Thorax 1998;**53**(Suppl 2):S58–S64

Oral appliances for the management of snoring and obstructive sleep apnoea

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Introductory article

A short term controlled trial of an adjustable oral appliance for the treatment of mild to moderate obstructive sleep apnoea

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Background. *Although oral appliances are effective in some patients with obstructive sleep apnoea (OSA), they are not universally effective. A novel anterior mandibular positioner (AMP) has been developed with an adjustable hinge that allows progressive advancement of the mandible. The objective of this prospective crossover study was to compare efficacy, side effects, patient compliance, and preference between AMP and nasal continuous positive airway pressure (nCPAP) in patients with symptomatic mild to moderate OSA.* ***Methods.*** *Twenty four patients of mean (SD) age 44.0 (10.6) years were recruited with a mean (SD) body mass index of 32.0 (8.2) kg/m^2, Epworth sleepiness score 10.7 (3.4), and apnoea/hypopnoea index 26.8 (11.9)/hour. There was a two week wash-in and a two week wash-out period and two treatment periods (AMP and nCPAP) each of four months. Efficacy, side effects, compliance, and preference were evaluated by a questionnaire and home sleep monitoring.* ***Results.*** *One patient dropped out early in the study and three refused to cross over so treatment results are presented on the remaining 20 patients. The apnoea/hypopnoea index (AHI) was lower with nasal CPAP 4.2 (2.2)/hour than with the AMP 13.6 (14.5)/hour ($p<0.01$). Eleven of the 20 patients (55%) who used the AMP were treatment successes (reduction of AHI to <10/hour and relief of symptoms), one (5%) was a compliance failure (unable or unwilling to use the treatment), and eight (40%) were treatment failures (failure to reduce AHI to <10/hour and/or failure to relieve symptoms). Fourteen of the 20 patients (70%) who used nCPAP were treatment successes, six (30%) were compliance failures, and there were no treatment failures. There was greater patient satisfaction with the AMP ($p<0.01$) than with nCPAP but no difference in reported side effects or compliance.* ***Conclusions.*** *AMP is an effective treatment in some patients with mild to moderate OSA and is associated with greater patient satisfaction than nCPAP. (Thorax* 1997;**52**:362–8)

Both snoring and obstructive sleep apnoea are caused by partial or complete collapse of the pharyngeal airway during sleep[1] due to a combination of reduction in muscle tone at sleep onset and structural factors such as obesity, retrognathia, tonsillar hypertrophy, and macroglossia. In some subjects increased respiratory effort required to overcome pharyngeal collapse[2] causes sleep fragmentation which then leads to excessive daytime sleepiness[3] (sleep apnoea syndrome). As our understanding of obstructive sleep apnoea (OSA) has improved, it is recognised that this condition has a wide spectrum of severity. At the mild end of this spectrum are those subjects with snoring and no sleep disturbance, while at the severe end are subjects with repetitive episodes of apnoea with up to 400–500 awakenings per night. Many subjects fall in the midst of this spectrum with variable amounts of snoring and OSA. This group has a wide range of severity of daytime sleepiness not closely related to objective severity of disease.[4 5]

Nasal continuous positive airway pressure (CPAP) is a highly effective and safe treatment for both snoring and sleep apnoea[6] but long term nasal CPAP may be an unacceptably cumbersome form of treatment for snoring alone, or for obstructive sleep apnoea not complicated by excessive daytime sleepiness. Even for subjects with confirmed sleep apnoea and excessive daytime sleepiness, nasal CPAP treatment is poorly tolerated by some patients[7] and there is a need for an alternative and less obtrusive treatment which is safe and cheap. In recent years oral appliances have attracted considerable interest for the treatment of snoring and OSA.[8 9] These devices, inserted intraorally at night, anteriorly displace the position of the mandible and/or tongue with the aim of enlarging the retroglossal space and thus reducing

