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A comparison of the Twin Block and Herbst mandibular advancement splints in the treatment of patients with obstructive sleep apnoea: a prospective study

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SUMMARY This prospective, randomized, crossover study of 16 patients with obstructive sleep apnoea (OSA) [12 males, four females; median body mass index (BMI) 29.2 kg/m^2 (range 23.8–51.1); median age 44.8 years (range 24.0–68.4)] analysed the efficacy of the Twin Block (TB) in relation to the Herbst appliance as a mandibular advancement splint (MAS). Each subject was fitted with a TB and Herbst MAS in a random order with a washout period of 2 weeks between appliances. Once each patient was subjectively happy with the performance of each appliance, questionnaires and a visual analogue scale (VAS) were used to determine differences in snoring, daytime sleepiness, quality of life, side-effects of the appliances and patient preference. All patients underwent overnight domiciliary sleep recordings prior to and after fitting each appliance in order to objectively assess sleep quality in terms of the apnoea-hypopnoea index (AHI), snoring frequency and arterial oxygen saturation.

The results suggested that there was no difference in the treatment performance of the TB and Herbst MAS for AHI ($P = 0.71$), snoring frequency ($P = 0.49$), arterial blood oxygen saturation ($P = 0.97$), quality of life and side-effects. The Herbst MAS proved to be the more effective appliance for reducing daytime sleepiness ($P = 0.04$) and was the more popular appliance among the patients. Side-effects with both appliances were minor and improved in the longer term. The TB MAS represents a viable alternative to the Herbst MAS in the treatment of patients with OSA.

Introduction

Obstructive sleep apnoea (OSA) is a potentially life-threatening disorder where repeated collapse of the upper airway during sleep causes cessation of breathing. OSA is diagnosed where five or more abnormal respiratory events occur per hour (Guilleminault *et al.*, 1978), but is only considered clinically significant where at least 20 such events are present (Riley *et al.*, 1983). The abnormal respiratory events may be apnoeas or hypopnoeas. An apnoea is defined as a break in respiration for at least 10 seconds. During an hypopnoea, respiration is present but there is a reduction in tidal volume leading to a drop in blood oxygen saturation of 4 per cent or more, which lasts for 10 seconds or longer. The apnoea-hypopnoea index (AHI) is defined as the number of apnoeas and hypopnoeas experienced by the patient per hour of sleep.

Young *et al.* (1993) found that 2 per cent of women and 4 per cent of men suffered from OSA (AHI ≥ 5). The prevalence of the disease increases with age (Hoch *et al.*, 1990) and is more common in the obese (Young *et al.*, 1993). Snoring is one of the cardinal symptoms of OSA, but not all those who snore suffer from OSA. Although not affected by the snoring directly, patients find this highly embarrassing socially due to complaints from both family and friends.

The other major symptom associated with OSA is excessive daytime sleepiness (EDS). This affects the patient's quality of life by impairing both psychosocial and cognitive functions so that the individual's career and social life may suffer (Kaplan, 1992). In addition, EDS increases the risk of having an industrial or road traffic accident by a factor of seven (Findley *et al.*, 1988).

There has been an increasing awareness over the years that patients suffering from OSA are at risk from a wide range of medical complications as a result of the recurrent nocturnal hypoxia and hypercapnia they experience during sleep. These include hypertension (Stradling *et al.*, 1996), heart failure (Sanner *et al.*, 1997) and cerebrovascular disease (Placidi *et al.*, 1998).

OSA is diagnosed using overnight polysomnography and may be classified as mild (AHI = 5–15), moderate (AHI = 16–30) or severe (AHI > 30). Severe OSA has traditionally been managed with nasal continuous positive airway pressure (nCPAP) (Sullivan *et al.*, 1981). More recently, mandibular advancement splints (MAS) have been used in the management of subjects with mild to moderate symptoms (American Sleep Disorders Association, 1995).

