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Original Research

SLEEP DISORDERS

Efficacy of an Adjustable Oral Appliance and Comparison With Continuous Positive Airway Pressure for the Treatment of Obstructive Sleep Apnea Syndrome

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Background: **We sought to establish the efficacy of an adjustable oral appliance (aOA) in the largest patient population studied to date, to our knowledge, and to provide a comparison with continuous positive airway pressure (CPAP).**

Methods: **We conducted a retrospective analysis of patients using an aOA. Results of overnight polysomnography with aOA titration were evaluated and compared with CPAP. Predictors of a successful aOA titration were determined using a multivariate logistic regression model.**

Results: **A total of 497 patients were given an aOA during the specified time period. The aOA reduced the mean apnea-hypopnea index (AHI) to 8.4 ± 11.4, and 70.3%, 47.6%, and 41.4% of patients with mild, moderate, and severe disease achieved an AHI < 5, respectively. Patients using an aOA decreased their mean Epworth Sleepiness Score by 2.71 (95% CI, 2.3-3.2; *P* < .001) at follow-up. CPAP improved the AHI by −3.43 (95% CI, 1.88-4.99; *P* < .001) when compared with an aOA, but when adjusted for severity of disease, this difference only reached significance for patients with severe disease (−5.88 [95% CI, −8.95 to −2.82; *P* < .001]). However, 70.1% of all patients achieved an AHI < 5 using CPAP compared with 51.6% for the aOA (*P* < .001). On multivariate analysis, baseline AHI was a significant predictor of achieving an AHI < 5 on aOA titration, and age showed a trend toward significance.**

Conclusions: **In comparison with past reports, more patients in our study achieved an AHI < 5 using an aOA. The aOA is comparable to CPAP for patients with mild disease, whereas CPAP is superior for patients with moderate to severe disease. A lower AHI was the only predictor of a successful aOA titration.** ***CHEST 2011; 140(6):1511–1516***

Abbreviations: AASM = American Academy of Sleep Medicine; AHI = apnea-hypopnea index; aOA = adjustable oral appliance; CPAP = continuous positive airway pressure; ESS = Epworth Sleepiness Score; MMP = maximum mandibular protrusion; OA = oral appliance; OSAS = obstructive sleep apnea syndrome; PSG = polysomnography; TAP = Thornton Adjustable Positioner

An oral appliance (OA) is a device that fits within the oral cavity and prevents upper airway collapse in patients with obstructive sleep apnea syndrome (OSAS). A recent American Academy of Sleep Medicine (AASM) guideline concluded that OAs are less effective than continuous positive airway pressure (CPAP) but are a reasonable alternative for patients with mild to moderate obstructive sleep apnea (OSA) in specific situations.[1,2] For patients with severe OSA, a trial of CPAP is required prior to their use, and

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surgery may be preferred over an OA for CPAP failures. Predicting which patients will have a successful OA titration and treatment response is difficult.[1,2]

The studies used to establish these guidelines are limited by small sample sizes, select patient populations, and the absence of device titration during polysomnography (PSG). The two largest trials enrolled only 256[3] and 263[4] patients. Trials included patients who failed or had a contraindication to CPAP,[4-6] which may bias the results toward a less responsive population. Most study protocols for performing a PSG with an OA in place did not include active titration during the study.[4,7,8] Given these limitations, the published data likely underestimate the efficacy of an OA and leave clinicians uncertain as to which patients might benefit from their use.

At the Walter Reed Army Medical Center sleep clinic, an adjustable OA (aOA) is often ordered for patients who are set to deploy, even if they are already using CPAP. This provides an opportunity to study a large patient population not biased by a high proportion of CPAP failures. In addition, all patients have their aOA setting optimized by titration during PSG. We analyzed data from patients who were given an aOA by our clinic to clarify their role in the treatment of OSAS, with the expectation that our success rate would be higher than previously published estimates.

Materials and Methods

Patients

This protocol was approved by the institutional review board at our hospital's Department of Clinical Investigations, IRB reference No. 05-17048EX-355294-1. Because the study was retrospective in nature and all patient identifiers were removed from the database, patient consent was not required. Using this protocol, we performed a retrospective review of all patients who were given an aOA by a provider from our clinic. All patients had an AHI > 5, and patients with Cheyne-Stokes respirations, central sleep apnea, and the obesity-hypoventilation syndrome were not given an aOA in our clinic. Patients with an edentulous jaw, known temporomandibular joint disease, and acute periodontal disease were not offered an OA. Data on craniofacial characteristics, BMI, age, Epworth Sleepiness Score (ESS), and comorbid hypertensive disease were abstracted from the initial sleep clinic visit.