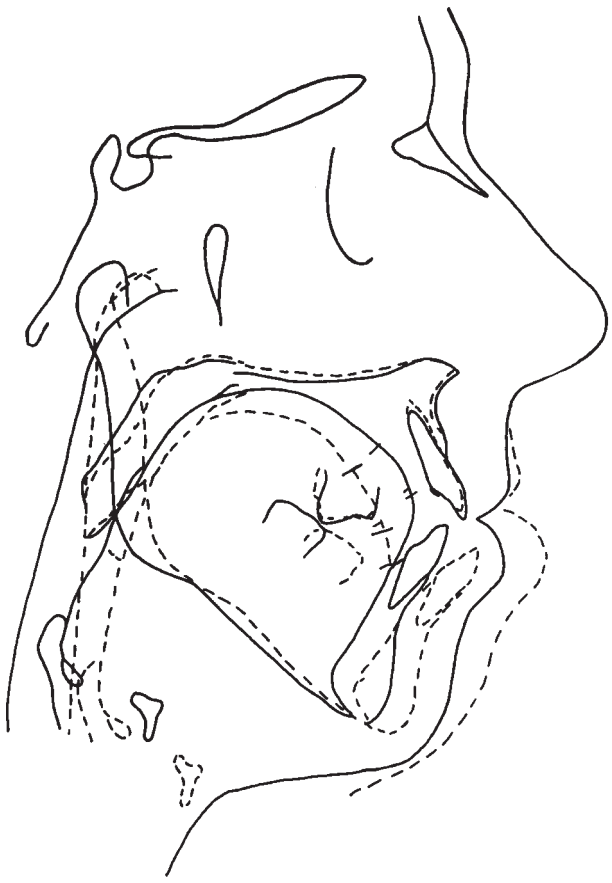


Figure 1 Lateral cephalometry with and without mandibular advancement.

the degree of upper airway obstruction and pharyngeal collapse (fig 1).[8] This article reviews the current evidence for the efficacy of oral appliances for treating snoring and OSA and discusses the role these devices might play in our current management of these conditions.

Background

Throughout the last decade oral appliances have been investigated as a possible new approach for the management of snoring and OSA. There are now over 20 different oral appliances which can broadly be divided into two basic designs: those which aim to reposition the mandible and those which aim to advance the tongue. Most devices are mandibular advancement devices which attach to one or both dental arches and pull the mandible forward to about 75% of the maximum possible (fig 2). These devices fix either just to the teeth or cover the gums as well, but the relative merits of each design is not known. Orthodontic type devices attaching to the teeth alone may cause teeth movement, but fully covering the teeth and gums may encourage caries and gingivitis. Construction of these devices usually requires dental impressions and manufacturing by a dental laboratory and an orthodontic type device can cost over £500. However, there are at least three generic mandibular advancement devices available over the counter (approximate cost £40) which are made from a thermolabile material that can be directly moulded to the patient's teeth.[10] The second group of oral appliances are the tongue retainers which are designed to keep the tongue in an anterior position during sleep

Figure 2 An adjustable anterior mandibular advancement device.

by means of negative pressure in a soft plastic bulb.[11] Unlike the mandibular advancement device, the tongue retainer can be used in edentulous patients.

Mechanism of action

The postulated mechanism of action of oral appliances is to increase the anteroposterior diameter of the retroglossal space by anterior displacement of the jaw and tongue and thereby reduce the degree of pharyngeal collapse[8]; however, this may not necessarily be the case in all individuals. Rodenstein[12] described the characteristic shape of the pharynx in patients with OSA and showed that the transverse diameter tends to be narrower than in normal subjects. Therefore, in healthy controls the pharynx is elliptical with the long axis orientated in the coronal plane, whereas in snorers and those with OSA it is either circular or elliptical but with the long axis orientated in the sagittal plane (fig 3). In this situation forward displacement of the jaw might reduce the pharyngeal lumen by stretching the ellipse and draw in the lateral walls further, hence increasing upper airway resistance. In some snorers and subjects with mild OSA the narrower dimension may be in the anteroposterior direction and an oral appliance designed to increase this diameter should help.

