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SCIENTIFIC SECTION

Non-apneic snoring and the orthodontist: the effectiveness of mandibular advancement splints

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Objective: Non-apneic snoring is a very common problem, which impacts on all family members. Oral appliances have been used in the management of snoring. These posture the mandible forward during sleep, opening the airway and so reducing the potential for noise generation. This articles aims to objectively evaluate the effectiveness of mandibular advancement splints (MAS) in non-apneic snorers.

Design: Prospective clinical trial.

Setting: University Dental Hospital and School.

Subjects and methods: 35 consecutively referred adults with proven non-apneic snoring.

Interventions: Subjects were fitted with a removable, adjustable Herbst MAS.

Main outcome measures: Questionnaires determined changes in snoring incidence, daytime tiredness, any side effects and their duration. Eleven subjects completed overnight domiciliary sleep recordings of oxygen saturations, pulse rates and sound profile, before and 1 month after fitting the MAS.

Results: The questionnaires and sleep recordings suggested that the MAS significantly reduced snoring incidence ($p < 0.05$) and improved sleep quality. Daytime tiredness, as assessed by the Epworth Sleepiness Scale, was significantly reduced ($p < 0.001$). Initial side effects of muscular and TMJ discomforts were mostly resolved after 1 month of appliance wear.

Conclusions: Use of a MAS improves snoring incidence and sleep quality in most patients with non-apneic snoring.

Key words: Dental devices, mandibular advancement splints, sleep disordered breathing, non-apneic snoring

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Introduction

Snoring is a very common problem with prevalence rates as high as 40% of the UK population,[1] rising to more than 50% in middle aged males.[2] The effects of snoring on other family members make the total number affected by this problem far greater. However, non-apneic snoring is more than just a socially embarrassing problem. Consequences can include daytime hypersomnolence due to the sleep fragmentation caused by the increased respiratory effort,[3] cognitive impairment[4] and the possibility of long-term vascular disease, although the role of snoring in the etiology of this condition is controversial.[5] Snoring is a recognized symptom of the much less common medical condition obstructive sleep apnea (OSA).

Snoring is characterized by audible, high frequency oscillations of the soft palate, pharyngeal walls, epiglottis and tongue, occluding and opening a narrowed pharyngeal airway.[6] During sleep there is a progressive reduction in all muscle activity, which results in the tongue relaxing and the airway narrowing.[7] This reduction in pharyngeal dimension is a universal phenomenon, but the degree of narrowing varies considerably between individuals. With the narrowing of the pharynx, the speed of airflow increases (Bernoulli's Theorem), producing a relative vacuum that sucks the walls closer together and increasing the airways resistance.[8] This increase in airflow velocity can cause vibration of the soft tissues, which results in the sound of snoring. Awake subjects with sleep-related breathing disorders have been shown to have already restricted airways[9] and this narrowing has been regarded

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as one of the most important contributing factors. The abnormal narrowing found in subjects with sleep-related breathing disorders may be due to anatomical factors, i.e. obesity,[10] a large soft palate,[11] a large tongue,[12] bimaxillary retrusion,[12] or to abnormal soft tissue function and increased collapsibility.[8] A supine sleeping posture is thought to further reduce the airway by allowing the effect of gravity on the soft tissues encouraging the tongue and soft palate to fall back against the posterior pharyngeal wall.

Management of the sleep-related breathing disorders is dependent on an accurate diagnosis, often utilizing polysomnography, within a multidisciplinary setting.[13] Treatment of non-apneic snoring includes conservative measures of weight loss,[14] alcohol restriction[15] and sleep position training,[16] as well as interventive measures of oral appliances,[17–21] nasal appliances[22] and surgery.[23]

The oral appliances that are used hold the mandible in a protruded position. The rationale behind this treatment involves the tongue and soft palate being drawn forwards thus maintaining the airway during sleep[24] and placing the lateral pharyngeal walls under tension.[25] Subjective reports suggest successful outcomes for the use of oral devices in non-apneic snorers, however, there is very little objective data available.[21,26]

The aim of this prospective study were, therefore, to assess subjectively and objectively the effectiveness of mandibular advancement splints in subjects with non-apneic snoring.

