± 7.7 90.5 [86.0-95.0]	87.3 ± 11.0 91.0 [84.0-95.5]	-1.6 ± 9.3 0.0 [-5.0-2.0]	0.448	0.526
Epworth Sleepiness Scale score (/24)	8.5 ± 5.3 8.0 [5.0-12.0]	8.1 ± 4.8 7.0 [5.0-10.0]	-0.4 ± 3.9 0.0 [-2.0-2.0]	0.836	8.1 ± 5.4 7.0 [4.0-11.0]	6.0 ± 4.6 5.0 [3.0-8.0]	-1.2 ± 3.6 -2.0 [-3.0-1.0]	0.112	0.035
FOSQ score	15.2 ± 3.8 16.4 [12.9-18.1]	15.3 ± 4.2 16.2 [13.1-18.6]	0.3 ± 2.9 1.0 [-1.8-2.0]	0.590	15.5 ± 3.5 15.8 [12.4-18.3]	15.2 ± 3.7 15.8 [12.5-18.8]	-0.5 ± 2.3 -0.2 [-2.0-1.0]	0.332	0.814

Mean ± SD

Median [Q1, Q3]

AHI, apnea hypopnea index; FOSQ, Functional Outcomes of Sleep Questionnaire; ITT, intention-to-treat; ODI, oxygen desaturation index; PP, per-protocol

^a Wilcoxon signed rank test^b Mann-Whitney Test at 3 months

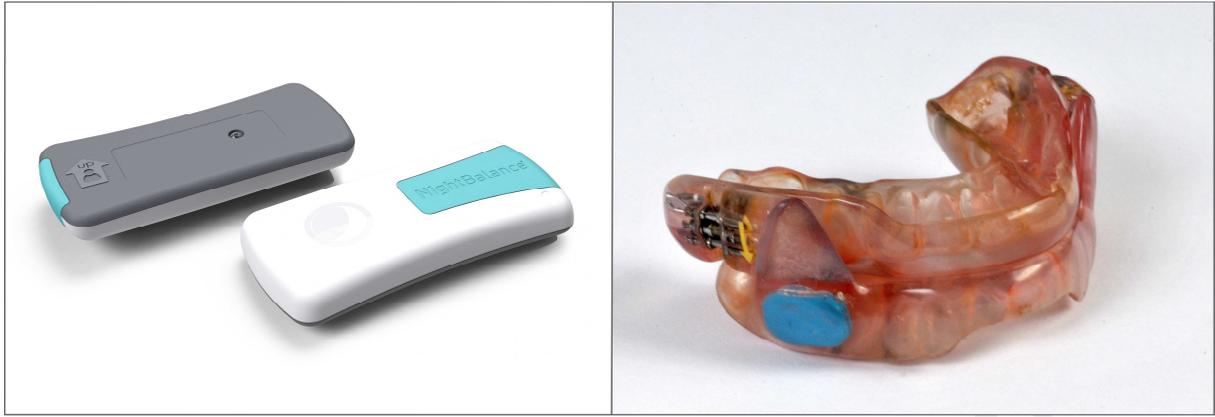
Table 3. Mean disease alleviation ($n = 81$)			
	SPT $N = 45$	OAT $N = 36$	p^a
Adherence (≥ 4 hours/night, ≥ 5 days/week), %	89.3 ± 22.4	81.3 ± 30.0	0.208
Adjusted compliance*, %	96.0 ± 10.1	88.8 ± 29.5	0.199
Therapeutic efficacy, %	38.7 ± 41.9	39.6 ± 35.9	0.912
Mean disease alleviation, %	36.1 ± 37.7	34.7 ± 35.4	0.879