Oral appliances for the treatment of snoring

Primary snoring (without sleep fragmentation and daytime sleepiness) is a much more common problem than sleep apnoea. Conservative measures to reduce snoring such as treatment of rhinitis and nasal obstruction, weight loss and alcohol restriction are important initial recommendations, but frequently these measures are ineffective. Soft palate surgery—for example, uvulopalatopharyngoplasty (UPPP)—is designed to increase the volume of the pharynx by resecting pharyngeal wall tissue and the soft palate.[13] Although there are several studies reporting an improvement in subjectively assessed snoring with UPPP,[14–16] the few studies using objective measures of snoring have found only small

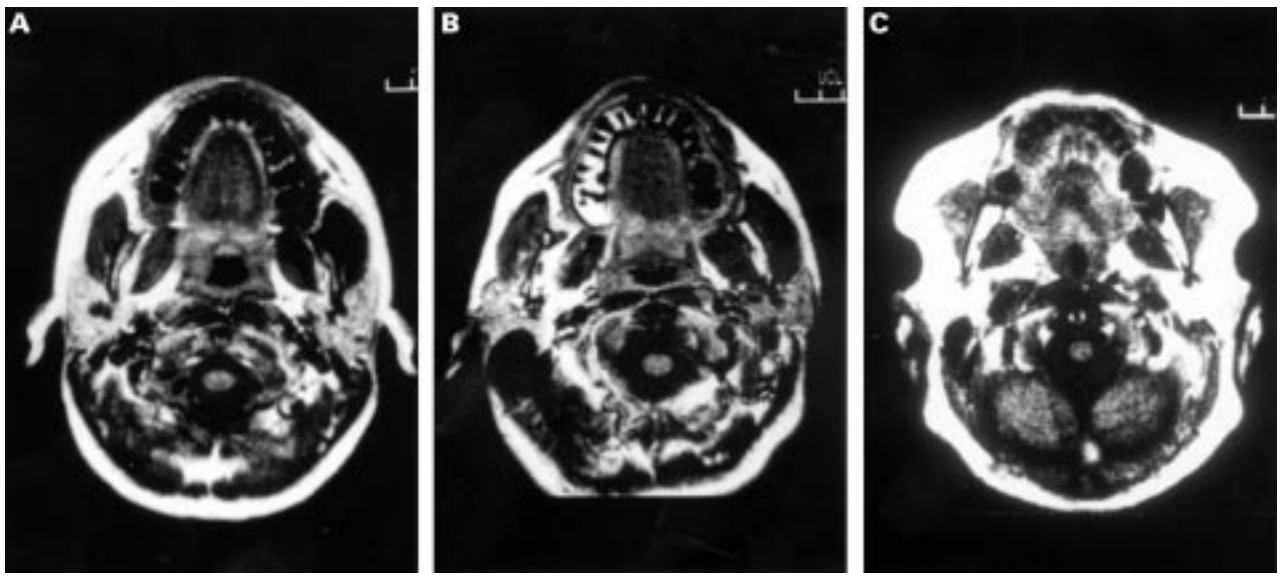


Figure 3 Transverse magnetic resonance images of the pharynx in (A) a normal subject, (B) a subject with simple snoring, and (C) a subject with sleep apnoea syndrome. In the normal subject the pharynx has an elliptical shape with the long axis orientated in the coronal plane. In the sleep apnoea subject, and to a lesser extent in the snoring subject, the pharynx has a round or elliptical shape with the long axis orientated in the sagittal plane. (Images courtesy of Dr DO Rodenstein.)

improvements[17–19] and its current role in the long term management of antisocial snoring is unclear.

