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ORIGINAL

Impact of a Mandibular Advancement Device on Sleep Stages and Micro-Awakenings: A Case Series Study

Impacto de un Dispositivo de Avance Mandibular en las Etapas del Sueño y Microdespertares: Estudio de Serie de Casos

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ABSTRACT

Introduction: snoring and obstructive sleep apnea (OSA) are prevalent sleep-related breathing disorders with significant social and medical implications. Mandibular advancement devices (MADs) are a recognized treatment option for managing snoring and mild to moderate OSA; however, their impact on sleep architecture requires further investigation.
Objective: this study aimed to evaluate the effects of MAD placement on total sleep duration, sleep stage distribution, and micro-awakenings.
Method: a total of 12 participants (66,67 % male, 33,33 % female) underwent polysomnography before and 60 days after MAD placement. Sleep duration in different stages and the frequency of micro-awakenings were analyzed. Descriptive and inferential statistical analyses were conducted using t stutends.
Results: after MAD placement, total sleep duration increased, along with prolonged stage 2 and 3 NREM sleep ($p > 0,05$). However, the number of micro-awakenings, particularly those associated with respiratory events and snoring, also increased significantly ($p < 0,05$).
Conclusion: the MAD contributed to an increase in total sleep duration and deeper sleep stages, which may indicate a beneficial effect on sleep architecture.

Keywords: Snoring; Sleep Apnea Obstructive; Mandibular Advancement Splints; Sleep Stages.

RESUMEN

Introducción: el ronquido y la apnea obstructiva del sueño (AOS) son trastornos respiratorios del sueño frecuentes, con importantes implicaciones médicas y sociales. Los dispositivos de avance mandibular (DAM) son un tratamiento ampliamente reconocido para el control del ronquido y la AOS leve a moderada; sin embargo, su impacto en la arquitectura del sueño aún no se ha explorado completamente.
Objetivo: evaluar el efecto del uso de un DAM sobre la duración total del sueño, la distribución de las etapas

del sueño y la frecuencia de los microdespertares.
Método: se realizó una polisomnografía a 12 participantes (66,67 % hombres, 33,33 % mujeres) antes y 60 días después de la colocación del DAM. Se analizaron la duración del sueño en diferentes etapas y la frecuencia de los microdespertares. Se aplicaron análisis estadísticos descriptivos e inferenciales utilizando la prueba t de Student, con un nivel de significancia de $\alpha = 0,05$.
Resultados: el uso del DAM se asoció con un aumento en la duración total del sueño y una mayor duración de las etapas 2 y 3 del sueño NMOR ($p > 0,05$). Sin embargo, también se observó un aumento significativo en el número de microdespertares, especialmente aquellos asociados con eventos respiratorios y ronquidos ($p < 0,05$).
Conclusión: aunque el DAM parece favorecer una mayor duración total del sueño y promover etapas de sueño más profundas, el aumento en los microdespertares sugiere posibles alteraciones en la continuidad del sueño.

Palabras clave: Ronquidos; Apnea Obstructiva del Sueño; Férulas de Avance Mandibular; Etapas del Sueño.

INTRODUCTION

The etiology of sleep-related respiratory disorders is multifactorial. Non-apneic snoring is characterized by audible, high-frequency oscillations of the pharyngeal soft tissues and partial, rapid, alternating occlusions and openings of the pharynx without episodes of apnea.[1] Snoring frequently leads to significant social consequences and severe medical sequelae, and it is considered the primary symptom, and sometimes the only one, of obstructive sleep apnea (OSA).[1] One of the accepted treatments for controlling snoring and mild or moderate OSA is the placement of a mandibular advancement intraoral device, which could influence sleep physiology. This project aimed to describe sleep stages in terms of duration and micro-awakenings after the placement of a new mandibular advancement device for snoring control.[2]

Snoring is a common acoustic phenomenon that can precipitate social disharmony, often leading to significant social consequences, either by disrupting a harmonious relationship between two people or, sometimes, bringing underlying disharmony to the surface. Additionally, snoring is believed to have serious medical consequences and is the main symptom, and sometimes the only one, of sleep apnea. In some patients, it can be a precursor to sleep apnea.[2] Snoring affects approximately 20 % of the adult population; 24 % of men and 14 % of women, with the prevalence rising to 50 % in men over 60 years of age.[3,4] A study conducted in Colombia indicates that the prevalence of sleep disorders is 27 %, making it a public health problem, although there are no exact data on the frequency of sleep diseases in the country.[5,6] The underlying mechanism of snoring involves sleep-induced hypotonia, which causes vibration of the soft tissues in the upper airway, a drop in pharyngeal pressure, and narrowing of the airway column during inspiration. Snoring can occur during both inspiration and expiration, and the spectral properties of snoring can change drastically within a single breath.[7] The disturbance can originate at different anatomical levels and may be intermittent or continuous. Furthermore, this health issue can be a symptom or lead to a more severe disorder known as OSA. The implementation and maintenance of effective treatment for snoring is of vital importance for individuals suffering from these disorders.[8]