The Herbst MAS is a custom-made dental device designed to hold the mandible in a protrusive position when worn at night. In posturing the mandible forwards,

the tongue and soft palate are moved anteriorly, with consequent opening of the oropharyngeal airway. Studies suggest that the Herbst MAS can be of benefit to many patients (Schmidt-Nowara *et al.*, 1995; Clark *et al.*, 1996; Johal and Battagel, 1999; Shadaba *et al.*, 2000).

Twin Blocks (TBs) designed by Clark (1982) are traditionally used in the treatment of children with Class II skeletal relationships. TBs have proved to be the best tolerated and most robust of all functional appliances (Clark, 1988; Parkin *et al.*, 2001). The forward posturing of the mandible during wear makes the TB an obvious candidate for a MAS in adults. With respect to OSA, TBs offer certain advantages. Like the one-piece monobloc and activator designs, they are relatively simple to construct yet, like the Herbst, are readily adjustable. This allows the mandible to be gradually advanced to a position of maximal comfortable protrusion, which is associated with optimal reduction in OSA symptoms (Lowe *et al.*, 1995). Unlike the Herbst appliance, TBs are made by many orthodontic laboratories in the UK, helping to maximize availability and minimize costs. This may be an important economic consideration as MAS do not cure OSA but only relieve the symptoms and reduce the risks of the associated medical complications. As such, these appliances will be a lifelong treatment, needing replacement and repair from time to time. TBs offer the potential for a more robust and cost-effective appliance (Parkin *et al.*, 2001). Some centres are already using TBs in the treatment of patients with OSA, but as yet there has been no controlled clinical trial.

The aim of this study, therefore, was to determine by means of a prospective, randomized, crossover study, the efficacy and clinical acceptance of the TB as a MAS in the treatment of patients with OSA.

Subjects and methods

Subjects

The subjects for this prospective, crossover study consisted of 16 adults, 12 males and four females. They were referred to the Orthodontic Department of the Royal London Hospital over a 15 month period for the construction of a MAS. All had been previously assessed with regard to their sleep-related breathing disorder in a multidisciplinary setting in order to establish a diagnosis of either mild, moderate or severe OSA (L'Estrange *et al.*, 1996).

Ethical approval for the research was obtained from the local research ethics committee. Basic demographic data, details of sleep history and medical and dental history were recorded. The subject's height and weight were measured and the body mass index (BMI) was calculated using the method described by Revicki and Israel (1986) (BMI = weight kg/height m^2). The neck circumference of each subject was measured at the level of the cricothyroid membrane and used in conjunction with the subject's height to calculate their percentage of predicted normal neck circumference (PPNC) (Davies and Stradling, 1990). Patients who had poor oral health, a history of poorly controlled epilepsy, an allergy to metals, who were edentulous or pregnant were excluded from the study.

Thirty-three of the original 49 referrals were not included in the study due to failed attendance or fulfilling one of the exclusion criteria. All patients were seen by one clinician (HML). Of these, three did not complete the study due to non-attendance, intolerance of the appliance and time limitations. Sixteen patients (12 males, four females) were included in both the questionnaire and the domiciliary sleep study. All the females and nine of the males were Caucasian. The remaining males consisted of one Afro-Caribbean and two of Chinese descent.

The ages of the patients ranged from 24.0 to 68.4 years with a median of 44.8 years. The median BMI (29.2) indicated that most of the subjects were overweight (BMI > 25). Six patients were obese (BMI > 30). These results were closely reflected in the PPNC (PPNC = 105.6 per cent) which rated most of those patients who were overweight or obese with a PPNC greater than 100 per cent (Table 1, Figure 1).

Table 1 Demographic data (n = 16: 12 males, four females).

Variable	Median	Range
Age (years)	44.8	24.0–68.4
Height (cm)	171.5	150.0–183.0
Weight (kg)	82.9	74.0–115.0
BMI (kg/m^2)	29.2	23.8–51.1
PPNC (%)	105.6	94.8–123.9

BMI, body mass index; PPNC, percentage of predicted neck circumference.

