Distribution Statement

Distribution A: Public Release.

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
POSTGRADUATE DENTAL COLLEGE
SOUTHERN REGION OFFICE
2787 WINFIELD SCOTT ROAD, SUITE 220
JBSA FORT SAM HOUSTON, TEXAS 78234-7510
https://www.usuhs.edu/pdc

THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: "The Success of Oral Appliance Therapy Based on Symptom-Driven Titration"

Name of Candidate: Ryan S. Kang
Master of Science Degree
20 MAY, 2021

THESIS/MANUSCRIPT APPROVED: DATE:

25 May 2021

Dr. Robert E. Masterson
PROGRAM DIRECTOR FORT HOOD AEGD-2
Committee Chairperson

20 MAY 21

Dr. Shelley Knowles
FORT HOOD Sleep Center - Sleep Physician
Investigator/Research Advisor

21 MAY 2021

Dr. Gen Paek
FORT HOOD AEGD-2 Prosthodontics Department
Thesis Advisor

02 JUN 2021

COL Stefan S. Olpinski
COMMANDER, US ARMY DENTAL HEALTH ACTIVITY, FORT HOOD
Dean, Fort Hood AEGD-2

Uniformed Services University of the Health Sciences
Manuscript/Presentation Approval or Clearance

Initiator

1. USU Principal Author (Last, First, Middle Initial) KANG, Ryan, S
2. Academic Title Resident, AEGD2
3. School/Department/Center Fort Hood Advanced Education in General Dentistry - 2yr
4. Phone 612-867-5686
5. Email ryan.s.kang.mil@mail.mil
6. Clearance ☐ Paper ☐ Article ☐ Book ☑ Presentation ☐ Other
7. Title Success of Oral Appliance Therapy Based on Symptom-Driven Titration
8. Intended Publication/Meeting Presentation
9. Required by 30 JUN 2021
10. Date of Submission May 2021

**Note: It is DoD policy that clearance of information or material shall be granted if classified areas are not jeopardized, and the author accurately portrays official policy, even if the author takes issue with that policy. Material officially representing the view or position of the University, DoD, or the Government is subject to editing or modification by the appropriate approving authority.

☑ Neither I nor any member of my family have a financial arrangement or affiliation with any corporate organization offering financial support or grant monies for this research, nor do I have a financial interest in any commercial product(s) or service(s) I will discuss in the presentation or publication.

☑ **The following statement is included in the presentation or publication:** The opinions or assertions contained herein are the private ones of the author(s) and are not to be construed as official or reflecting the view of the DoD or the USUHS.

☑ **The following items have been included in the presentation and/or publication:** Student and/or faculty USU affiliation. Examples: 1) LCDR Jane Doe, DMD, Resident, Naval Postgraduate Dental School and Uniformed Services University of the Health Sciences Postgraduate Dental College. 2) COL John Doe, DDS, Endodontics Program Director, Fort Bragg, NC and Associate Professor of Endodontics, Uniformed Services University of the Health Sciences Postgraduate Dental College. 3) USUHS logo included on title slide and/or poster

Chair/Department Head Approval**

Name (Last, First, Middle Initial) Masterson, Robert E

Signature

Commander Approval** (if applicable)

Name (Last, First, Middle Initial) OLPINSKI, STEFAN S.

School FORT HOOD AEGD-2

Higher approval clearance required (for University- DoD, or US Gov't-level policy, communications systems or weapons review

Signature

Uniformed Services University of the Health Sciences
Manuscript/Presentation Approval or Clearance

Service Dean Approval**	
Name (Last, First, Middle Initial)	
School	
Higher approval clearance required (for University-, DoD, or US Gov't-level policy, communications systems or weapons review)	
Signature	
Executive Dean Approval**	
Name (Last, First, Middle Initial)	
Higher approval clearance required (for University-, DoD, or US Gov't-level policy, communications systems or weapons review)	
Signature	
Vice President for External Affairs Action	
Name (Last, First, Middle Initial)	
☐ USU Approved	☐ DoD Approval Clearance Required
☐ Submitted to DoD (Health Affairs) on	
☐ Submitted to DoD (Public Affairs) on	
☐ DoD Approved/Cleared (as written)	☐ DoD Approved/Cleared (with changes)
DoD Clearance Date	DoD Disapproval Date
Signature	