One of the treatment options for snoring, after considering weight control and sleeping position, is the placement of mandibular advancement devices (MAD). Accurate assessment of the effect of mandibular advancement oral appliances on sleep in snoring subjects is crucial to achieving optimal results. It has been known for several decades that sleep is an important modulator of hormone release, glucose regulation, and cardiovascular function. In particular, slow-wave sleep, which is believed to be the most restorative stage of sleep, is associated with a decrease in heart rate, blood pressure, sympathetic nervous activity, and cerebral glucose utilization compared to wakefulness.[9] This project will compare the duration in minutes of sleep stages and the number of micro-awakenings before and after the placement of a MAD.

METHOD

Design

This descriptive observational case series study was conducted based on the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure rigor and transparency in observational research.[10] The study protocol was approved by the Bioethics Committee of the Autonomous University of Manizales (Colombia). Code: 092-2019 and adhered to the regulations of Resolution N 8430 governing health research, in accordance with the Helsinki Declaration.[11]

Context

This study was conducted at the sleep laboratory of the Autonomous University of Manizales (Colombia) and focuses on the prevalence and social and medical impact of sleep-related respiratory disorders, particularly

snoring and OSA. These disorders underscore the need for identifying effective management strategies. Although snoring is common, it is more than just an innocuous acoustic phenomenon; it is linked to a wide range of social and medical consequences, from disrupting relationships to exacerbating severe conditions such as OSA. Given the significant prevalence of this disorder worldwide, especially among men over 60 years of age, it has become a priority in public health research. In this context, MAD has emerged as a widely accepted therapeutic option for managing both snoring and mild to moderate OSA. However, there is still a need for in-depth evaluation of how these devices not only reduce the severity of snoring but also influence sleep quality and cause physiological changes. This study aims to compare the duration in minutes of sleep stages and the number of micro-awakenings before and after the placement of a MAD.

Participants

The study included 12 patients who were selected based on intent, due to the economic cost and the complexity of the diagnostic tests for mandibular advancement devices (MAD). The eligibility criteria considered participants over 18 years of age with chronic oral snoring symptoms, which were not structurally determined, assessed through a screening process based on the following sensitivity indicators:

a) Self-reported snoring or interrupted breathing during sleep, either by self-report or by roommate's report.

b) Snoring episodes recorded using a snoring detection app (App: Roncolab®).

On the other hand, exclusion criteria included subjects with fewer than eight teeth in their mouth, active periodontal disease, temporomandibular joint disorders, structural respiratory diseases, issues with the nasal septum, turbinates, adenoids, polyps, hypertrophic tonsils, elongated soft palate, or epiglottis, which required evaluation by an otolaryngologist.

Intervention

The intervention involved the installation of a MAD in participants, aimed at controlling snoring and OSA.[12] The MAD was composed of two plates, one for the upper jaw and another for the lower jaw. To create the device, alginate impressions of the dental arches were taken, and the molds were cast using type III dental plaster, following the manufacturer's instructions.[13,14] The plates were then thermoformed, and the vestibular and lingual borders were trimmed. Afterward, individual fitting tests were conducted to assess retention, areas of soft tissue compression, and any misfits or issues with the device. Once the occlusion was checked, participants were instructed to advance their jaw 3 to 5 mm, and guides were used to assemble the device in this protrusive position. Control visits were scheduled every 20 days to monitor participant comfort, assess improvements, evaluate adaptability, and make any necessary repairs or even replace the device if required.

Outcome Measures

The primary outcome measures for this study were focused on assessing the changes in sleep duration across various stages before and after the installation of the MAD.[14,15] Sleep quality was evaluated by measuring the duration of each sleep stage, including light sleep, deep sleep, and rapid eye movement (REM) sleep, both at baseline and 60 days after the participants began using the MAD nightly.[16,17]

The polysomnography, a comprehensive sleep study, provided detailed information about the sleep architecture, including sleep onset latency, total sleep time, and the percentage of time spent in each sleep stage.[18,19] These metrics were essential in evaluating the effectiveness of the MAD in improving sleep quality, by observing whether there were any changes in the duration of deep sleep or REM sleep, which are typically the most restorative stages.[20] Additionally, the study aimed to identify potential disruptions or improvements in sleep continuity, including the frequency of micro-awakenings or awakenings during the night.