Most studies exploring treatment efficacy have depended on subjective reports by the patients themselves[10 20 21] or bed partners[22] as the method of assessing snoring. An objective reduction in snoring level was shown in a study by O'Sullivan *et al*[23] who examined the acute effects of a mandibular advancement device on snoring during a one night study. A more recent study[24] of 15 patients already established on a mandibular advancement device for control of snoring also showed an improvement in snoring when measured objectively using a surface throat microphone. These 15 subjects were studied over two nights using a portable sleep monitoring device at home, both with and without their mandibular advancement device in place. There was a clear effect on snoring measured as either number of snores/hour (median 193 versus 20 snores/hour, $p<0.0001$), time spent snoring (818 seconds versus 50 seconds, $p<0.0002$), or mean sound level across the night (1.5 versus 0.2 arbitrary units, $p<0.0001$). This study also included >4% oxygen saturation dips/hour and, using measurement of pulse transit time, recorded indirect arterial beat to beat blood pressure, providing an index of autonomic "arousal"[25] and a measure of inspiratory effort.[26] There were significant reductions ($p<0.05$) in all these measures with the mandibular advancement device including a 30% reduction in inspiratory effort whilst the device was in, implying that the decrease in snoring was due to an opening up of the airway (hence reduction in upper airway resistance) rather than just a tautening of the pharyngeal walls with less vibration.

Oral appliances for the treatment of sleep apnoea syndrome

Schmidt–Nowara published a detailed review of the use of oral appliances in patients with sleep apnoea up to 1994 which included 20 publications reporting the effects of oral appliances on OSA in 304 patients.[8] Data for this review were derived from computer searches of the clinical literature (Medline, July 1994). The 19 papers identified using the authors' search strategy are summarised in table 1. Most of these publications were case series and there were no randomised controlled studies. All studies showed varying improvements in the average apnoea/hypopnoea index (AHI) with the oral appliance. The review includes several different types of oral appliances including both tongue retaining and mandibular advancement devices with no consistent differences found among these various devices. Most studies have focused mainly on improvements in respiratory disturbance during sleep and the results are variable. Seventy per cent of patients in these studies had at least 50% reduction in AHI although many did not correct to normal levels. Some patients did not improve or became worse. Fourteen papers presented data for individual patients and 13% of these had a greater AHI with treatment than without.[10 11 22 30–33]

Controlled trials

Since Schmidt–Nowara's review there have been three crossover studies comparing mandibular advancement devices with nasal CPAP.[41–43] Clarke[41] reported results on 21 subjects with a wide range of sleep apnoea severity (AHI 33.86 (14.3)). The device used advanced the mandible by approximately 65% of maximal protrusion and reduced the AHI by 39% compared with 60% reduction on nasal CPAP (AHI on nasal CPAP, 11.15 (3.93)). Normally, in subjects with confirmed OSA one would expect the AHI on nasal CPAP to be near zero, and the high AHI on treatment in this study raises concerns that perhaps the methods used for nasal CPAP pressure titration underestimated the actual pressure needed for adequate treatment. Sleepiness was assessed using a non-validated sleep questionnaire on sleep quality as well as excessive daytime somnolence, and these symptoms were improved equally with both nasal CPAP and the mandibular advancement device. Each treatment was only given for two weeks which may be insufficient time for subjects to acclimatise to treatment and achieve maximal benefit. In addition, the order of treatment was not randomised and most subjects had the nasal CPAP treatment first due to delays with construction of the oral appliance.

Table 1 Review of papers published on the effects of oral appliances on obstructive sleep apnoea and sleepiness[8]