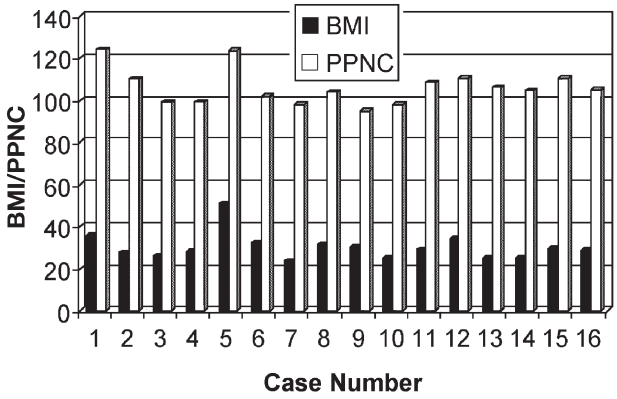

Figure 1 Relationship between body mass index (BMI) and percentage of predicted neck circumference (PPNC).

Methods

Management. Once a subject had agreed to participate in the study, they were randomly allocated to one of two groups. One group wore the Herbst MAS first and then the TB, whereas in the second group the order was reversed.

The following baseline data were collected before treatment commenced: Epworth Sleepiness Scale (ESS), SF-36 Quality of Life Questionnaire, visual analogue scale (VAS) scores for snoring and daytime sleepiness and an overnight domiciliary sleep study. Alginate impressions and a protrusive wax bite were taken for the construction of each appliance. Each device was fitted and then reviewed 4–6 weeks later. If appropriate, the appliance was advanced until each patient was subjectively happy with its effects. Questionnaires and the VAS were completed and an additional sleep study performed. Once the first appliance had been tested this was withdrawn and a 2 week washout period was implemented before the second device was fitted. The questionnaires and sleep study were repeated.

The MAS. The wax bite was recorded with the mandible in the position of maximal comfortable protrusion. The inter-occlusal distance registered for the TB device was a few millimetres greater to allow for the differing design of this splint. The Herbst and TB appliances, as shown in Figure 2a, b, were constructed. With the Herbst appliance the mandible was kept postured forward with the use of bilateral telescopic tubes, and for the TB this was achieved using acrylic blocks with vertical block interfaces. Bilateral interarch 2.5 oz elastics were used to help keep the jaws closed during sleep. Both appliance designs allowed for a stepwise adjustment of mandibular protrusion where this was necessary for maximum efficacy.

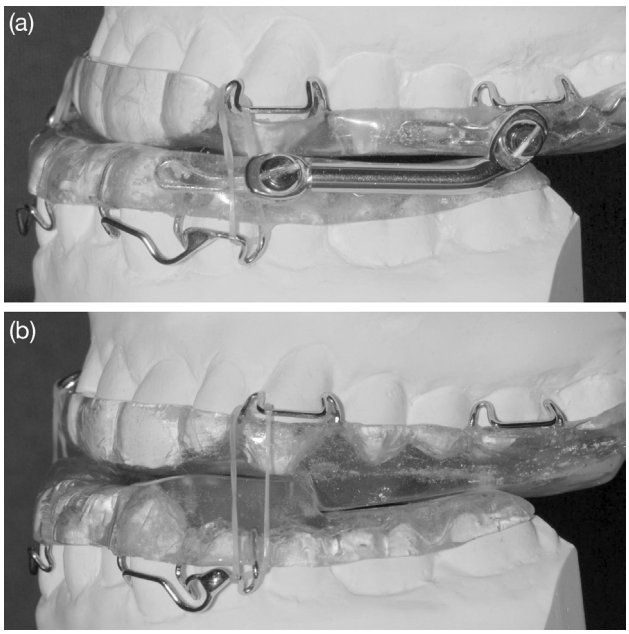

Figure 2 (a) The Herbst and (b) the Twin Block mandibular advancement splints.

Outcome measures

These comprised questionnaires, VAS and domiciliary, overnight sleep monitoring. Questionnaires and VAS were used to assess daytime sleepiness, quality of life, snoring (as perceived by the patient's bed partner) and the short- and long-term effects of the MAS.