CPT Ryan S. Kang
Fort Hood AEGD-2
Uniformed Services University
02 MAR 2021

Pages: 16
Abstract: 217
Words: 3958
Tables: 2
Figures: 2
References: 19
Contact: 612-867-5686
Email:ryan.s.kang.mil@mail.mil

The Success of Oral Appliance Therapy Based on Symptom-Driven Titration

Ryan S. Kang, DMD, CPT, DC, USA[1,2]

Matthew Dekow, DMD, MS, ABGD, FAGD, D-ABDSM[1]

Shelley Knowles, MD, MSBA, FAASM[1]

Gen Paek, DMD, COL, DC, USA, FACP[1,2]

[1]Carl R Darnall Army Medical Center, 36065 Santa Fe Ave, Fort Hood, TX 76544;

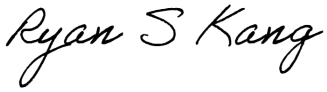
[2]AEGD-2YR, Billy Johnson Dental Clinic, 36014 Wratten Dr, Fort Hood, TX 76544;

Funding/COI: None

Acknowledgment:

1. This research project would not have been possible without the support of Dr. Rob Masterson, current Director, and Dr. John Kreider, assistant director of Fort Hood AEGD-2yr Residency.
2. Successful navigation through the eIRB process for this project was done with the assistance of Dr. Rachell Jones and Dr. Sheila Frankfurt, who furthermore provided guidance and advice during research design, statistical analysis, and Institutional Review.
3. I have obtained written permission from all persons named in the Acknowledgment.

CPT Ryan S. Kang, DMD
Fort Hood AEGD-2
Uniformed Services University
9 MAY 2021



ABSTRACT

Study Objective: Obstructive sleep apnea (OSA) is a chronic condition that could lead to debilitating, and sometimes life-threatening consequences. Oral appliance therapy (OAT) is effective in providing a conservative, non-surgical treatment option for patients diagnosed with mild to moderate OSA. The primary goal of this study is to describe a symptom-based titration protocol and determine if the patients can be effectively managed with oral appliances. ***Method:*** A retrospective chart review of patients who were treated with oral appliances was analyzed for the management of obstructive sleep apnea. Patients were self-titrated for symptomatic improvement before post-treatment titration sleep studies were conducted. ***Results:*** Our study has found 87.5% of the test population were successfully managed with oral appliances after overnight titration. 75% of the patients were titrated to AHI <5 with an average of 79.6% reduction from the baseline. Statistical studies showed patients' BMI and age at baseline PSG studies significantly influenced the reduction of AHI achieved whereas the baseline AHI did not show any significant correlation. ***Conclusion*****:** OAT can be a reliable treatment modality to treat OSA and performing a separate overnight post-treatment titration study further ensures its effectiveness. Furthermore, OAT can be an effective treatment modality even for moderate to severe OSA with post-treatment titration. ***Keywords:*** Obstructive sleep apnea, oral appliance therapy, post-treatment titration, active duty military.

BACKGROUND

Obstructive sleep apnea (OSA) is a chronic condition that could lead to debilitating, and sometimes life-threatening consequences. Clinical manifestations of OSA patients include but are not limited to mood alterations, decreased alertness, poor concentration, and increased risk of car accidents [1]. Untreated OSA is associated with long-term health consequences including hypertension, heart disease, diabetes, depression, metabolic disorders, and stroke [2]. It also presents a serious threat to one's ability to carry out daytime activity due to excessive sleepiness. More commonly, it may lead to

performance deficits, neurobehavioral impairments, impaired vigilance, mood disturbances, morning headaches, and general malaise.

Currently, positive air pressure (PAP) therapy is considered the gold standard when treating patients with OSA. However, patient compliance for the device has been repeatedly been shown to be lacking in previous studies, which subsequently leads to a decreased efficacy [3]. The alternative treatment includes behavior changes, diet modification, surgical intervention, or oral appliance therapy. Oral appliance therapy (OAT) has been shown by multiple studies to be effective in providing a conservative, non-surgical treatment option for patients diagnosed with mild to moderate OSA [3]. In another study, it has been shown that PAP and OAT showed similar health outcomes, suggesting that despite different efficacy between the two modalities, treatment usage profiles result in similar overall effectiveness [4]. Based on the published American Academy of Sleep Medicine (AASM) guidelines, oral appliances (OA) are recommended as an alternative for patients with mild to moderate OSA and patients who cannot tolerate PAP or are not adherent to the therapy [5]. It is also the recommended treatment modality for those diagnosed with severe OSA with similar adherence issues when all other alternative treatment modalities have been ineffective.