Reference	No of patients	Study design	Device	Mean AHI		AHI with treatment		Sleepiness
				With appliance	Without appliance	<50% initial AHI (% of patients)	AHI>20 (% of patients with initial AHI>20)	
Bernstein[27]	1	Case report	MAD	35	9	100	0	
Bonham[22]	12	Case series	MAD	54	34	58		9/12 improved, patient report
Calderelli[28]	16	Case series	TRD			56		
Cartwright[29]	14	Case series	TRD	56	27	71	43	14/14 improved, patient report
Cartwright[30]	16	Case series	TRD	54	33	50	73	
Cartwright[31]	12	Case series	TRD	37	17	75	17	
Cartwright[11]	15	Case series	TRD	27	11	73	57	
Clark[32]	24	Case series	Herbst	48	12	87	20	Improved, subjective scale
Eveloff[33]	19	Case series	Herbst	35	13		33	
George[34,35]	9	Case series	NAPA	45	11	78	29	
Ichioka[36]	14	Case series	MAD	32	9	100	9	Improved, symptom score
Kloss[37]	7	Case series	Esmarch	37	12	71	40	Improved, patient report
Knudson[38]	2	Case series	MAD	30	7	100	0	
Nakazawa[21]	12	Case series	MAD	50	19			10/12 improved, patient report
O'Sullivan[23]	51	Case series	MAD	32	18			
Schmidt-Nowara[10]	20	Case series	Snore guard	47	20	75	31	18/35 improved, subjective scale
Lowe[20]	1	Case report	MAD	57	2	100	0	Improved, patient report
Lyon[39]	15	Case series	MAD	47% decrease				
Meier-Ewert[40]	44	Case series	Esmarch	50	23	59		Improved, vigilance test
Total	304					70	39	

AHI = apnoea/hypopnoea index; MAD = mandibular advancement device; TRD = tongue retaining device; NAPA = nocturnal airway patency device.

The first randomised crossover study in which nasal CPAP was compared with a non-adjustable mandibular advancement device[42] studied patients with mild to moderate sleep apnoea (AHI 24.6 (8.8)). Each treatment period was four months with a two week washout period. As in the study by Clarke,[41] nasal CPAP produced greater improvement in the AHI (mean 17.6 pretreatment, 3.6 on nasal CPAP) than the oral appliance (19.7 pretreatment, 9.7 with oral appliance) but, in contrast to the above study, the oral appliance was less effective than nasal CPAP in relieving symptoms of excessive daytime sleepiness ($p<0.05$). The authors of this study have developed the design of their oral appliance and have now produced a new mandibular advancement device with an adjustable hinge to allow progressive advancement of the mandible to achieve an optimal mandibular position. The introductory article[43] reports the results of a randomised crossover study of this adjustable oral appliance with nasal CPAP in the treatment of an unselected group of patients with mild to moderate OSA.

Introductory article

The aim of this crossover study was to compare nasal CPAP with an adjustable mandibular advancement device for the treatment of mild to moderate OSA. As well as measuring objective efficacy (AHI and sleep quality) on both treatments, the authors also used a detailed questionnaire to assess symptoms including snoring, patient satisfaction, side effects and measured subjective sleepiness using the Epworth Sleepiness Scale,[44] but did not measure sleepiness with an objective technique. Twenty four subjects were recruited for the study with the following inclusion criteria: an AHI of 15–55/hour of sleep from the original diagnostic study and at least 10 teeth in each of the maxillary and mandibular arches. The mandibular advancement device used for this study is adjustable, allowing progressive advancement of the mandible to achieve an optimal mandibular position (anterior mandibular positioner, AMP). Perhaps surprisingly for a study on sleep apnoea treatment, excessive daytime sleepiness was not covered in the inclusion criteria. Subjects were randomised to treatment with the AMP or nasal CPAP and were treated for four months on each treatment with a two week washout period in between. Questionnaires and polysomnography were performed prior to each treatment period and repeated at the end.