ESS. Daytime sleepiness was assessed using the ESS as described by Johns (1993). A score of between 0 and 24 is possible with normal values being less than 10 (Johns, 1993).

SF-36 Quality of Life Questionnaire. The SF-36 questionnaire was used to assess the quality of the subject's life before and after treatment with each MAS. The questionnaire is subdivided into categories. These are: change in health, physical function, role limitation due to physical problems, role limitation due to emotional problems, social functioning, mental health, energy and vitality, pain and general health perception. Scores range from 0 to 100 per cent in each category, except for role limitation due to physical and emotional problems where the subject may score between 100 and 200 per cent. The maximum score is the ideal outcome.

Outcome questionnaire. The outcome questionnaire examined the short- (2–3 days) and longer-term (4–6 weeks) responses to the appliances. The subject answered 'yes' or 'no' to questions related to muscular discomfort, temporomandibular joint (TMJ) discomfort, abnormal bite after splint removal, dry mouth and excessive salivation, depending on whether they had experienced these side-effects or not. A positive response scored one and a negative response zero. Thus, on each occasion, a minimum score of 0 and a maximum score of 5 was achievable. It was also possible to look at the individual side-effects. In addition to this, each patient was asked to state which appliance they preferred, if any, once they had used both, and the reason why.

VAS. In addition to the questionnaires, two linear VAS numbered from 0 to 10 were completed to assess sleepiness and snoring. For each scale, a score of 0 represented no daytime sleepiness or snoring, while 10 indicated the most extreme tiredness and the loudest noise. These were analysed by dividing the scale into quartiles.

Domiciliary sleep studies. Domiciliary sleep studies were carried out using the Densa Compact (Ferraris Medical, Enfield, Middlesex, UK) sleep apnoea screening system. The Densa Compact software is able to identify

Table 2 Median values for sleepiness visual analogue scale (VAS) and Epworth Sleepiness Scale (ESS) questionnaires at baseline and with Herbst and Twin Block mandibular appliance splint (MAS) (n = 16).

Variable	Baseline median (range)	Herbst MAS median (range)	Twin Block MAS median (range)	Statistical significance between appliances
VAS	3.0 (1.0–4.0)	2.0 (1.0–4.0)	2.5 (1.0–4.0)	*
ESS	10.0 (2.0–18.0)	8.0 (4.0–18.0)	8.5 (3.0–17.0)	ns

*P < 0.05; ns, not significant.

apnoeas, hypopnoeas and mixed events, calculating an overall AHI for the time the patient is monitored. Snoring frequency (snores/hour) and arterial oxygen saturation are also recorded. An 'apnoea summary' is then calculated which includes AHI score, oxygen saturation and the number of snores per hour.

Each subject underwent three domiciliary sleep recordings: at baseline and once each appliance was considered subjectively successful, with the MAS *in situ*. The use of the equipment was demonstrated fully to each subject prior to the initial recording and then before each of the additional recordings if the subjects felt this was necessary. Comprehensive written instructions and diagrams were also provided.

Overnight domiciliary sleep studies were performed on 16 patients. Two subjects failed to complete all the recordings.

Statistical analysis

SPSS PC+ (version 10.0 for Windows, SPSS Inc., Chicago, Illinois, USA) was used to assess the data. Non-parametric tests were used due to the small sample sizes. For paired data, the Wilcoxon matched-pairs signed-ranks test at the 5 per cent level of significance was used. This included all the questionnaires, VAS and domiciliary sleep study AHI scores, average arterial oxygen saturation and snoring.

To test any treatment order effects, the Mann–Whitney U-test was used with statistical significance at the 5 per cent level.

Results

Treatment order effects

Eight patients wore a TB appliance first followed by the Herbst. For the remaining eight patients, this order was reversed. Treatment order effects were found not to be significant (P = 0.35), indicating that the order in which the splints were fitted and used did not bias the results. Data for all patients were therefore pooled.