Subjects

Thirty-five dentate adults (20 males, 15 females) with non-apneic snoring (confirmed by polysomnography) who had been consecutively referred to the department of orthodontics for the construction of a custom made removable, adjustable Herbst mandibular advancement splint (MAS; Figure 1) formed the basis of this study.

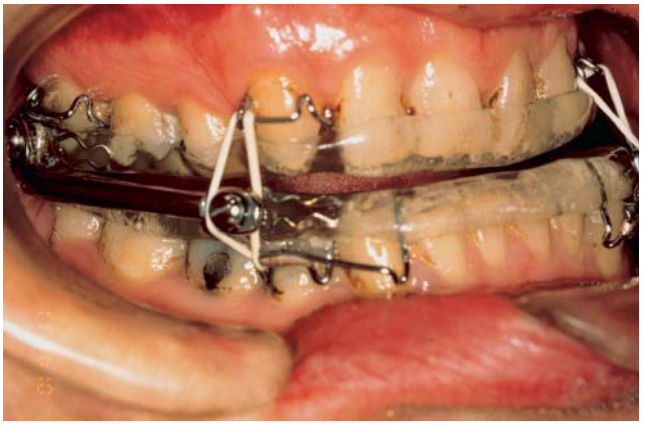

Figure 1 The Herbst Mandibular Advancement Splint

Their diagnosis had been made in a multidisciplinary setting and the treatment of choice for these subjects was a MAS, rather than palatal surgery.

The MAS consisted of two separate upper and lower full coverage clear acrylic splints, which were connected buccally with bilateral rod and tube devices: the telescopic Herbst attachments. These attachments allowed opening, protrusive and some lateral excursive movements, but no retrusive movement. The appliance was designed to advance the mandible by the maximum comfortable amount of protrusion possible, with minimum vertical opening. An advancement of at least 5 mm was attempted. Anterior intermaxillary elastics were fitted to prevent mandibular opening. The appliance was only worn whilst sleeping.

All subjects received a comprehensive patient information leaflet prior to entry into the study and written consent was gained from all individuals. Ethical approval was attained from ELCHA research ethics committee.

Method

The study was in two parts: questionnaires and mini-sleep studies.

Questionnaires

At the initial visit, a questionnaire was completed by the subject in order to assess demographic data and base line snoring incidence. The Epworth Sleepiness Scale, described by Johns was used to identify initial daytime tiredness.[27] This questionnaire evaluates the likelihood of the subject falling asleep in different situations (Appendix 1). This was completed at the first visit and was repeated following use of the appliance for 1 month. Unfortunately, not all subjects returned for the review appointment, reducing the questionnaire sample size to 29. At the 1-month review appointment subjects also completed a questionnaire regarding side effects and overall outcome of the treatment (Appendix 2). Short- (2–3 days) and longer-term (1 month) responses were compared.

Mini-sleep study

Eleven subjects completed unsupervised overnight domiciliary sleep recordings before and 1 month after fitting the appliance. This allowed time for patients to adapt to the appliance, and for any necessary adjustments to its comfort or protrusion to be carried out.

Snoring noise levels, oxygen saturation and pulse rate were recorded, as suggested by White *et al.*,[28] utilizing a microphone connected to a noise level meter and a pulse oximeter (Ohmeda, Biox 3740®, Datex-Ohmeda,

Hatfield, UK). This pulse oximeter has been shown to be suitable for domiciliary overnight recordings.[29] The microphone, which recorded respiratory sound levels, was placed at the same vertical height and approximately 50 cm from the subject's head. The subject was requested to secure the pulse oximeter finger probe to their index finger, switch the microphone on and start the computer. An analogue-digital converter (ADC PL4.02) was used to transfer the data to a lap top computer in real time, where up to 8 hours of data of sound profile and oxygen saturations were synchronized and stored using a specialist software program (Picolog, Pico Technology Ltd®, St Neots, UK). The computer automatically stopped recording after 8 hours, but could be stopped by the subject on awakening. At both the initial appointment where the appliance was fitted and the review appointment, subjects were shown how to use the equipment prior to leaving the clinic and were given comprehensive instructions to take home. Subjects were asked to replicate the position of the equipment and abstain from alcohol on the evenings of the recordings.