Despite numerous studies showing the effectiveness of oral appliances, there is little agreement on what is an appropriate titration protocol. Polysomnography (PSG) is required for the diagnosis of sleep apnea and its severity and is also recommended for patients after receiving OAT to ascertain improvements in their sleep [6]. Several different protocols have been proposed where overnight titration was conducted by removing the appliance from the patient's mouth and adjusting it manually [7]. Another study proposed the use of the remote motorized system (MATRx™, Zephyr Sleep Technologies) that can change the setting without waking up the patient [8]. Both approaches are considered experimental and their benefits are still not definitive.

We have adopted a clinical protocol in which the dentist performs the initial titration until symptoms improve before a follow-up PSG, with a possibility of further titration if the patient does not

adequately respond to the treatment. The primary goal of this study is to describe the symptom-based titration protocol and determine if the OSA patients can be effectively managed with oral appliances. An additional aim is to identify clinical and polysomnographic predictive factors for OAT success.

METHODS

OSA is currently diagnosed based on the Apnea-Hypopnea Index (AHI). AHI is determined by calculating the number of apneic and hypopneic events occurring per hour. Apnea is defined as cessation or near-complete cessation – greater than 70% reduction – of airflow. For this study, the definition of hypopnea was set as the nasal airflow signal excursion dropping by ≥ 30% of baseline and the duration of the drop for at least 10 seconds with ≥3% desaturation from pre-event baseline or the event associated with an arousal. At least 90% of the event's duration must meet the amplitude reduction criteria for hypopnea. Based on the AHI, patients are diagnosed as having mild (AHI 5-15), moderate (AHI 15-30), or severe (AHI >30) OSA.

Patients were initially referred to the Fort Hood Army Sleep Center from a variety of sources including primary care, ENT, dental, and other specialties. Initial PSGs were conducted either at the Fort Hood Army Sleep Center, at other military installations, or private sleep centers partnered with the Army. These standardized PSGs incorporated electroencephalogram (EEG) with the standard 10-20 hookup, submental electromyogram (EMG) electrodes for both chin and legs, electrooculogram (EOG), and electrocardiogram (EKG) for evaluating the sleep stages of the patients following the guidelines of AASM. The sleep physician followed up with the patients to discuss the results and recommended the treatment modalities best suited for each patient. The patients were then referred to a qualified sleep dentist after being prescribed an oral appliance. The main reasons for considering OAT were due to PAP intolerance, patient preference over PAP, need for combination therapy for severe OSA cases, and as a last resort upon exhausting all other treatment modalities. Patients were also referred to the dental provider for primary snoring that did not qualify for PAP therapy under Tricare. All patients were evaluated by the dentist for comprehensive dental, head and neck exams, and detailed history. If the

patients had other emergent dental needs or were otherwise unqualified for oral appliances, they were instructed to return to the referring sleep physician to receive PAP therapy.

Focused evaluation including a questionnaire for subjective symptoms was conducted through the Epworth Sleepiness Scale (ESS). ESS assesses the daytime sleepiness of the patients and their scores are categorized into groups. Those with any scores above 10 are considered to have excessive daytime sleepiness. PVS impressions of the maxillary and mandibular arches were taken as well as the George Gauge (Great Lakes Orthodontics, New York, United States) bite registrations at a comfortable and reproducible protrusion, approximately 60 to 70% of the maximum range. The occlusal record was taken with a minimum of 3mm of clearance between the arches following the manufacturer's requirements.

The [IA] Standard Sleep Appliance (ProSomnus Sleep Technologies, Pleasanton, California, United States) is indicated for reducing snoring and mild to moderate OSA by holding the lower jaw forward during sleep [9]. The device is milled with Polymethylmethacrylate (PMMA) and offers customization options to fit the patients' needs. The majority of the patients have been prescribed the [IA] sleep appliance device due to patient preference and the success in treating OSA [9]. Each patient received an initial set of upper and lower arch milled at bite registration. Through preset advancement protocol, additional advancements in 1.0mm increment from the baseline are possible.