Questionnaires and VAS

The return of the questionnaires and VAS was very good, as all patients were asked to complete them while in the department.

Sleepiness VAS. The VAS sleepiness scores (Table 2) for the two appliances were found to be significantly different (P = 0.04), indicating that the patients felt less sleepy while using the Herbst than the TB MAS. The median score at baseline was 3.0 and was reduced in the Herbst and TB to 2.0 and 2.5, respectively.

ESS. No significant difference (Table 2) was found between the ESS scores for the Herbst and TB appliances (P = 0.41), suggesting that both devices had a similar effect on patient sleepiness. The median baseline ESS score of 10.0 was reduced to 8.0 for the Herbst and 8.5 for the TB.

Snoring VAS. The median values gained from the snoring VAS were 3.5 for the Herbst and 4.0 for the TB (Table 3). These were the same or very close to the baseline score of 4.0. No significant difference was found in the degree of snoring between the two appliances (P > 0.05).

SF-36 Quality of Life Questionnaire. In none of the nine categories of the SF-36 (Table 4) did the effect of the Herbst and TB MAS differ significantly: physical function (P = 0.53), role limitation due to physical problems (P = 0.68), role limitation due to emotional problems (P = 0.74), social functioning (P = 0.25), mental health (P = 0.97), energy and vitality (P = 0.29), pain (P = 0.21), general health perception (P = 0.87) and change in health (P = 1.00).

Side-effects of appliances

Initial side-effects were common for both appliances (Figure 3), but improved with time (Figure 4). For the

Table 3 Visual analogue scale (VAS) snoring scores at baseline and with Herbst and Twin Block appliances (n = 16).

	Baseline VAS snoring	Herbst VAS snoring	Twin Block VAS snoring
Median	4.0	3.5	4.0
Range	3.0–4.0	1.0–4.0	2.0–4.0
		ns	

ns, not significant.

Table 4 SF-36 questionnaires at baseline and with Herbst and Twin Block mandibular appliance splint (MAS) (n = 16).

Variable	Baseline median (range)	Herbst MAS median (range)	Twin Block MAS median (range)	Statistical significance between appliances
Physical function	70.0 (5.0–85.0)	72.5 (5.0–85.0)	65.0 (5.0–85.0)	ns
Role limitation due to physical problems	175.0 (100.0–200.0)	200.0 (100.0–200.0)	187.5 (125.0–200.0)	ns
Role limitation due to emotional problems	200.0 (100.0–200.0)	200.0 (100.0–200.0)	200.0 (166.7–200.0)	ns
Social functioning	66.7 (20.0–80.0)	68.9 (31.1–80.0)	67.8 (37.9–80.0)	ns
Mental health	68.0 (40.0–84.0)	70.0 (8.0–84.0)	66.0 (40.0–88.0)	ns
Energy/vitality	47.0 (25.0–70.0)	47.5 (20.0–70.0)	45.0 (25.0 –65.0)	ns
Pain	74.4 (13.0–100.0)	75.5 (22.2–100.0)	68.9 (24.4–100.0)	ns
General health perception	59.5 (20.5–82.0)	62.0 (30.0–82.0)	53.5 (20.5–87.0)	ns
Change in health	50.0 (25.0–75.0)	50.0 (0.0–75.0)	50.0 (25.0–75.0)	ns

ns, not significant.

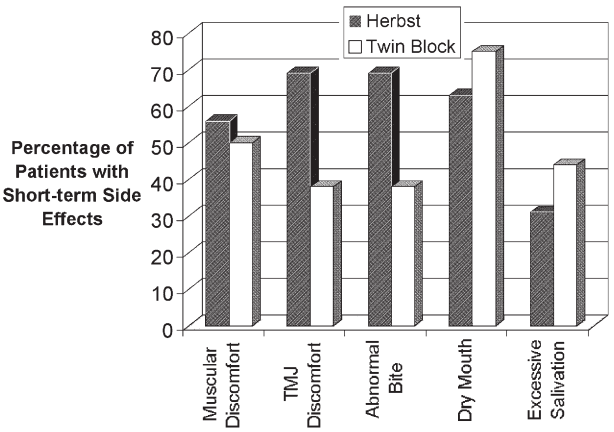

Figure 3 The percentage of patients with short-term side-effects experienced with the Herbst and Twin Block appliances.