Many patients in our clinic deploy to austere environments where electricity is not available. Reliance on CPAP may result in duty restrictions or separation from service, so from 2004 to 2006 it was standard practice to prescribe both CPAP and an OA for patients diagnosed with OSAS who were expected to deploy. Patients did not have to try or fail CPAP prior to being given an OA. Patients were advised to use CPAP whenever possible, whereas the OA was reserved for travel to locations that could not support a CPAP unit.

All patients diagnosed with the OSAS at our institution undergo education regarding the health effects of untreated OSA and the need for adequate therapy. Whether they are given CPAP, an OA, or both, they are trained in the proper care for and maintenance of their device(s). We provide serial clinical evaluations after therapy is initiated, during which methods to maximize adherence are discussed. When applicable, active sinus disease is adequately treated prior to initiating OA therapy.

Oral Appliance

All patients received a Thorton Adjustable Positioner (TAP) (Airway Management, Inc; Dallas, Texas), an aOA designed for PSG titration and used for the treatment of snoring and OSAS. The TAP is a custom-made, two-piece appliance that fits over the upper and lower teeth. It aims to prevent the tongue and soft tissues of the throat from collapsing into the airway by forward protrusion of the lower jaw. The TAP has an anterior dial that allows adjustment to achieve maximum comfort and efficacy. Each turn is equal to 0.25 mm of additional jaw protrusion.

After receiving a diagnosis of OSAS, patients were followed by a board-certified sleep medicine physician. They were referred to one of two dentists, each specifically trained in sleep medicine, to be fitted for an individually customized device. After the maximum mandibular protrusion (MMP) was estimated, the dentist then fit the appliance, instructed the patient on how to adjust and care for the device, and counseled the patient on side effects. The initial setting was usually at 70% to 80% of the MMP.

After being fitted, patients began an at-home adjustment protocol with the aOA set in a neutral position. Patients were instructed to advance the device 0.25 mm (one turn) each night as tolerated, with the goal of optimizing subjective sleep quality. In the event of discomfort, the device was regressed 0.5 mm (two turns) and subsequent advancement was resumed at a slower pace. Using the setting that the patient settled on during the at-home titration protocol and the patient's sleep diary, the degree of mandibular advancement that optimized sleep quality was estimated.

Follow-up PSG with aOA titration was scheduled after subjective improvement in sleep quality. At follow-up PSG, the aOA was set to 1 mm of mandibular advancement less than the number of turns used at home, and incrementally advanced to eliminate respiratory events (apneas, hypopneas, and snoring). If the patient was uncomfortable at a given number of turns, the technician was instructed to dial back two turns and to cease advancing the device for the remainder of the study. Technicians were instructed not to advance the device past the MMP. After their titration PSG, patients used the number of turns that provided the lowest AHI, provided side effects were tolerable.

Polysomnography

The diagnosis of OSA was made by an attended, overnight level I polysomnogram in all subjects. The apnea-hypopnea index (AHI) was used to define the severity of OSA in accordance with the AASM criteria, as follows[9,10]:

- Mild AHI: 5-15/h
- Moderate AHI: > 15-30/h
- Severe AHI: > 30/h

Hypopneas were defined by the AASM alternative criteria.[10] For the overnight CPAP titration on PSG, patients were titrated according to AASM guidelines.[11]

All PSGs were scored by a certified sleep technician in accordance with the published AASM guidelines[10] and interpreted by a board-certified sleep physician. Relevant PSG data were abstracted, including oxygen saturation nadir, total time with oxygen saturation < 90%, and AHI in both the supine and lateral positions. Patients were labeled as having "positional" sleep apnea if the AHI in the lateral position was < 5 and was 50% lower than that seen in the supine position. For aOA titration studies, the time,

AHI, and amount of rapid eye movement sleep at the maximum number of turns were recorded. For CPAP titration studies, the final pressure and the AHI at that pressure were recorded.