The patients received the appliances and wore them for at least a week before the first follow-up with the dentist. Patients were given written and oral instructions and were told not to increase the advancement from the initial setting. Patients were also given morning aligners for each day of use to check for any changes in their normal occlusions. Morning aligners are thermoplasticized or milled splints for the patients to check and reorient their habitual occlusion. During the first follow-up, patients' concerns were addressed and the appliances were adjusted as needed. Patients were then instructed to self-titrate themselves until their subjective symptoms improved. Patients' feedbacks were recorded regarding their daytime sleepiness, snoring, and other issues. Another follow-up was done with the dentist one month after the delivery and patients were then referred back to the Sleep Center for post-treatment

titration studies. The titration studies provided objective data on the effectiveness of the appliances and appropriate levels of advancements to achieve a maximum therapeutic effect.

The sleep technicians were instructed to start the PSG with either the baseline advancement or the currently used set of appliances. If the current set did not eliminate snoring and/or respiratory events, the sleep technicians exchanged out the appliances to the next iteration at a 1.0 mm increment. During the post-treatment titration PSG, the technicians were instructed to titrate the oral appliance that maintained the AHI less than 5 and the lowest O_2 saturation (0_2 nadir) at or above 93%. Each setting was recorded for at least 60 minutes and raw study data was collected. Patients were encouraged to sleep in a supine position throughout the study.

Outcome Measures

Based on the post-treatment titration sleep studies, each patient was categorized into one of three outcome groups: Complete success, Partial success, and Inadequate. Complete success group is defined as those achieving AHI $\leq$5 with greater than 50% reduction from baseline AHI and 0_2 nadir no lower than 90%. The partial success group is defined by those with AHI $\leq$10 with at least 50% reduction from baseline AHI and 0_2 nadir no lower than 88%. If the patient did not meet either of the criteria, then the OAT was deemed inadequate. The treatment was also considered inadequate for those who did not have symptomatic improvement despite clinical success with titration or were unable to tolerate the recommended oral appliance setting. These patients were directed to seek other treatment modalities such as PAP.

Each patient was followed up by the sleep provider and/or sleep dentist for oropharyngeal/dental exam, appliance recheck/adjustments, and individual sleep counseling after the titration study. Patients were also referred back to the dentist if any dental issues arose from the use of the appliance including tooth movement, pain, and discomfort to soft tissue or temporomandibular joints. Oral appliance usage, comfort, and effect on sleep and daytime functions were discussed.

Records Review

The local Institutional Review Board and Defense Health Agency (DHA) approved this retrospective chart review. The subjects were selected from a pool of patients who were treated between April 2016 and July 2019. Only the patients who met the following criteria were included in the study: a) patients who have been prescribed oral appliance therapy to manage their obstructive sleep apnea; and b) patients who have completed both the baseline and post-treatment titration sleep studies with oral appliances. Those who have been fitted with the oral appliance but have not yet gone through the post-treatment titration study were excluded. Those treated with combination therapy – PAP and OA combined – were excluded to eliminate any skew in our data. Only the active-duty military patients were included and there was no age restriction on the study subjects.

Sleep study and patient data were gathered via AHLTA along with the Sleep-Dental Clinical Coordination tracker developed by the co-investigators to facilitate inter-clinic communication. AHLTA is the Military Health System (MHS) electronic health record (EHR) and is the target healthcare system of the Department of Defense (DoD). The investigators compiled the following data: baseline and post-treatment titration AHI, RDI, 0_2 nadir, ESS, sleep efficiency, % sleep time in REM, age, gender, BMI, subjective clinical responses, final oral appliance settings, and treatment outcomes.

The patients' dental records were also accessed through Corporate Dental Application (CDA). The Corporate Dental System (CDS) is the solution used to document and track appointment data, readiness, and workload for all patients treated at Tri-Services dental treatment facilities. The appointment records were reviewed to document any issues encountered with oral appliances and reported side effects.

Statistical Analysis

Comparisons between the pre- and post- AHI and RDI were tested using the Wilcoxon signed-rank test. Changes in the continuous measurements including the 0_2 nadir, sleep efficiency, and

percentage total sleep in REM were tested using the 2-tailed paired t-test. Categorical measurements between pre- and post-treatment ESS were tested using the 2-sided exact McNemar test. Associations between the post-treatment AHI and age, BMI, and baseline AHI were studied via Spearman rank correlations. For all of the statistical tests conducted, $P < 0.05$ was considered significant. The 95% confidence intervals (CIs) were selected for correlation coefficients. All statistical tests were performed with SPSS Statistics 25.0.0 (IBM, Armonk, New York, United States).