The results are presented on 20 patients because four subjects dropped out of the study. One patient dropped out early in the AMP treatment period because of refusal to return for follow up and three refused to cross over from the AMP to nasal CPAP (two treatment successes, one treatment failure). Table 2 shows the respiratory disturbance indices and sleep quality measurements before and with the AMP, and table 3 shows these measurements before and after nasal CPAP. Both nasal CPAP and the AMP device significantly ($p<0.005$) reduced the AHI, although, as might be expected, the

Table 2 Mean (SD) home sleep monitoring data before and with the anterior mandibular positioner (AMP)

	Before AMP	AMP
AHI*	25.3 (15.0)	14.2 (14.7)
Apnoea index*	8.2 (9.9)	3.6 (6.4)
% TST supine	47.1 (28.2)	42.3 (28.4)
Desaturations <90% (no/h)	13.7 (11.7)	12.1 (16.9)
Minimum Sa_{O_2} (%)	78.7 (8.6)	75.8 (11.6)
Total sleep time (min)	390 (65.9)	402 (72.1)
Sleep latency (min)	18.1 (10.4)	14.8 (11.2)
Sleep efficiency (%)	85.9 (5.7)	87.9 (5.5)
NREM (%)	83.9 (13.2)	85.4 (7.1)
REM (%)	16.1 (13.6)	13.1 (6.0)
Awakenings (n)	29.6 (12.8)	23.8 (12.4)

TST = total sleep time; Sa_{O_2} = arterial oxygen saturation; NREM = non-rapid eye movement sleep; REM = rapid eye movement sleep. *$p<0.005$.

Table 3 Mean (SD) home sleep monitoring data before and with nasal continuous positive airways pressure (nCPAP)

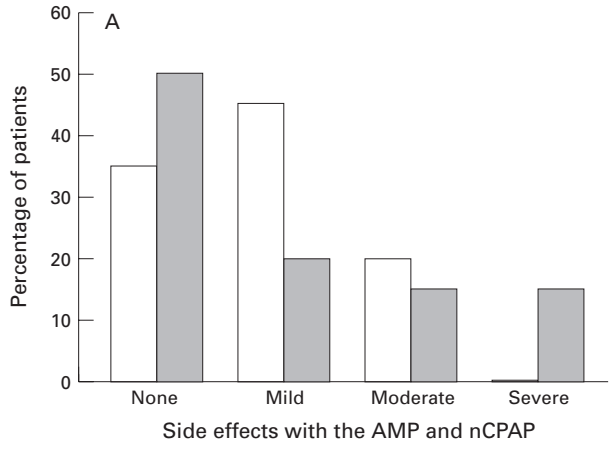
	Before nCPAP	*nCPAP*
AHI*	23.5 (16.5)	4.0 (2.2)
Apnoea index*	9.0 (9.5)	0.7 (1.3)
% TST supine	32.5 (21.4)	42.7 (35.5)
Desaturations <90% (no/h)*	19.4 (21.8)	0.4 (0.6)
Minimum Sao_2 (%)*	76.8 (9.1)	87.7 (2.4)
TST (min)	340.4 (104.2)	387.9 (110.8)
Sleep latency (min)	12.8 (8.9)	14.6 (17.3)
Sleep efficiency (%)	88.4 (8.9)	89.8 (3.4)
NREM (%)	81.2 (16.6)	85.4 (8.8)
REM (%)	17.3 (15.0)	12.1 (5.4)
Awakenings (n)	27.1 (19.2)	21.1 (9.0)

TST = total sleep time; Sao_2 = arterial oxygen saturation; NREM = non-rapid eye movement sleep; REM = rapid eye movement sleep. *p<0.005.

magnitude of improvement in AHI was greatest with nasal CPAP (mean 23.5 pretreatment, 4.0 on nasal CPAP) compared with the AMP (25.3 pretreatment, 14.2 with the AMP). Despite this improvement in AHI, use of the AMP did not improve the <90% oxygen saturation dip rate (<90% Sao_2 dips/hour) which had a mean value of 13.7 on the control night and 12.1 on the AMP treatment night. In contrast, the mean <90% Sao_2 dips/hour fell from 19.4 on the control night to 0.4 on the nasal CPAP treatment night. Snoring was only assessed subjectively in this study and 55% of subjects felt their snoring had improved with the mandibular advancement device compared with 100% with nasal CPAP.