Mean \pm SD standard deviation

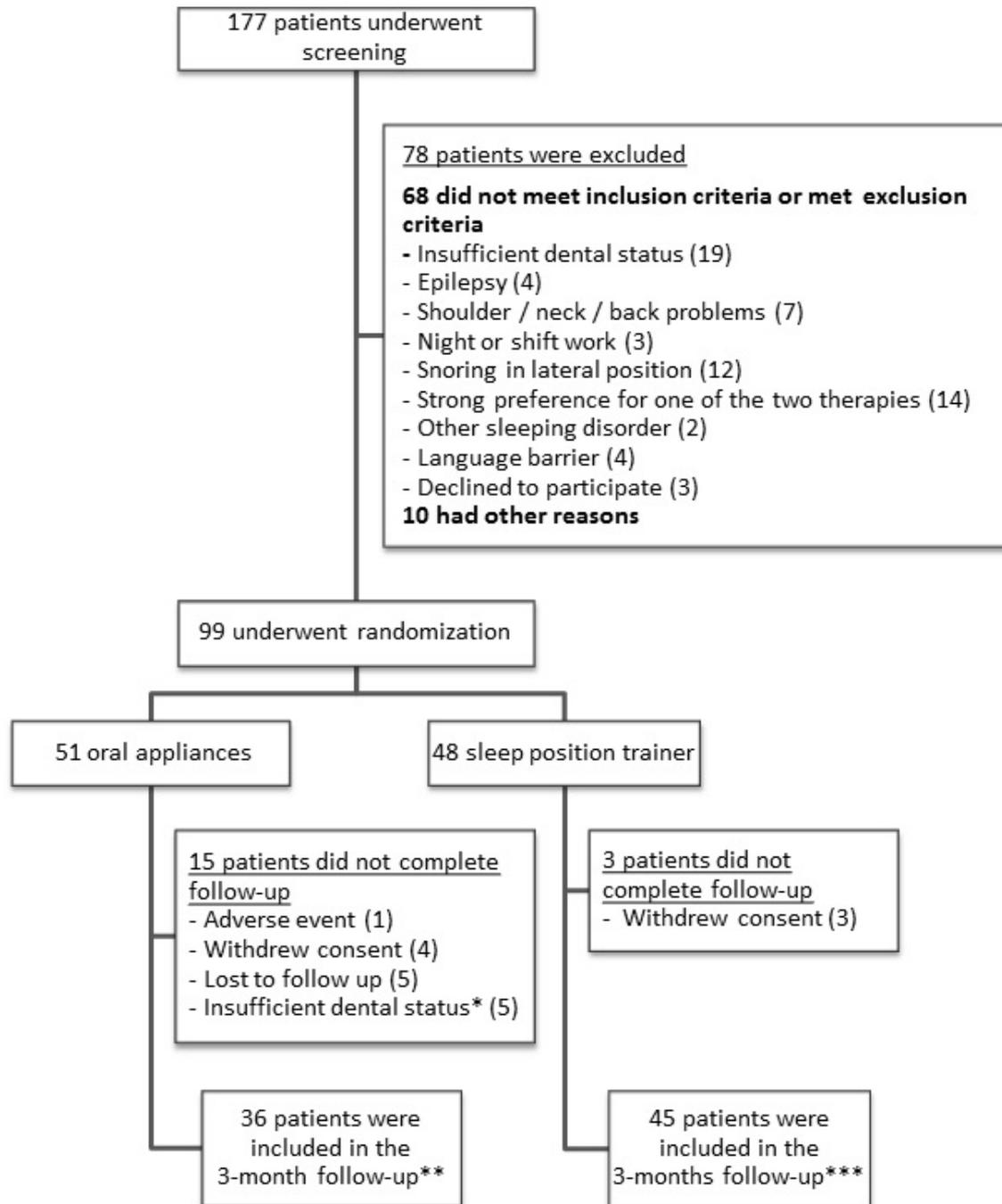
OAT, oral appliance therapy; SPT, sleep position trainer; TST, total sleep time

^a Independent t -test

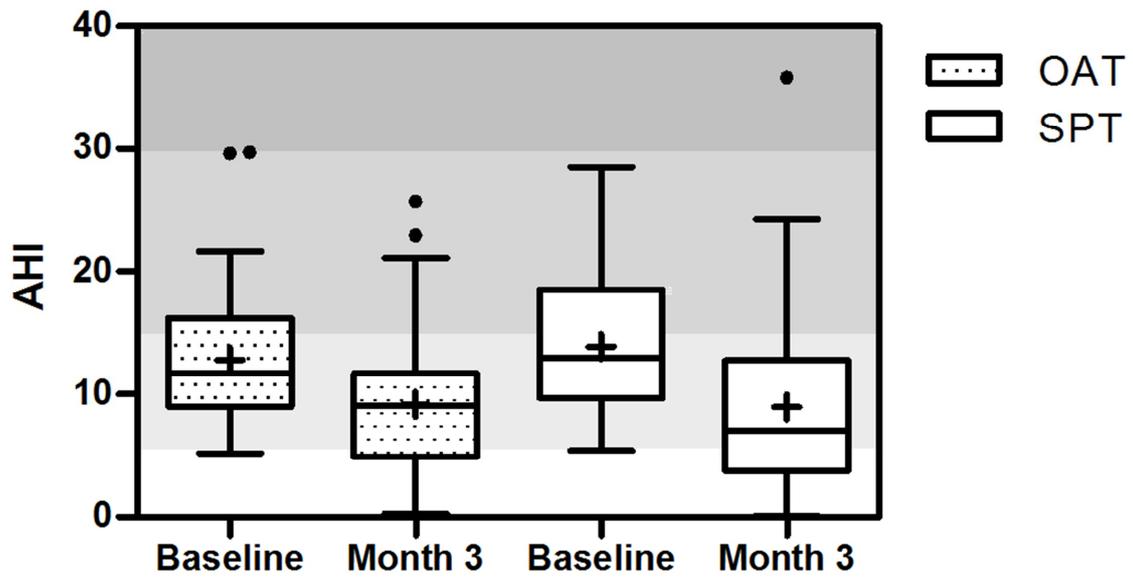
*Used nightly hours as percentage of polysomnography-derived TST



ACCEPTED MANUSCRIPT



ITT analysis



PP analysis