RESULTS

A total of 34 patients met the criteria but only 26 had complete records. Of those, one was treated with dual therapy and another was found to have an unreliable record. A total of n=24 met the inclusion criteria and were included as part of the study. The group of patients analyzed included 23 males and one female. The age ranged from 22 to 54, with an average age of 37. The average BMI of the patients was 29.5 ± 3.75.

The patient group's baseline PSG showed an average AHI of 13.2 ± 9.4/h. The patient demographics and baseline sleep study summaries are presented in **TABLE 1**. A total of 17 patients had mild OSA (AHI 5-15), six had moderate OSA (AHI 15 to 30) and only one had severe OSA (AHI > 30) at the time of the initial PSG studies. The average minimum oxygen saturation level at the baseline study was 87.5 ± 3%. The average proportion of total sleep time in REM sleep was 17.4 ± 6.2% (norm of 20-25%). The average sleep efficiency recorded during the baseline PSG study was 87.9 ± 6.9%. The subjective daytime sleepiness recorded using ESS had an average score of 12.3 ± 4.7 during the initial screening.

	Total (n=24)
Age (years)	37.1 ± 7.84
Gender (male/female)	23/1
Body mass index (kg/m2)	29.4 ± 3.75
Apnea-hypopnea index (/h)	13.18 ± 9.43
Respiratory disturbance index (/h)	13.62 ± 9.43
Minimum oxygen saturation (%)	87.50 ± 2.98
REM Sleep (%)	17.43 ± 6.19
Sleep efficiency (%)	87.94 ± 6.93
Epworth Sleepiness Scale	12.29 ± 4.70

Table 1 *Patient demographic and baseline polysomnographic profile of all patients*

Treatment Outcomes

Based on the predetermined success criteria, the oral appliance therapy was found to be completely successful on eleven patients and partially successful on the other ten patients. The presented OAT protocol was found to be unsuccessful among three of the patients analyzed. Of those diagnosed with mild OSA (n=17), eight patients achieved a complete success (AHI<5 and ≥50% reduction), six patients achieved a partial success (AHI ≤10 and ≥50% reduction), and three patients were ultimately unsuccessful in managing their OSA. Of those diagnosed with moderate to severe OSA (n=7), 4 achieved complete success and 3 showed partial success with no failure.

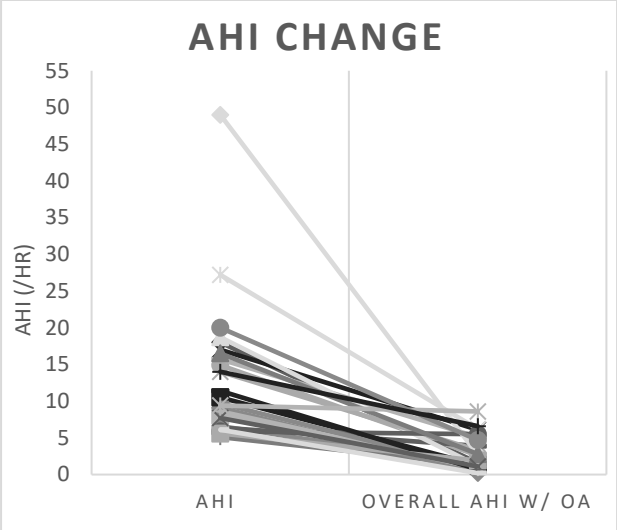


Figure 1 *Baseline and post-treatment titration AHI. Significant reduction in AHI level pre-treatment and post-treatment titration has been found.*

The post-treatment titration PSG showed a significant improvement in AHI, RDI, minimum oxygen saturation level, and the proportion of total sleep time in REM among the patients titrated with oral appliances (**TABLE 2**). 75% of the patients were titrated to AHI <5 with an average of 79.6% reduction from the baseline. All remaining patients achieved AHI <10 after titration. The biggest improvement observed was from an AHI of 49 reduced to 2.7 in a patient with severe OSA. A Wilcoxon signed-rank test showed a statistically significant change in AHI ($Z = -4.286$, $p < 0.001$) and RDI ($Z=-4.171$, $p < 0.001$). The average AHI and RDI of the patients improved from 13.2 to 2.9 (78% reduction) and from 13.6 to 3.2 (76% reduction), respectively. The average amount of advancement made during the titration was 2.2±1.4 mm and the greatest amount of advancement made was 5mm from the baseline.