Although nasal CPAP was more effective at improving the AHI, sleep arterial oxygen desaturation and snoring, both treatments were equally effective at significantly improving daytime sleepiness as measured by the Epworth Sleepiness Scale (ESS) which fell from a mean of 10.3 to 4.7 with the AMP, and from 11.0 to 5.1 with nasal CPAP. These mean ESS values are very low for a group of patients with OSA, reflecting their mild disease, and most studies using the ESS have mean values in patients with OSA of about 16.[45] However, the improvement in daytime sleepiness seen is likely to be due to the correction of respiratory related sleep fragmentation, but part of it may be a placebo effect. Resolving this issue is difficult and the problems of designing a suitable placebo for this study are self–evident. The inclusion of an objective measure of sleepiness[46 47] may have been helpful in resolving this uncertainty.

There was no difference in reported side effects between the treatments. Mild side effects were common with the AMP, particularly in the first month of treatment, and these usually improved with time. Common side effects included sore teeth, sore jaw muscles, excessive salivation, and difficulty chewing in the morning. At the end of the four month treatment period four subjects had moderate side effects with the AMP compared with three subjects with the nasal CPAP; no subjects experienced severe side effects with the AMP compared with three subjects with the nasal CPAP (fig 4). The most common side effects with the nasal CPAP treatment included nasal congestion, rhinorrhoea, eye irritation, and a sense of suffocation. There was little difference in patient satisfaction with 16 subjects being moderately or very satisfied with AMP treatment compared with 14 subjects with the nasal CPAP. However, five subjects were very dissatisfied with nasal CPAP and none were very dissatisfied with the AMP. At the end of the study 12 patients preferred to continue with the AMP, citing improved comfort, lack of noise, and portability as reasons for this preference. Six subjects continued with nasal CPAP treatment, one subject used a different oral appliance, and one proceeded to UPPP. In this group of patients it is perhaps not surprising that more chose the less obtrusive treatment (even though it was less successful at treating the AHI) as nearly half of them must have had ESS values in the normal range (<10).



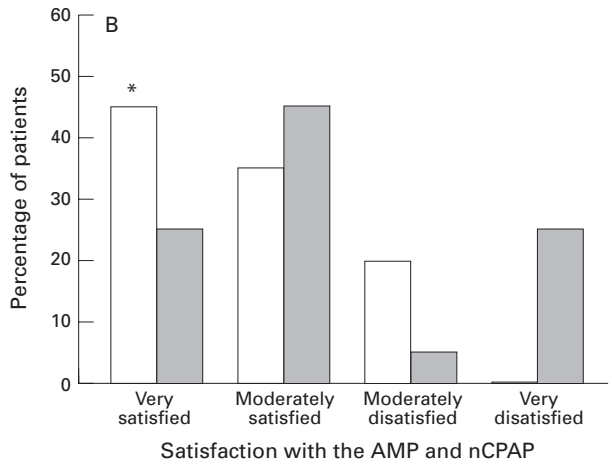


*Figure 4 (A) Side effects and (B) satisfaction with the anterior mandibular positioner (AMP) and nasal CPAP (shaded). *p <0.01.*

The authors conclude that mandibular advancement devices are useful in the management of mild to moderate sleep apnoea and, although the AHI did not return to normal in all subjects, there was an overall improvement in subjective daytime sleepiness. Unfortunately it appears that not all subjects had sleep apnoea syndrome defined as a nocturnal objective respiratory disturbance associated with excessive daytime sleepiness. Usually, the main aim of treating sleep apnoea syndrome is to improve this symptom and the absence of excessive somnolence in some subjects suggests that treatment was being offered on the basis of the sleep study result rather than daytime sleepiness (although perhaps treatment was offered to improve snoring). As the study group includes patients who might not normally be offered treatment, the relevance of their findings and how it should influence our clinical practice is unclear. Also, it should be noted that the authors are very experienced in the use of oral appliances and that the AMP used in this study is a highly sophisticated adjustable device. Even so, one patient in the study had a worsened AHI using the AMP due to a