Bias

This case series study presents several potential biases that could impact on the validity and generalizability of the results. First, there is a selection bias, as the inclusion and exclusion criteria limit the sample to patients with specific characteristics, reducing the ability to generalize the findings to the broader population with OSA or sleep-related respiratory disorders. Additionally, the small sample size of only 12 patients increases the likelihood that the results may not be representative or that any observed effects could be due to chance. Another potential bias is information bias, as the diagnosis and follow-up of snoring are based on self-reports from patients or their bed partners, which may not always be accurate. While a mobile application is used to record snoring episodes, this method does not fully eliminate measurement errors. Observer bias is also relevant, as the lack of a control group makes it difficult to determine whether changes observed in sleep stages are solely attributable to the MAD device or to other factors. Furthermore, the follow-up visits and adaptation process of the device may influence the outcomes due to the direct interaction between researchers and

participants. A temporal bias is also present, as the study only includes a 60-day follow-up, limiting the ability to assess the long-term effects of the MAD. Finally, interpretation bias may arise if external factors, such as stress or medication use, which could also affect sleep quality, are not controlled for in the study. To mitigate these biases, it would be beneficial to include a control group, increase the sample size, extend the follow-up period, and adopt a more rigorous approach to data collection and analysis.

Sample Size

The sample size calculation was performed using G*Power software, which determined that a total of 12 participants was sufficient for this observational study, assuming a moderate effect size (d = 0,5) and a significance level of 0,05. The analysis indicated a statistical power of 35 %, which, while lower than the typical 80 % power generally sought for definitive conclusions, still provides valuable preliminary insights into the sleep disturbances associated with snoring and OSA.[21,22] The limited power is primarily due to the small sample size, which is a common limitation in early-stage research or studies investigating less common conditions. Despite this limitation, the findings from this study offer a foundation for future research with larger sample sizes, which would improve statistical power and further explore the relationship between MAD and sleep disturbances. Additionally, the homogeneity of the sample and the careful control of potential confounding variables helped maintain the internal validity of the study, reducing variability and enhancing the reliability of the results.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27.0 for Windows. The normality of the data distribution was assessed using the Shapiro-Wilk test, and homogeneity of variances was evaluated with Levene‘s test. Descriptive statistics, including the mean, were calculated. Inferential analysis was performed using the Student‘s t-test, with a significance level set at α = 0,05 for all analyses.

RESULTS

Table 1 presents a total of 12 subjects were included in the study, with 66,67 % (8 subjects) being male and 33,33 % (4 subjects) female. The age range for males was between 27 and 64 years (mean = 41,75; SD = 13,03), while for females, it ranged from 30 to 55 years (mean = 48,5; SD = 11,42).

After the installation of the MAD for snoring control, a significantly longer total sleep duration was observed compared to baseline measurements (p > 0,05). Additionally, the duration of stages 2 and 3 of NREM sleep also showed an increase in minutes (p > 0,05).

Table 1. Difference in average total sleep time and duration of sleep stages 1, 2, and 3 (REM and NREM sleep) before and after the installation of a MAD for snoring control (n = 12)

Measure	Before (mean)	After (mean)	p-value
Total sleep time (min)	412,8	429,5	0,19
Stage 1 sleep duration (min)	22,6	13,5	0,08
Stage 2 sleep duration (min)	199,2	207,38	0,86
Stage 3 sleep duration (min)	70,25	80,58	0,64
NREM sleep duration (min)	292,1	301,4	0,28
REM sleep duration (min)	138,5	128,13	0,81

Note: REM = Rapid Eye Movement; NREM = Non-Rapid Eye Movement.

There was an increase in the number of micro-awakenings after the installation of the MAD. The difference in the number of micro-awakenings associated with snoring events reached statistical significance (table 2).

Table 2. Difference in the average number of total micro-awakenings and those with respiratory and snoring events, before and after the installation of an MAD for snoring control (n = 12)

Measure	Before (mean)	After (mean)	p-value
Total micro-awakenings	62,2	79,67	0,11
Micro-awakenings with respiratory events	4,33	9,25	0,08
Micro-awakenings with snoring events	8,75	14,08	0,04*

Note: * statistically significant difference.