Respiratory noise levels were assessed at the 95 and 5 percentile levels, as suggested by Dalmasso *et al.*[30] The L5 level is the sound pressure level exceeded 5% of the time in the test period and represents the highest noise levels. This level has been found to be a clinically useful descriptor of sleep quality.[31] The L95 is the noise level exceeded 95% of the test period and represents background noise. These distinctions allow snoring sounds to be distinguished from background noise levels.

Percentage mean and minimum oxygen saturation levels, as well as 4% drops in the overnight oxygen saturation were calculated for each patient. Oxygen desaturations are known to occur with virtually every apneic event and there is close correlation reported between the 4% dips per hour and the Apnoea Hypopnoea Index (AHI),[32] that is the number of episodes of breath holding or 50% reduced ventilation for longer than 10 seconds per hour of sleep.

A graphical display on the computer allowed visual assessment of the whole night and identification of artefactual sounds that were unrelated to the other variables.

This pilot kit was built in house as an affordable alternative to the more expensive, commercially available equipment. However, it was bulky and heavy, required a degree of computer literacy to use, and some subjects felt incapable or couldn't manage to use the equipment or only completed one study. This reduced the sample size for the objective assessment of the appliance to 11. Although bias could have been introduced by this reduction in number, the reasons for this group being restudied had no links with the aims of the study as there is no known correlation between non-apneic snoring and computer literacy! At the time this study was carried out, there was no equipment specifically designed to record snoring and few authors have recorded objective data for non-apneic snorers. Stradling *et al.* used a voice activated tape recorder and reduced snores per hour from 193 to 20 using a vacuum formed MAS,[33] but no indication as to the severity of the snoring could be determined.

Statistics

Data were analyzed using SPSS for Windows, version 6.1 (SPSS Inc., Chicago, Illinois, USA). Median and ranges were calculated for differences in daytime tiredness as shown by the Epworth sleepiness score and the duration of side effects. Medians and ranges were calculated for the overnight sleep study recordings in order to assess differences in noise level and oxygen saturations.

Statistical evaluation was performed using the Wilcoxon matched-pairs signed ranks test for differences in Epworth sleepiness score, noise levels and oxygen saturation, and the McNemar test was used to identify differences in side-effects in the short and longer term. Statistical significance was set at the 5% level for all tests.

Results

Demographic data

The age at presentation of the 35 patients varied between 29 and 61 years for males, and 28 and 60 years for females, with a mean of 44 years in each group. The mean body mass indices (BMI) for both male (28.4, SD 2.8) and female (26.8, SD 5.3) groups indicate that the majority of patients were overweight although not obese ($BMI = Ht^2/Wt$).

Assessment of questionnaires

Unfortunately, not all subjects returned their questionnaires, resulting in a reduction of sample size to 29. The demographic details of this were group were similar to those of the original sample with a mean BMI of 27.4 and a mean age of 45 years.

Epworth Sleepiness Scale Questionnaire. The difference in pre- and post-treatment Epworth Sleepiness Scale scores is demonstrated in Figure 2.

The mean pre-treatment score of 9.4 (SD 5.0) reduced to 6.9 (SD 4.8) demonstrating a change of 2.5 (SD 2.5; $p < 0.001$). Nearly all subjects had a reduction in score, implying that these patients were much less sleepy following use of the appliance.