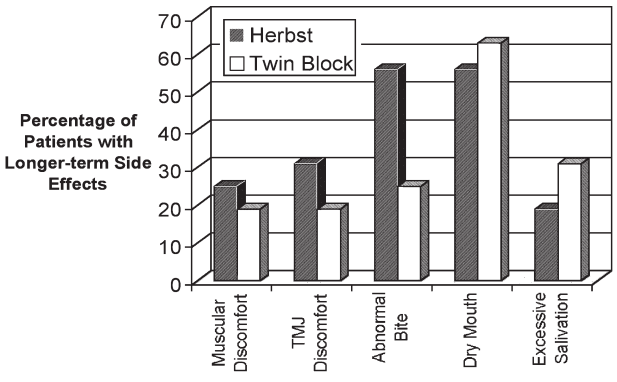

Figure 4 The percentage of patients with longer-term side-effects experienced with the Herbst and Twin Block appliances.

Herbst appliance, muscular discomfort was experienced by 56 per cent initially, but this improved to 25 per cent after 4–6 weeks. With the TB there was a reduction from 50 to 19 per cent. Initial TMJ discomfort improved from 69 to 31 per cent and 38 to 19 per cent, respectively, for the Herbst and TB appliances. An abnormal bite was experienced initially by 69 per cent of Herbst and 38 per cent of TB patients and this reduced to 56 and 25 per cent, respectively, in the longer term. A dry mouth reduced from 63 to 56 per cent with the Herbst and from 75 to 63 per cent with the TB. Excessive salivation was experienced by 31 per cent of subjects while wearing the Herbst, reducing to 19 per cent over time: a similar improvement from 44 to 31 per cent was seen with the TB.

There were no significant differences between the Herbst and TB MAS in either the short ($P > 0.50$) or longer term ($P > 0.50$). There was, however, a significant improvement in the side-effects over time for both the Herbst ($P = 0.02$) and TB ($P = 0.01$) appliances.

Fifteen out of 16 subjects felt the advantages of the Herbst MAS outweighed the disadvantages, while 14 felt that this was the case with the TB. Overall, nine patients preferred the Herbst MAS, five preferred the TB device and two had no preference.

Domiciliary sleep study

AHI. There was no significant difference (Table 5) in the median AHI scores produced by treatment with the Herbst (24.5, n = 16) and TB (34.0, n = 15) appliances ($P = 0.71$). Both median scores were an improvement on the baseline value of 45.5. Treatment effects of the MAS were variable. In some patients the AHI scores were similar for both devices, whereas in others one splint proved to be far more effective.

Snoring. Treatment with the Herbst (n = 16) and TB (n = 14) MAS reduced the median snoring levels from a baseline of 144.0 to 64.0 and 62.0, respectively (Table 5). There was no significant difference between the two appliances ($P = 0.49$).

Arterial oxygen saturation. There was an insignificant improvement (Table 5) in the median arterial oxygen saturation from a baseline of 87.5 to 89 per cent for the Herbst (n = 16) and 88 per cent for the TB appliance (n = 15). There was again no significant difference between the two appliances.

Table 5 Domiciliary sleep recordings [apnoea hypopnoea index (AHI), snoring frequency and arterial oxygen saturation (SaO_2)] at baseline (n = 16) and after treatment with the Herbst (n = 16) and Twin Block mandibular appliance splint (MAS) (n = 15 for AHI and SaO_2; n = 14 for snoring).