Treatment Success

Because a CPAP titration is considered unsuccessful unless an AHI <5 is achieved,[11] we used an AHI <5 as our criterion for success when we compared the aOA to CPAP. Many OA studies cited in the AASM practice guideline used an AHI <10[1,3,4,7,12-16] to define success, so success rates according to this standard are also provided.

Statistical Analysis

All means are followed by SD. Comparisons between categorical variables were performed using χ^2 and McNemar χ^2 analyses. Differences between means were compared using the paired samples and independent samples *t* tests. To identify baseline demographic, polysomnographic, and physical examination predictors of an AHI <5 on an aOA titration, logistic regression was performed. Variables were entered into models if they reached a *P* value of $<.10$ in univariate analysis or if association was assumed clinically (Statistical Package for Social Sciences 17.0; SPSS Inc; Chicago, Illinois).

Results

A total of 720 consecutive patients were given an OA at our clinic between August 1996 and March 2009. Of these, 96 were excluded because they were given a fixed device that could not be adjusted. This left 624 patients who received an adjustable appliance during the specified time period, and 497 had data from their aOA titration available for analysis. The 127 patients who received an adjustable appliance but did not have data available for the aOA titration were younger (39.3 ± 9.0 y vs 41.3 ± 9.0 y; $P = .03$) and had more subjective sleepiness according to the ESS (14.2 ± 5.0 vs 12.9 ± 5.1; $P = .02$), when compared with the 497 patients with data. There was no significant difference in AHI, oxygen nadir, or percent time below an oxygen saturation of 90% on the initial PSG and no difference in BMI, percent of patients with positional OSA, gender, or OSA severity between the two groups. Baseline demographics and PSG data for the 497 patients who had an aOA titration are listed in Table 1. The average time between diagnostic PSG and aOA titration was 296.5 ± 315.7 days.

Tables 2 and 3 list the results of the aOA titration. An ESS was documented at the time of the aOA titration and the diagnostic PSG for 330 patients. Presumably, they had been given and were using their aOA in the interim. The average time between studies for these 330 patients was 297.3 ± 317.2 days, and the ESS was 13.0 ± 5.0 prior to the diagnostic PSG and 10.4 ± 5.3 at the time of the aOA titration (-2.7; 95% CI, -2.2 to -3.1; $P < .001$).

There were 378 patients who had both CPAP and aOA titrations available for comparison, and titrations with the aOA were completed an average of 232 ± 355 days after those with CPAP. Most patients (98.7%) had their CPAP titrations performed first. Results for the CPAP titration studies are shown in Table 4. When compared with the aOA, CPAP

Table 1—*Baseline Characteristics*

Age	41.3 ± 9.0
BMI	28.7 ± 4.4
Men	86.4
HTN	28.7
ESS	12.9 ± 5.1
Mallampati	
1	7.3
2	17.4
3	50.0
4	25.3
Retrognathia/micrognathia	63.5
Diagnostic PSG results	
AHI	30.0 ± 24.8
Supine	23.7 ± 17.9
Side	13.6 ± 17.5
Positional	37.4[a]
Spo_2 nadir	83.8 ± 7.5
Spo_2% TST <90%	5.1 ± 10.0
Mild OSA	33.4
Moderate OSA	30.8
Severe OSA	35.8

Data are presented as mean ± SD or %. AHI = apnea-hypopnea index; ESS = Epworth Sleepiness Score; HTN = physician diagnosis; OSA = obstructive sleep apnea; PSG = polysomnogram; Spo_2 = oxygen saturation by pulse oximetry; TST = total sleep time (in min).
[a]AHI 50% less on side when compared with supine, and AHI <5 on side.

Table 2—*aOA Titration Results*

AHI[a]	8.3 ± 11.4
AHI supine	12.4 ± 13.5
AHI side	6.7 ± 13.3
Spo_2 nadir	85.1 ± 7.3
Spo_2% TST <90%	3.3 ± 8.8
REM at final turns	84.4
Time at final turns, min	221.4 ± 124.1
AHI <5[a]	53.8
AHI <10[a]	73.9
Mild OSA (n = 186)	
AHI[a]	5.2 ± 7.3
AHI <5[a]	69.9
AHI <10[a]	86.0
Moderate OSA (n = 144)	
AHI[a]	7.4 ± 8.1
AHI <5[a]	47.9
AHI <10[a]	75.0
Severe OSA (n = 167)	
AHI[a]	12.3 ± 15.4
AHI <5[a]	41.9
AHI <10[a]	60.5

Data are presented as mean ± SD or %. aOA = adjustable oral appliance; REM = rapid eye movement sleep. See Table 1 legend for expansion of other abbreviations.
[a]Data reflect AHI at final turn.