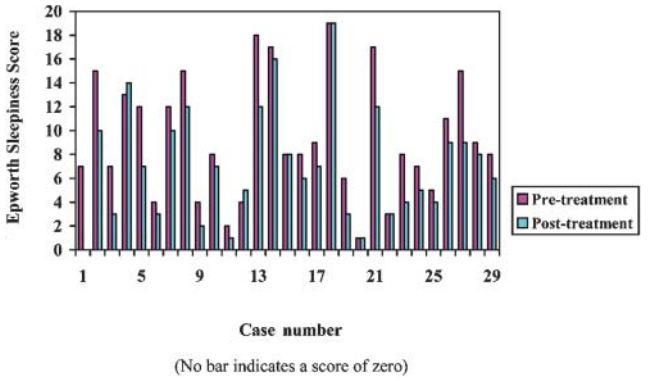

Figure 2 Epworth sleepiness scores pre- and post-treatment

Table 1 Side-effects in the short and longer term after use of the MAS

Question ($n=29$)	Short term (2–3 days)	Longer term (1 month)	Significance
1 Muscular discomfort	20 (69%)	5 (17%)	***
2 TMJ discomfort	22 (76%)	8 (28%)	***
3 Wakes with abnormal bite	11 (40%)	8 (28%)	NS
4 Dry mouth	8 (28%)	5 (17%)	NS
5 Excessive salivation	6 (21%)	1 (3%)	NS

Statistical significance: ***$p<0.001$.

Outcome questionnaire. Side-effects associated with MAS wear and their duration were assessed by the outcome questionnaire (Appendix 2) and the results are shown in Table 1.

At 1 month, subjective compliance rates were good with 26 out of the 29 patients who returned the questionnaire still wearing the appliance. Subjects were asked whether they thought the advantages outweighed the disadvantages: 90% stated that they did. Three subjects were unhappy wearing the Herbst splint and the reasons given for this dissatisfaction were the appliance aesthetics (2) and TMJ problems (1).

Many subjects complained of initial muscular and TMJ discomfort (69 and 76%, respectively). However, this had reduced significantly after 1 month (17 and 28%, respectively). In one subject, wear of the MAS exacerbated an existing TMJ problem. Once the MAS therapy was stopped, these symptoms returned to their initial state.

Mini-sleep study

Eleven subjects completed both the pre-treatment sleep recording and the second recording 1 month later with the appliance *in situ*. The demographic details for this group are similar to the original sample with a median BMI of 27.5, although they were a slightly younger age group with a median age of 41.5 years. Table 2 shows statistically significant reductions ($p<0.05$) in snore noise level (L5) with use of the MAS with the background noise level (L95) remaining fairly constant. The median number of dips in oxygen saturation larger than 4% reduced with appliance wear, although this was always within normal limits. Figure 3 demonstrates that all subjects, with the exception of patient 4, showed a reduction in noise level whilst wearing the MAS. This bar chart shows the difference in snoring noise once the changes in background noise level have been taken into account. Patient 4 showed a small increase in noise level of 7 mV.

Figures 4 and 5 show the pre- and post-treatment overnight sleep recordings for one subject. The green spikes represent sudden increases in the noise level associated with snoring and were seen more frequently in the pre-treatment tracing, particularly in the early part of the night. With the MAS *in situ*, the overnight profile for this subject showed considerable change with a great reduction in noise output, although the sound level was still increased when compared to the background noise level. The dips in oxygen saturation (red), which are closely associated with the noise level in the pre-treatment recording, were much reduced in the post-treatment recording.

Table 2 Median oximetry and sound level results ($n=11$)

Variable ($n=11$)	Pre-MAS		Post-MAS		Diff. of median	Statistical significance
	Median	Range	Median	Range		
Mean % O_2	95	93–97	95	93–96	0	NS
Minimum % O_2	89	86–94	90	86–94	–1	NS
O_2 dips >4%/hour	2.8	0.0–129.5	1.7	0.0–37.8	1.1	NS
L5 Snoring (mV)	449	53–1212	161	9–442	288	*
L95 Background (mV)	61	0–322	12	0–334	49	NS
L5-L95 (mV)	240	51–1015	75	9–417	165	**

Statistical significance: *$p<0.05$; **$p<0.01$.