There has been a significant increase in O_2 nadir ($p = 0.002$), the proportion of total sleep spent in REM ($p = 0.013$), but no significant improvement in sleep efficiency ($p = 0.677$) after post-treatment

titration. The subjective sleepiness reported through ESS has significantly improved after post-treatment titration from 12 ± 4.70 to 8 ± 4.51 ($t(23) = 5.235$, $p < 0.01$).

Despite all patients having achieved AHI below 10 initially, three patients could not be adequately managed with OAT. Two patients were recommended to return to PAP therapy due to either not tolerating the oral appliances or due to the lack of improvement in self-reported symptoms. Only one patient was deemed inadequately treated with oral appliances despite multiple titration sleep studies at various settings and subsequently recommended for PAP use.

	Baseline PSG	Post-treatment titration PSG	p-value
Apnea-Hypopnea Index	13.18 ± 9.43	2.82 ± 2.27	.000018[a*]
Respiratory Disturbance Index	13.62 ± 9.43	3.09 ± 3.06	.000030[a*]
Minimum oxygen saturation (%)	87.6 ± 2.98	89.3 ± 2.999	.002372[b*]
REM Sleep (%)	17.4 ± 6.19	21.6 ± 6.52	.013297[b*]
Sleep efficiency (%)	87.9 ± 6.92	88.7 ± 6.86	.677386[b]
Epworth Sleepiness Scale	12.29 ± 4.70	8.00 ± 4.51	.000026[c*]

Table 2 *Baseline Polysomnographic Data and post-treatment titration Polysomnographic Data in all patients (n=24)*

[a] Wilcoxon signed-rank test
[b] 2-tailed paired t-test
[C] 2-sided exact McNemar test
[*] statistically significant (p<.05)

The association between AHI and the variables

The association between the post-treatment AHI scores on a continuous scale and the demographic variables was assessed with Spearman's rank-order correlation. No gender evaluation was conducted due to having only one female patient in our sample. When the post-treatment titration AHI was expressed as a continuous variable, there was a statistically significant correlation between post-treatment AHI and age ($r_s(24) = .553$, $p = .007$) and BMI ($r_s(24) = .452$, $p = .027$). The association between the pre- and post-treatment AHI on a continuous scale was also assessed with Spearman's rank-order correlation and found a negligible correlation between them ($r_s(24) = .330$, $p = .116$).

DISCUSSION

The primary goal of this study was to present a symptom-based protocol and determine if the patients diagnosed with OSA can be effectively managed with oral appliance therapy. Additional aims were to identify clinical and polysomnographic characteristics linked with successful treatment outcomes.

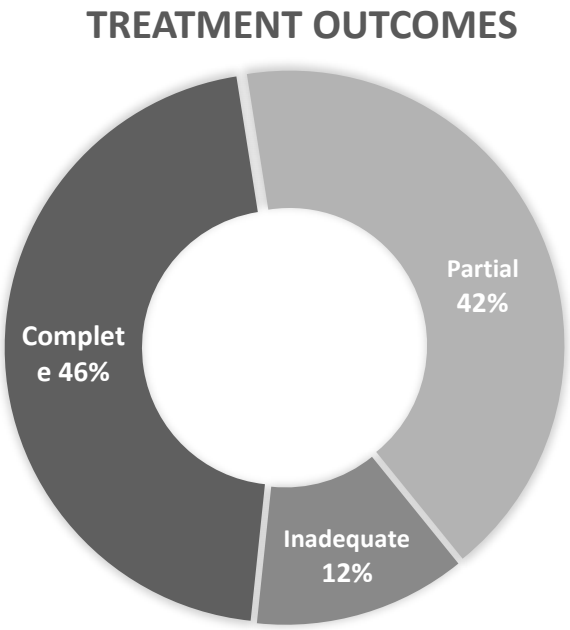


Figure 2 *Treatment outcome based on the pre-determined success criteria for oral appliance therapy. Complete success is defined as achieving AHI less than 5 with a greater than 50% reduction from baseline AHI and O_2 nadir no lower than 90%. Partial success is defined as AHI less than 10 with at least 50% reduction from baseline AHI and 02 nadir no lower than 88%.*

The patients who were diagnosed with OSA were given at least two in-lab PSG studies: one was to determine the severity of the condition and another was to ensure sleep apnea is appropriately managed by titrating custom oral appliance settings. In between the studies, the patients were given a trial period to get accustomed to oral appliances and monitor for any symptomatic improvements. Patients were advised to self-titrate until experiencing symptomatic relief prior to being referred back for titration studies.