LEARNING POINTS

- **Both snoring and OSA are caused by collapse of the pharyngeal airway during sleep due to a combination of reduction in muscle tone at sleep onset and anatomical factors.**
- **Two types of oral appliances are used as possible treatment options for snoring and OSA: the mandibular advancement device and the tongue retainer.**
- **The probable mechanism of action of the mandibular advancement device is to enlarge the retroglossal space by anterior displacement of the tongue and thus reduce pharyngeal tendency to collapse.**
- **The mandibular advancement device reduces snoring and improves symptoms of daytime sleepiness in some subjects with mild/moderate sleep apnoea.**
- **Mandibular advancement devices may be tried for subjects with severe OSA who are intolerant of nasal CPAP but they must be followed up with a sleep study.**
- **Oral appliances are not recommended when OSA is complicated by daytime ventilatory failure and nasal CPAP or BiPAP is the treatment of choice in these cases.**
- **More data are needed to enable us to predict which patients are most likely to improve with an oral appliance.**

downward rotation of the mandible and a subsequent reduction in upper airway diameter. Finally, it is disappointing that, although detailed cephalometric measurements were taken, none of these was predictive of a successful treatment outcome and this study is not able to provide any insights into the identification of patients most likely to improve with a mandibular advancement device.

The authors conclude that further studies are needed to clarify the precise role of oral appliances for treating sleep apnoea syndrome. At present they are coordinating a randomised prospective parallel multicentre study comparing the efficacy, compliance, and side effects with an adjustable AMP and nasal CPAP in patients with OSA. Treatment is for two years and efficacy will be assessed by symptom and quality of life questionnaires, subjective and objective measures of daytime vigilance, as well as respiratory indices. Compliance will also be measured subjectively and objectively using a covert compliance monitor, and the mechanism of action of the AMP will be determined by lateral cephalometry and videoendoscopy. It is hoped that results from this study will further determine the role of oral appliances for sleep apnoea syndrome, particularly for those subjects who are excessively sleepy, where currently their role is unclear, and also to clarify whether any specific anatomical configuration can be used to predict success or failure of these devices. Preliminary results from this study suggest that they are not very effective in particularly obese subjects (J Fleetham, personal communication, 5th International Symposium on Sleep Disorders, Edinburgh, 1997).

Conclusions

The use of mandibular advancement devices during sleep reduces snoring and, despite their apparent inability to correct upper airway obstruction as effectively as nasal CPAP, improves subjective daytime sleepiness in some subjects. For patients with mild to moderate OSA they provide an alternative treatment for those in whom conservative management measures fail but whose symptoms do not lead to the acceptance of nasal CPAP. Whether these devices are sufficient for treating more severe sleep apnoea is not yet established, nor is their ability to improve objective daytime sleepiness. The typical pharyngeal shape of patients with severe sleep apnoea (longer anteroposterior diameter) may mean that successful treatment of sleep apnoea is unlikely with these devices and more information is needed to identify the anatomical factors predictive of success. Also, little is known about the effects of long term use and whether permanent change in the occlusive alignment or damage to the temporomandibular joint and teeth occurs. While results from larger studies are awaited, it may be appropriate to try an oral appliance in selected cases of severe OSA when these patients are intolerant of or refuse nasal CPAP.[9] As nasal CPAP is more effective at correcting the respiratory abnormality[43] and improves subjective and objective daytime sleepiness, subjects with moderate to severe OSA should have an initial trial of nasal CPAP. If this treatment cannot be tolerated then an oral appliance can be considered. It is recommended[9] that, when used in this way, a follow up sleep study and assessment of daytime sleepiness is made as oral appliances may cause a worsening of OSA in some patients.[8] It is not recommended that oral appliances are used when OSA is complicated by daytime ventilatory failure and nasal CPAP or BiPAP is the treatment of choice in these cases.

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