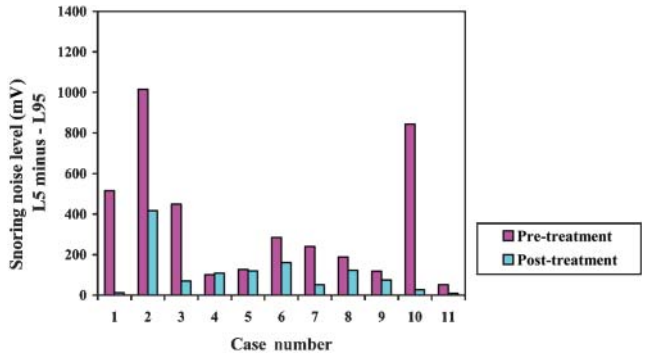

Figure 3 Pre- and post-treatment snoring noise levels without background noise (L5 minus L95)

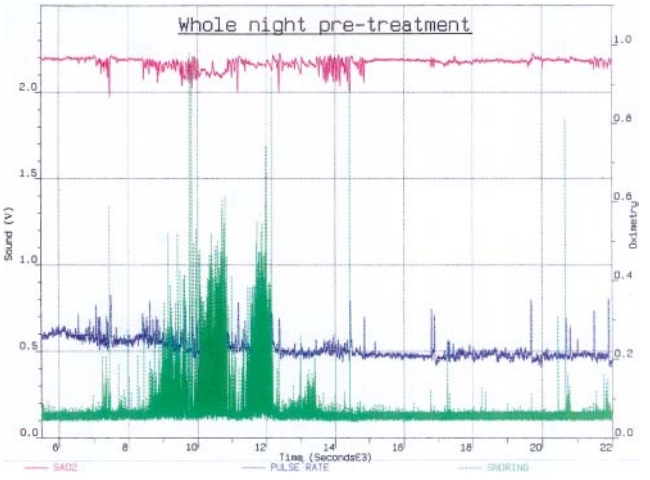

Figure 4 Pre-treatment whole night sleep recording tracing for one subject, showing noise level in green, pulse in blue and oxygen saturation in red. Snoring is most frequently seen in the early part of the night and is associated with dips in oxygen saturation

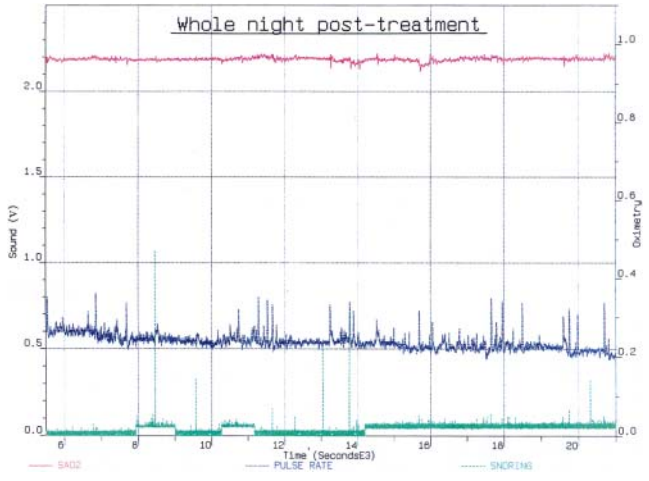

Figure 5 Whole night sleep recording tracing with the MAS *in situ*, showing noise level in green, pulse in blue and oxygen saturation in red. Noise level and dips in oxygen saturation are minimal and much reduced for this subject compared to his pre-treatment recording

Discussion

One of the treatment regimes available for the management of sleep-related breathing disorders is the MAS.[21] Although prospective, randomized, clinical trials on subjects with OSA have suggested that the MAS is an effective and popular treatment technique in mild to moderate cases when compared with nasal continuous positive airway pressure[18,34] or surgical uvulopalatopharyngoplasty,[35] less work has been carried out to assess objectively the outcome of this therapeutic technique in non-apneic snoring patients. Previous studies have shown placebo or passive appliances to be significantly less effective than postured devices[20,26] and, therefore, only the effect of the activated appliance was assessed in this study.