Table 3—*Improvements With aOA*

Measure	Improvement	95% CI	*P* Value
Mean AHI reduction at final turn			
Overall	−21.6	19.4-23.8	< .001
Mild	−4.46	3.3-5.6	< .001
Moderate	−13.5	12.0-15.0	< .001
Severe	−44.5	40.7-48.4	< .001
Change in O_2 saturation nadir			
Overall	+1.27	0.5-2.1	.001
% Time SpO_2 < 90%			
Overall	−1.88	0.8-3.0	.001

O_2 = oxygen. See Table 1 and 2 legends for expansion of other abbreviations.

improved the AHI by −3.43 (95% CI, 1.88-4.99; $P < .001$). When adjusted for severity of disease, the difference in AHI improvement between CPAP and an aOA was −1.9 (95% CI, −3.8 to 0.02; $P = .053$), −1.7 (95% CI, −4.0 to 0.7; $P = .17$), and −5.88 (95% CI, −8.95 to −2.82; $P < .001$) for mild, moderate, and severe disease, respectively. On CPAP titration, 70.1% (268 of 378) of patients achieved an AHI < 5 at final pressure, compared with 51.6% (195 of 378) at final turn on their aOA titration ($P < .001$ for difference). When the same comparison was done, adjusting for disease severity, success rates (AHI < 5) for CPAP vs aOA were 76.2% vs 62.3% ($P = .15$), 71.0% vs 50.8% ($P = .001$), and 63.4% vs 39.9% ($P < .001$) for mild, moderate, and severe disease, respectively.

Results for the univariate analysis are shown in Table 5, and multivariate modeling in Table 6. Patients who achieved an AHI < 5 on their aOA titration were younger, had a lower BMI, and had less severe OSA as measured by the AHI and degree of nocturnal hypoxia. They were also more likely to be women. On multivariate analysis, only baseline AHI retained significance, whereas age showed a trend toward significance. Using an AHI < 10 as the dependent variable, AHI at baseline remained the only significant predictor in multivariate modeling (OR, 0.98; 95% CI, 0.97-0.99; $P = .002$).

Table 4—*CPAP Titration Results*

AHI at final pressure	5.6 ± 10.9
Final CPAP pressure	8.7 ± 2.9
AHI < 5 at final pressure	69.1
AHI < 10 at final pressure	84.3
Mild OSA (n = 113)	
AHI at final pressure	3.8 ± 7.4
AHI < 5 at final pressure	76.2
AHI < 10 at final pressure	85.7
Moderate OSA (n = 114)	
AHI at final pressure	5.7 ± 11.0
AHI < 5 at final pressure	70.7
AHI < 10 at final pressure	87.7
Severe OSA (n = 151)	
AHI at final pressure	6.8 ± 12.8
AHI < 5 at final pressure	62.9
AHI < 10 at final pressure	80.1

Data are presented as mean ± SD or %. CPAP = continuous positive airway pressure. See Table 1 legend for expansion of abbreviations.

Discussion

We found that the majority of patients using an aOA achieved an AHI < 5 on the PSG titration, and the ESS decreased significantly after an aOA was prescribed. In multivariate analysis, only AHI remained a significant predictor of aOA success. Although CPAP was superior for patients with severe OSA, the difference in AHI reduction between the aOA and CPAP was not significant for patients with mild and moderate disease.

In comparison with previous studies, the OA success rate at our clinic was higher. The AASM guidelines[1,2] and a recent review[17] both quote a summary success rate from the literature, using AHI < 10, of just over 50%. Our population's success rate using the same criteria was 73.6%. The largest studies performed to date quote success rates of 54%,[3,4] 51%,[7] and 49.1%[12] using an AHI < 10, and 36%[8] using an AHI < 5 as the definition for success, all considerably lower than our rates. Our success rate for patients with severe disease was also higher than previously seen.[1,2,4,17]

The absence of a statistically superior AHI reduction with CPAP in comparison with the aOA in a large group of patients with mild and moderate disease is an important addition to the existing literature. Other investigators have reported mixed results for the comparison of CPAP to an OA for this outcome. Most have found significant differences favoring CPAP for mild to moderate disease,[12,14,15,18,19] but a few have not.[13,16]

All of the variables identified as predictors in our univariate analysis have been cited in the literature before.[1,17] Evaluations of predictors performed by different investigators have varied based on the outcomes predicted, the definitions used for positional apnea, the type of analysis performed (linear vs logistic regression), and whether cephalometric and other variables were included in the models.[4,7,20-24] This makes comparisons difficult, and the lack of prospective validation limits the inferences that can be made from the existing data on predictors of success.