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DISCUSSION

In this study, we observed an increase in total sleep duration following the installation of the MAD ($p < 0,05$). This result suggests a positive effect of the MAD on sleep duration. Sleep plays a vital role in numerous physiological processes, including hormonal regulation, glucose homeostasis, and cardiovascular health.[23] Adequate sleep helps maintain the balance of hormones that regulate appetite, such as leptin and ghrelin, which are crucial for managing hunger and satiety signals. Notably, research has shown that insufficient sleep duration is associated with an increased risk of weight gain and obesity, making the importance of sleep duration in metabolic regulation even more significant.[24] Consequently, the increase in total sleep duration observed in this study can be seen as a potential benefit in managing weight and improving metabolic health, as better sleep patterns are closely linked to more favorable hormonal and metabolic outcomes.[25,26]

Furthermore, we found that NREM sleep duration also increased ($p > 0,05$) after the installation of the MAD, which is another positive clinical finding. NREM sleep encompasses stages 2 and 3, which are characterized by a reduction in the electroencephalographic rhythm, but still maintain muscle tone and the absence of eye movements. Stage 4, deep sleep, is the most restorative phase of sleep and is associated with a significantly lower electroencephalographic rhythm, absence of eye movements, and greatly reduced or absent muscle tone. This phase of sleep is essential for physical and mental recovery and accounts for approximately 25 % of total sleep time.[27,28] The observed increase in NREM sleep could be considered a beneficial outcome of the MAD, as it suggests a shift toward more restorative stages of sleep, potentially enhancing the overall quality of rest.

However, our study also revealed an increase in micro-awakenings following the installation of the MAD, both with respiratory events and snoring events ($p < 0,05$). Micro-awakenings are brief disruptions in sleep that fragment the sleep cycle, preventing it from reaching its full restorative potential. Research has consistently shown that an increased frequency of micro-awakenings is linked to difficulties in both initiating and maintaining sleep, and can also result in daytime sleepiness.[29] Despite the positive effects on sleep duration and NREM sleep, the increase in micro-awakenings could negatively affect sleep quality by reducing the overall continuity of rest. This highlights a crucial point: while the MAD may help extend sleep duration, it may not necessarily improve sleep quality in all aspects. Micro-awakenings could be a sign of discomfort or maladaptation to the device, or they could reflect an underlying issue with the device's interaction with the user's sleep physiology.[30,31]

These findings present a somewhat paradoxical scenario: while the MAD appears to improve sleep duration, particularly by increasing NREM sleep, the rise in micro-awakenings suggests that the device may have unintended consequences that undermine its overall effectiveness.[13,32,33] These contradictory results could be attributed to several factors, including the limitations inherent in the study design. For instance, the use of a convenience sample without randomization may have introduced selection bias, affecting the generalizability of the findings. Additionally, the small sample size limits the statistical power of the study, making it difficult to draw definitive conclusions about the broader impact of the MAD on sleep patterns.[34,35,36] Furthermore, the measurement of sleep disturbances through polysomnography, while comprehensive, may not fully capture all the nuances of how micro-awakenings interact with other sleep parameters, such as the individual's response to the MAD or other sleep-related variables.[36,37]

Moreover, the increase in micro-awakenings could suggest that while the MAD is effective in promoting longer sleep duration and deeper NREM sleep, the device might require further adjustments for optimal comfort and efficiency. Future studies should explore whether customizations or modifications to the MAD could reduce the occurrence of micro-awakenings and improve overall sleep quality.[38,39] Additionally, larger randomized controlled trials (RCTs) are necessary to validate the findings and examine the long-term effects of MAD use, focusing not only on sleep duration but also on sleep continuity, restorative sleep, and the physiological mechanisms underlying the increase in micro-awakenings.[40]

In summary, while the present study indicates that the MAD has the potential to improve sleep duration and increase time spent in restorative NREM sleep, the increase in micro-awakenings warrants further investigation.[41] The study's design limitations, including the use of a convenience sample and the lack of randomization, highlight the need for more robust research to explore the full range of effects that MADs may have on sleep architecture and quality. Future research should seek to optimize MAD treatment protocols to minimize disruptions in sleep continuity and maximize the restorative benefits of sleep for individuals suffering from snoring and mild to moderate obstructive sleep apnea.

CONCLUSIONS

In conclusion, the use of a MAD for snoring control resulted in an overall increase in total sleep duration, as well as longer stage 2 and 3 NREM sleep. These findings suggest a potential benefit of the MAD in promoting deeper and more restorative sleep. However, a significant increase in micro-awakenings associated with both respiratory events and snoring was also observed, which may indicate a potential disruption in sleep continuity. While the MAD appears to enhance certain aspects of sleep architecture, the increased frequency of micro-

awakenings highlights the need for further investigation to optimize its effectiveness and ensure improvements in both sleep duration and overall sleep quality. Future studies with larger sample sizes and randomized designs are necessary to confirm these findings and refine MAD interventions for better therapeutic outcomes.

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CONFLICT OF INTERESTS

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