Demographics

The subjects were generally overweight adults (mean BMI = 27.6, range 21.4–41.5) with an age range of 28–61 years. The literature indicates this group reflects the prevalence and age range of snoring in the general population.[1]

Daytime tiredness

The Epworth sleepiness scale (ESS) was described by Johns and measures daytime tiredness on a scale of 0–24.[27] In our study, before treatment, the sample group proved to be reasonably sleepy with a median pre-treatment ESS score of 9.4 with a range of 1–19. Following treatment, the scores for most of subjects were significantly reduced, suggesting that the MAS improved daytime sleepiness. This agrees with other studies where sleepiness is reduced with use of the MAS in subjects with OSA[20,33] and sleepy snorers.[36]

Appliance wear

Subjective compliance rates for this study were very good with most of our patients who returned the questionnaire, still wearing the splint. This may be due in part to the appliance design as adjustable appliances are thought to have improved treatment success and fewer compliance failures than non-adjustable devices.[37] Marklund *et al.* reported that subjects with their appliances adjusted or replaced experienced better long-term effects than subjects still using their original devices.[38] However, the results of those subjects in this study who failed to return for review and complete the questionnaire are unknown. One month is a short time and follow-up is required to determine the true long-term compliance rates for this appliance. Compliance with mandibular advancement

devices varies in the literature. McGown *et al.*, in a recent questionnaire-based study, reported that only 55% of patients were still using the MAS regularly, despite the fact that 97% still considered it to be effective.[39] Reasons given for ceasing treatment included discomfort, social circumstances, dental treatment and a lack of perceived efficacy. However, the authors showed that non-apneic snorers with daytime tiredness were likely to continue MAS use, whereas the presence of daytime symptoms did not predict usage in subjects with OSA.

In our study, appliance aesthetics was recorded by two individuals as the reason for ceasing treatment with the splint. Other side effects noted in this study and by other authors include awakening with an abnormal bite, a dry mouth and excessive salivation, and it has been suggested that these may prevent early acceptance of the appliance.[21,40]

Ninety per cent of subjects stated that the advantages of wearing the appliance outweighed any side effects. Mehta *et al.*, in their randomized controlled study of subjects with varying severities of OSA, showed that 96% of their group were happy with the perceived advantages of the MAS.[20]

Mini-sleep study

Only eleven subjects managed to complete both pre- and post-treatment overnight sleep recordings: this was a reflection of the bulk and complexity of the equipment.

In order to accurately determine the treatment effects of the MAS with domiciliary sleep studies the subject is required to reproduce his sleep conditions on two separate occasions and this is very difficult to control. However, the use of domiciliary equipment produces a more natural sleep pattern and removes the chance of the hospital 'first night effect', as described by Agnew *et al.*[41] Domiciliary sleep recordings have been used successfully by many authors as a less expensive, yet reliable, method of recording sleep quality.[42] The addition of a sound profile to the pulse oximetry has been shown to increase the sensitivity when recording subjects with milder sleep-related breathing disorder.[28] Series *et al.* showed no significant differences between hospital and home monitoring in assessing non-apneic snoring, but noted that the subjects spent less time asleep and had higher snoring noise levels, whilst in hospital.[42] However, home monitoring has less specificity and sensitivity, and sleep time and position are less accurately determined. The overnight recordings in this study were not used as diagnostic tools, merely to assess changes in oxygen saturation and sound profile as a result of treatment with the MAS.

Pre-treatment status. The mean pre-treatment L5 sound level confirmed that these subjects were snorers. One subject's L5 level was only 53 mV; however, this does not necessarily imply he is not a snorer as night-to-night variability is well recognized, especially in patients with mild sleep-related breathing disorders.[43] One patient showed a particularly high sound profile with L5 values reaching 1212 mV on a background noise level of 197 mV. This was not associated with any dips in oxygen saturation and, therefore, any apneic event.

Authors have reported on the close correlation of 4% oxygen dips with the AHI.[32] The AHI can only be determined accurately at full polysomnography; however, the 4% dips in oxygen saturation indicate the possibility of an apneic event in a domiciliary setting. The median number of 4% oxygen dips per hour was 2.8 for this sample, confirming that this group were non-apneic snorers. However, one subject demonstrated 129 dips per hour. This might suggest that this patient was suffering from mild OSA despite his initial diagnosis from polysomnography.

Post-treatment status. Ten out of the 11 patients had a significant reduction in snore noise sound level with use of the MAS. The median L95 values, which indicate background noise, show no statistical differences between the pre- and post-treatment groups. This would suggest that, for the majority of subjects, the 'test' rooms were standardized and that the drop in sound level represents a true reduction in noise with use of the MAS.