Variable	Baseline median (range)	Herbst MAS median (range)	Twin Block MAS median (range)	Statistical significance between appliances
AHI	45.5 (29.0–68.0)	24.5 (0.0–45.0)	34.0 (9.0–63.0)	ns
Snoring (snores/hour)	144.0 (1.0–519.0)	64.0 (6.0–344.0)	62.0 (2.0–356.0)	ns
SaO_2	87.5 (82.0–92.0)	89.0 (81.0–91.0)	88.0 (81.0–92.0)	ns

ns, not significant.

Discussion

Limitations of the study

The relatively small number of patients (16) involved in this study may have been too few to highlight any differences between the two MAS. Although there was an adequate number of potential patients, several declined to participate and time and equipment availability were important limiting factors.

The subject group was not ideal as it included four patients with severe OSA who were nCPAP failures. MAS therapy, however, is known to be more effective in those with mild and moderate symptoms (Marklund *et al.*, 1998).

The appliances were re-evaluated after a relatively short time and this is not ideal for a device that is likely to be worn on a lifelong basis. Longer-term follow-up after 2 (or more) years would be valuable.

The modified TB design has not yet been perfected. Although alternative designs, extending the blocks into the palate, have been suggested, this may still not be ideal, as the blocks will intrude into the tongue space. This may displace the tongue posteriorly, encroaching on the airway. However, the design does merit further trials.

Domiciliary sleep studies

There has been no research comparing the Densa Compact sleep monitoring equipment with overnight polysomnography. For other types of sleep equipment, however, a high degree of correlation has been shown to exist (Redline *et al.*, 1991). Caution must therefore be exercised when looking at absolute figures, but the equipment is effective in showing the relative differences between the two appliances.

AHI

No significant differences in AHI scores were found between the two appliances. In eight subjects, one or other of the devices reduced the AHI to 20 or less. In two individuals the Herbst MAS performed significantly better than the TB, reducing the AHI to less than 5—the normal situation (Block *et al.*, 1979). However, nine patients still exhibited moderate or severe OSA with one or both devices.

These post-treatment AHI scores were not as low as those achieved in other studies (Schmidt-Nowara *et al.*, 1991; Clark *et al.*, 1996; Ferguson *et al.*, 1997; Bloch *et al.*, 2000; Tan *et al.*, 2002), but baseline values were also higher. As the success of MAS has generally been found to be inversely related to disease severity (Marklund *et al.*, 1998), this may explain the poorer results. The MAS design is also known to have an impact on effectiveness (Lamont *et al.*, 1998) and the TB design may benefit from further modification.

In two subjects with severe OSA, the AHI score worsened with the TB but improved with Herbst wear. The TB appliance is bulkier than the Herbst and it may be that the additional reduction in airway volume was enough to negate the positional benefits of the appliance. This possible worsening of OSA underlines the need for post-treatment sleep studies for all apnoeic subjects (Marklund *et al.*, 1998).

Arterial blood oxygen saturation

No significant differences in blood oxygen saturation were found between the two appliances and the low baseline arterial blood oxygen saturation levels were essentially unaltered by treatment. There are a number of factors that may have contributed to this, including a supine sleeping position, a lower patient haematocrit, and heart failure, leading to less efficient pulmonary circulation. When the median arterial blood oxygen saturation value for this group is related to the blood oxygen desaturation curve, these patients are just on the edge of the plateau before the graph drops. If the arterial blood oxygen saturation was to drop from this point, the hypoxic drive would set in (Bowes *et al.*, 1981). This may explain why some subjects were still experiencing increased levels of EDS.

Sleepiness

Using the ESS, there was no significant difference in EDS between the two appliance systems. The reduction

in ESS was similar to that found by Hans *et al.* (1997) but less than that reported by Ferguson *et al.* (1997).

Some subjects criticize the ESS, complaining that the eight situations referred to do not apply to them and thus they find the questionnaire difficult to answer. A VAS is much simpler and was, therefore, incorporated into the study. Here a significant difference between the two MAS treatments was found, with the subjects reporting a significantly lower level of daytime somnolence with the Herbst MAS. This may represent a truer reflection of the subject's overall sleepiness, but the VAS has not been scientifically validated in the case of sleep disorders.