As a result of the symptom-based titration protocol, OSA in 46% of the patients was managed with complete success (**Figure 2)**. The protocol was efficacious in achieving partial success among the other 42% of the patients. Based on a broader definition of success, 88% of the patients were successfully managed to AHI below 10. Compared to other studies, our results are in line if not slightly better than the rate of success achieved [10,11,12]. It is also noteworthy that every patient with moderate to severe OSA achieved partial to complete success in our study, suggesting OAT may be an effective treatment modality even for those with a severe diagnosis with a proper titration protocol. The OAT was found to be unsuccessful among three cases and two were due to the patients' intolerance to the oral appliances

despite adequate titration. Only one patient failed to consistently maintain AHI <10 despite multiple titration studies with oral appliances.

During the post-treatment titration PSGs, patients had to be awakened by the sleep technician to exchange the trays and increase the advancement. This was only done when the patients were in non-REM sleep to evaluate the efficacy of the degree of mandibular advancements in the REM stage. There was a modest but statistically insignificant increase in sleep efficiency (p=.67).

Patient characteristics were evaluated to determine if they have any correlation with OAT success. Lower BMI and patient age and showed a significant association with lower post-treatment AHI. Previous studies have shown patients who are younger and have lower BMI were found to be more responsive to OAT [10]. This is significant as the military population tends to be much younger and less obese than the general population. In contrast, the baseline AHI has shown no significant correlation to the change in post-treatment AHI. This finding is consistent with previous studies that also showed initial PSG results do not predict the AHI reduction achieved with OAT [12]. However, contrasting studies have shown a lower baseline AHI was indeed a significant predictor for achieving clinical success when treating OSA with oral appliances [10]. More robust studies are necessary to evaluate the impact of OSA severity on OAT success rate.

The vast majority – 83% – of the patients in this study had their oral appliances titrated above the initial settings despite having achieved subjective improvement in their sleep quality. None of the subjective measurements was found to be a good predictor of who will be more responsive to the therapy and will not need further in-lab titration. This study supports the recommendation shared by ADSM and AASM that all patients be referred for overnight titration study to determine objective success with OAT. Future studies are necessary to assess which patients may be more responsive to OAT and require less amount of post-treatment titration.

The proportion of total sleep spent in the REM stage showed significant improvement with an average of 21.6% when patients were titrated with oral appliances. Previous studies have shown the importance of achieving an appropriate amount of REM sleep during the sleep cycle [13]. Inability to achieve REM sleep between 20-25% of total sleep time has been associated with impaired memory consolidation, impaired attenuation of emotional response to aversive experiences [14,15,16]. The deleterious effects of REM deprivation can be mitigated with the help of titrated oral appliances.

Some patients who were treated with oral appliances displayed several side effects. These included jaw soreness, dry mouth, oral mucosal irritation, gingival inflammation, gingival bleeding, mucosal blisters, and skin distraction. Most of the encountered side effects are well documented and recommended to be addressed with palliative measures and escalating to higher levels of management of the complications only when necessary [17]. Despite the possibility of developing side effects, the benefits of successful oral appliance therapy far outweigh the risks.

This study was conducted with several limitations in its design. First, the patients were all drawn from the active-duty military personnel that may not represent the general population. Also, all but one of the patients in this study were male. Our sample size was small because the inclusion criteria were limited to those who have gone through both the baseline and post-treatment titration PSG studies. Because this was a retrospective review, there was no control over how each patient case was treated by either the sleep clinic or the dental clinic that handled each subject. Several of the baseline PSGs conducted on the patients were performed at various sites, which may or may not have followed the same protocol as the Fort Hood Sleep Clinic. Also, there was close to 3 months delay on average between the delivery of the oral appliances and the post-treatment titration study. Because we did not control for any change in patient habit, BMI, or compliance, such delays may or may not have affected the results of the study. For these reasons, conclusions from our study cannot be extrapolated to the greater population despite statistically significant results.

CONCLUSION

Relying on subjective changes was found to be a poor predictor of clinical success in managing OSA [18]. As described in this protocol, all of the patients were first evaluated for symptomatic improvements before titration sleep studies. Despite the subjective improvements, 83% of the patients were titrated to higher settings with an additional 2.2mm on average. The results of our study support the joint AASM&AADSM recommendation to have all patients go through a post-treatment titration study upon being fitted with oral appliances to ascertain the patient is appropriately managed [19]. Despite several limitations of our study, it was able to show that a separate overnight post-treatment titration study is necessary to maximize the benefit of oral appliance therapy.