The large reduction in snoring noise levels may explain the significant difference in ESS scores seen, as it has been shown that it is multiple arousals during sleep that are responsible for daytime hypersomnolence.[44] There was no significant change in oxygen saturation levels which would be expected in a non-apneic group whose oxygen levels remained within the normal range. One subject had an increase in the sound level and demonstrated increases in the number of 4% oxygen dips per hour of sleep (27.1–37.8), yet reported he felt better with treatment. This patient also demonstrated a slight increase in post-treatment ESS score (13–14). This may be as a result of a 'placebo effect' on the patient where he wished to respond to treatment, or it is possible that his initial pre-treatment recording, which suggested a quiet night, was not a true representation of a normal night's sleep for this patient without the MAS.

This subject demonstrates that subjective and objective assessments do not always correlate, as suggested by Miljeteig *et al.*[45] and confirms the importance of post-treatment sleep monitoring and follow-up.

Limitations of this study

This study has some limitations. Not all subjects returned for their review appointment or returned their questionnaire and, therefore, the true compliance rate of this study is unknown. One month is a short space of time,

and the longer-term effects of this splint regarding efficacy and side effects need to be determined. Only a small sample completed both overnight recordings. The equipment used in this study was bulky, heavy and required a degree of computer literacy. This is not always available in a middle-aged population, which is the age this condition generally effects. Smaller, more portable devices are now becoming available, which are less reliant on the patient's computer skills. However, the expense of this equipment may limit its widespread use. The results of this study do, however, reflect those of other work with a larger sample size.[26]

Conclusions

- Use of a MAS significantly improves snoring incidence and sleep quality in the majority of patients with non-apneic snoring.
- Subjects tend to be less sleepy during the day as a result of MAS wear.
- Initial side effects of muscular and TMJ discomfort are mostly resolved after 1 month of appliance wear.
- The majority of subjects considered the benefits of MAS wear outweighed any disadvantages.

Acknowledgements

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Authors and Contributors

JB was responsible for the conception and design of the studies. The data was collected by AMS. Both JB and AMS were responsible for the analysis and interpretation of the data. AMS drafted the articles, which were revised by JB. Both JB and AMS approved the final version to be published. JB is the guarantor.

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Appendix 1: Epworth Sleepiness Questionnaire

The Epworth Sleepiness Scale

How likely are you to doze off or fall asleep in the following situations (in contrast to just feeling tired)?
Even if you haven't been in some of these situations recently, try to work out how they would have affected you.
Use the scale to choose the most appropriate number for each situation:
0 = would NEVER doze
1 = SLIGHT chance of dozing
2 = MODERATE chance of dozing
3 = HIGH chance of dozing

Situation	**Chance of dozing**
Sitting and reading	.....
Watching TV	.....
Sitting, inactive in a public place (e.g. theatre or a meeting)	.....
As a passenger in a car for an hour without a break	.....
Lying down to rest in the afternoon when circumstances permit	.....
Sitting and talking to someone	.....
Sitting quietly after lunch without alcohol	.....
In a car, while stopped for a few minutes in traffic	.....
Total score	.....

Thank you for your co-operation

Appendix 2: Outcome Questionnaire

Please complete all the questions below by circling the correct answer:

(A) Short term: Within the first few days, did you experience any of the following?

1. Discomfort in the muscles of your face? Y/N
2. Discomfort in your jaw joint? Y/N
3. An abnormal bite when you first woke up, that may have interfered with eating your breakfast? Y/N
4. A dry mouth during the night? Y/N
5. Excessive salivation during the night? Y/N

(B) Now: Do you still have any of the following symptoms?

1. Discomfort in the muscles of your face? Y/N
2. Discomfort in your jaw joint? Y/N
3. An abnormal bite when you first woke up, that may have interfered with eating your breakfast? Y/N
4. A dry mouth during the night? Y/N
5. Excessive salivation during the night? Y/N

(C) Do you consider that the benefits outweigh the disadvantages? Y/N