SF-36 Quality of Life Questionnaire

The SF-36 is used throughout medical research to assess a patients' quality of life and the effects of treatment. No significant changes were seen from baseline and no differences were noted between the two appliances. This is in contrast to a study by Walker-Engstrom *et al.* (2000) who found a significant improvement in the quality of life after 1 year of MAS treatment. Quality of life changes in this study were tested after only a few weeks and it may be that this was too soon: there may yet be improvements with continued appliance wear.

Side-effects of appliances

Initial side-effects experienced by the patients included muscular and TMJ discomfort, excessive salivation and a dry mouth or abnormal bite on waking. In common with other studies (Schmidt-Nowara *et al.*, 1991; O'Sullivan *et al.*, 1994; Bondemark and Lindman, 2000; Shadaba *et al.*, 2000), these effects had reduced after 4–6 weeks of splint wear.

The prevalence of muscular and TMJ discomfort and an abnormal bite was lower in the TB group. This may be related to the fact that its design requires greater vertical opening, allowing the mandible to rotate downwards as it comes forwards, relieving the pressure on the TMJ and muscles of mastication. Two subjects were unable to tolerate the increased vertical opening, however, and a reduction in the block height was only successful in one individual. Complaints of a dry mouth on waking and increased salivation, however, were high, similar in both groups, and had altered little at the 4–6 week review. OSA patients frequently sleep with their mouths open and therefore a dry mouth is a frequent pre-treatment complaint and may be unrelated to appliance wear. Shadaba *et al.* (2000) reported an incidence of 36 per cent in a long-term follow-up of Herbst appliance wearers, supporting the contention that this was a pre-existing condition.

Despite these side-effects, 94 per cent of the patients wearing the Herbst felt that its advantages outweighed the side-effects and 88 per cent felt this way with the TB.

Herbst versus TB as a MAS

In terms of quality of life, AHI, snoring, blood oxygen saturation and side-effects, the TB MAS proved to be as effective as the Herbst MAS. In relation to EDS, this is not as clear-cut. The Herbst may be the more effective appliance, but the numbers involved in the study were small.

The Herbst appliance has been used successfully over many years (Schmidt-Nowara *et al.*, 1995; Clark *et al.*, 1996; Johal and Battagel, 1999; Shadaba *et al.*, 2000; Fritsch *et al.*, 2001). The design is complex, with an associated high cost of fabrication, and not widely available in the UK. The appliance is also relatively susceptible to breakages, especially in patients who grind their teeth. The TB is constructed in all UK orthodontic laboratories and its cost is approximately half that of the Herbst MAS. Like the Herbst it has the advantage that it may be progressively advanced. This may be done at the chairside using cold-cure acrylic. Advancement of the Herbst appliance, which requires the application of solder to secure the advancement rings, is more safely done in the laboratory.

The depth of the wax bite taken for the TB was 2–3 mm greater than for the Herbst MAS to allow sufficient height for the blocks to effectively interlock. Despite these precautions, one of the subjects' main complaints was that they were waking up during the night and their lower jaws had 'slipped back'. In this situation, the TB was adapted by a combination of increasing the mandibular advancement and vertical height. From a clinical point of view, the TBs required more adjustment than the Herbst MAS.

Conclusions

1. The MAS may not have been the ideal therapy for all patients in this study, as in some individuals their OSA was too severe.
2. The TB MAS was as effective as the Herbst MAS in treating subjects with OSA with respect to the AHI, snoring, and arterial blood oxygen saturation. Daytime sleepiness was treated more effectively with the Herbst MAS.
3. The quality of life achieved while utilizing the TB MAS was similar to that obtained with the Herbst MAS.
4. The side-effects with both MAS were minor and improved with time.
5. Five patients preferred the TB appliance, nine preferred the Herbst MAS and two had no preference.

6. The TB MAS represents a viable alternative to the Herbst MAS, at a reduced cost, in the treatment of patients with OSA. Modification of its design may improve its effectiveness.

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