The primary goal of this study was to describe the symptom-based protocol and determine if OSA can be effectively managed with oral appliances via post-treatment overnight titration studies. Our study has found that based on our success criteria, the protocol was successful in managing 88% of patients treated with OAT. Future studies with randomized control and greater sample size will be necessary to address the limitations of this study and be applied to the general population.

REFERENCES

1. Flemons WW, Tsai W. Quality of life consequences of sleep-disordered breathing. J Allergy Clin Immunol. 1997;99(2): S750-S756.
2. Dong JY, Zhang YH, Qin LQ. Obstructive sleep apnea and cardiovascular risk: meta-analysis of prospective cohort studies. Atherosclerosis. 2013;229(2):489-495.
3. Engleman HM, Martin SE, Deary IJ, Douglas NJ. Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea/hypopnoea syndrome. Lancet. 1994;343(8897):572-575.
4. Epstein LJ, Kristo D, Strollo PJ Jr, et al. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. J Clin Sleep Med. 2009;5(3):263-276.
5. Sutherland K, Phillips CL, Cistulli PA. Efficacy versus effectiveness in the treatment of obstructive sleep apnea: CPAP and oral appliances. J Dent Sleep Med. 2015;10;2(4):175-81.
6. Ramar K, Dort LC, Katz SG, et al. Clinical Practice Guideline for the Treatment of Obstructive Sleep Apnea and Snoring with Oral Appliance Therapy: An Update for 2015. J Clin Sleep Med. 2015;11(7):773-827. Published 2015 Jul 15.
7. Raphaelson MA, Alpher EJ, Bakker KW, Perlstrom JR. Oral appliance therapy for obstructive sleep apnea syndrome: progressive mandibular advancement during polysomnography. Cranio. 1998;16(1):44-50.
8. Tsai WH, Vazquez JC, Oshima T, et al. Remotely controlled mandibular positioner predicts efficacy of oral appliances in sleep apnea. Am J Respir Crit Care Med. 2004;170(4):366-370.
9. ProSomnus-Doctor-IFU. https://prosomnus.com/wp-content/uploads/2020/05/PRO3-061-D-ProSomnus-Doctor-IFU-1.pdf.
10. Holley AB, Lettieri CJ, Shah AA. Efficacy of an adjustable oral appliance and comparison with continuous positive airway pressure for the treatment of obstructive sleep apnea syndrome. Chest. 2011;140(6):1511-1516.
11. Fleury B, Rakotonanahary D, Petelle B, et al. Mandibular advancement titration for obstructive sleep apnea: optimization of the procedure by combining clinical and oximetric parameters. Chest. 2004;125(5):1761-1767.
12. Krishnan V, Collop NA, Scherr SC. An evaluation of a titration strategy for prescription of oral appliances for obstructive sleep apnea. Chest. 2008;133(5):1135-1141.
13. Kryger M, Roth T, and Dement WC. Sixth ed. Principles and Practice of Sleep Medicine. Saunders/Elsevier; 2017.
14. Rasch B, Born J. About sleep's role in memory. Physiol Rev. 2013;93(2):681-766.
15. Walker MP. The role of sleep in cognition and emotion. Ann N Y Acad Sci. 2009;1156:168-197.
16. Amzica F, Lavigne GJ, Sessle BJ, Chouchou F. Chapter 2: Sleep Neurobiology. In: Lavigne GJ, Cistulli PA, Smith MT, eds. Sleep Medicine for Dentists. 2nd ed. Quintessence Publishing; 2020: 9-14.
17. Sheats RD, Schell TG, Blanton AO, et al. Management of side effects of oral appliance therapy for sleep-disordered breathing. J Dent Sleep Med. 2017;4(4):111-125.
18. Almeida FR, Parker JA, Hodges JS, Lowe AA, Ferguson KA. Effect of a titration polysomnogram on treatment success with a mandibular repositioning appliance. J Clin Sleep Med. 2009;5(3):198-204.
19. Ramar K, Dort LC, Katz SG, et al. Clinical Practice Guideline for the Treatment of Obstructive Sleep Apnea and Snoring with Oral Appliance Therapy: An Update for 2015. J Clin Sleep Med. 2015;11(7):773-827. Published 2015 Jul 15.