We cannot determine with certainty why our aOA success rates were higher than those seen previously, but we believe there are two possible reasons. First, our patients' aOAs were titrated during the follow-up PSG, which is a relatively new technique that is only briefly mentioned in the 2006 AASM guidelines.[1,25,26]

Table 5—*Univariate Analysis for Successful aOA Titration*

Variable	AHI < 5	AHI > 5	*P* Value
Age	40.0 ± 8.8	42.9 ± 8.8	< .001
BMI	28.1 ± 4.7	29.3 ± 4.0	.007
ESS	12.9 ± 5.0	12.9 ± 5.2	.99
Spo_2% TST < 90%	3.6 ± 7.7	7.1 ± 12.3	.003
AHI	24.3 ± 20.2	36.5 ± 27.8	< .001
Retrognathia/micrognathia	64.0	62.6	.78
Women	16.8	9.3	.014
Positional[a]	43.1	31.8	.18

Data are presented as mean ± SD or %. See Table 1 and 2 legends for expansion of abbreviations.
[a]AHI 50% less on side when compared with supine, and AHI < 5 on side.

Although previous studies routinely allowed a variable period of time for self-adjustment,[4,7,8,12,22,27] very few specifically stated that they followed up with an in-laboratory titration. Most follow-up PSGs with the OA in place appear to have occurred at a single device setting without changes during the study. Titration in the laboratory likely provided a superior improvement in the AHI for our patients. Second, because the 1995[28,29] and 2006 AASM OA guidelines state that OAs should be considered second line, and that patients with moderate[28,29] or severe[1,2,28,29] disease should have a trial of CPAP prior to using an OA, previous studies only included patients with moderate or severe disease if they had already failed CPAP.[4,24] Even for those studies that did not explicitly state whether patients failed CPAP prior to using an OA, given the guidelines it is reasonable to assume that a portion of the patients enrolled had tried and failed CPAP. Because many of the patients seen at our clinic had not failed CPAP when their OA was prescribed, that population was not subject to the same degree of selection bias.

Our study has several limitations. Because it was retrospective, we were not able to collect variables that others found predictive of OA success, to include the maximum jaw protrusion and the cephalometric analysis that was done at the initial dental visit. Our population includes a large portion of active duty military members, so our findings may not generalize to a civilian population with different demographics and anthropomorphic features. Although the long time interval between diagnostic PSG and aOA titration likely reflects issues with timely access to dental care and PSG wait times, if the patient lost weight during this period or made additional adjustments to treatment, this could bias our results toward a better aOA titration. We also have no data on side effects, treatment preferences, adherence, or clinical failures, so it is not possible to perform a risk-benefit analysis for aOA therapy.

Table 6—*Multivariate Logistic Regression*

Variable	OR	95% CI	*P* Value
Age	0.97	0.95-1.00	.06
BMI	0.97	0.91-1.01	.20
Spo_2% TST < 90%	1.00	0.97-1.03	.94
AHI	0.98	0.97-0.99	< .001
Female	1.88	0.88-4.02	.11

See Table 1 legend for expansion of abbreviations.

In summary, in the largest patient population studied to date, we found a higher aOA success rate than previously seen. Based on our results, an aOA would be a reasonable, first-line alternative to CPAP for patients with mild disease. For patients with moderate to severe disease, our higher success rates call into question the recommendation that a CPAP failure is required prior to using an adjustable OA. Future studies should focus on measuring aOA adherence and side effects along with patient treatment preferences so that a comprehensive comparison with CPAP can be conducted.

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Dr Holley: wrote the manuscript, performed all statistical analyses, edited the manuscript, and contributed to database construction. He is the primary guarantor of the manuscript.
Dr Lettieri: contributed to intellectual design and project initiation, data collection, database construction, and editing and writing the manuscript.
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