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A comparison of dental changes produced by mandibular advancement splints in the management of obstructive sleep apnoea

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Background: Mandibular advancement splints (MAS) are a recognised and popular treatment option for obstructive sleep apnoea (OSA) due to their simplicity, tolerance and non-invasiveness.
Objectives: To investigate and compare the dental changes associated with the use of monoblock and duoblock appliances.
Methods: Fifty-two pretreatment and follow-up study models of patients from a public hospital and private dental clinic were assessed. Seventeen subjects used a soft elastomeric monoblock appliance (MB), 29 subjects used a hard acrylic duoblock (DB) and six subjects wore a monoblock followed by a duoblock appliance (MB-DB). Measurements of dental and arch changes were obtained and analysed on study models and standardised bitewing radiographs.
Results: A statistically significant reduction was observed in the maxillary intercanine distance in all splint categories, with DB users showing the greatest decrease ($p < 0.05$). The change in the mandibular intercanine distances differed according to splint categories ($p < 0.05$). MB and MB-DB patients demonstrated a decrease in this measurement variable, whereas an increase was seen in DB users. A statistically significant increase in the mandibular intermolar distance was also observed in all splint categories ($p < 0.05$), with DB users showing the greatest increase.
Conclusions: Both MB and DB appliance systems produced similar, but mild dental effects. No particular appliance can be recommended and the choice of appliance should be considered on a case-by-case basis.
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Introduction

Obstructive sleep apnoea (OSA) is a chronic medical condition characterised by repetitive episodes of upper airway collapse during sleep which results in apnoeic and hypopnoeic episodes, despite persistent thoracic and abdominal respiratory effort.[1] OSA is a significant and heavy burden on society, not only in a financial sense, but also from the aspect of health morbidity. It is estimated that six per cent of the Australian population (i.e. over 1.2 million people) experience sleep disorders, the most common of which is OSA.[2]

Therapeutic options to manage this condition include conservative measures, continuous positive airway pressure (CPAP)[3–5] and surgery.[6] The conservative management of OSA includes the use of oral appliances, the most common of which is the mandibular advancement splint (MAS) that could be of one-piece design (monoblock) or of two pieces (duoblock).[7] The one-piece design fixes the mandible rigidly in a forward position, while a two-piece MAS allows some mandibular movement and the possibility of further mandibular advancement.[7,8]

Previous studies have investigated the dental effects of either the monoblock or the duoblock systems.[9–15] There has yet to be a comprehensive study comparing the arch changes associated with both splints, which may influence the clinician's decision when selecting an appropriate splint for the patient. We aimed to investigate the dental changes associated with the use of both splints and to compare the extent of changes between both systems.

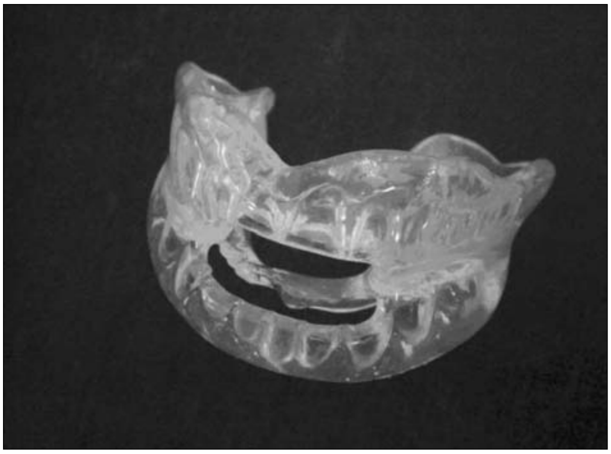

Figure 1. Monoblock appliance.

Figure 2. Twinblock appliance.

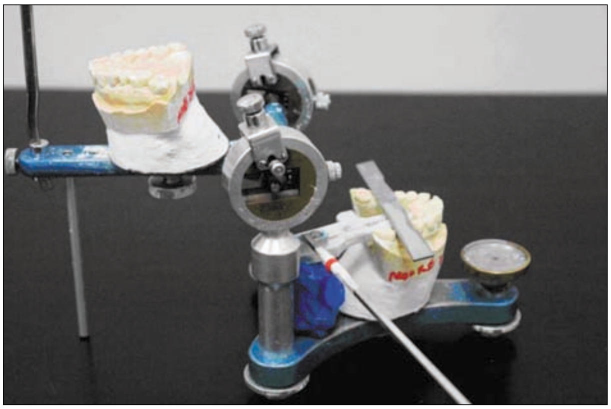

Figure 3. Positioning of the modified Snapex film holder on the study model.

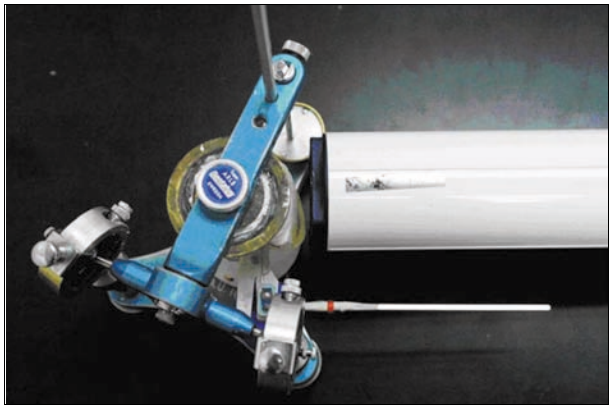

Figure 4. Positioning the cone for a radiograph.

Materials and methods

The study was designed as a prospective, cross-sectional examination of study models of OSA subjects from an institution and a private dental clinic. The following inclusion criteria were applied:

1) Subjects with maxillary and mandibular first permanent molars and canines.

2) Subjects who had worn a MAS continuously (minimum of five to six hours per night) for at least 6 months.

Of the 191 subjects who fulfilled the inclusion criteria, only 52 (17 females, 35 males) attended for review. Of these: 17 subjects (Mean age: 47 years; Range: 32 to 72 years) wore soft elastomeric monoblock appliances (Figure 1); 29 subjects (Mean age: 51 years; Range: 30 to 73 years) wore hard acrylic duoblock appliances (Figure 2); and six subjects (Mean age: 45 years; Range: 25 to 60 years) wore a monoblock followed by a duoblock appliance (MB-DB).

At recall, repeat study models were taken using alginate impression material and a bite registration was taken with softened brown wax. Pretreatment and follow-up study models were articulated in the intercuspal position on a Dentatus adjustable articulator. Measurements were made on the articulated study models using electronic digital calipers to 0.01 mm.

Vertical changes were measured directly on standardised bitewing radiographs using the digital calipers. Liquid barium was painted on the cusp tips of the

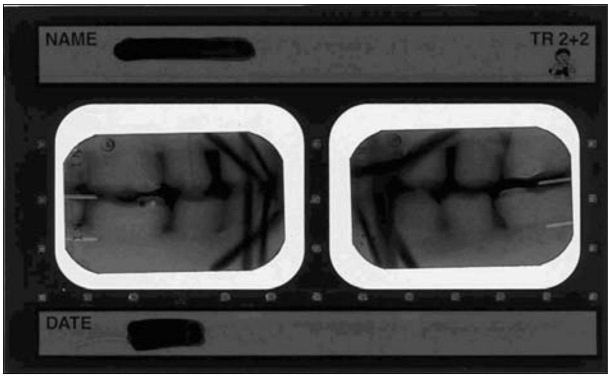

Figure 5. Example of radiographs taken to measure the posterior open bite.

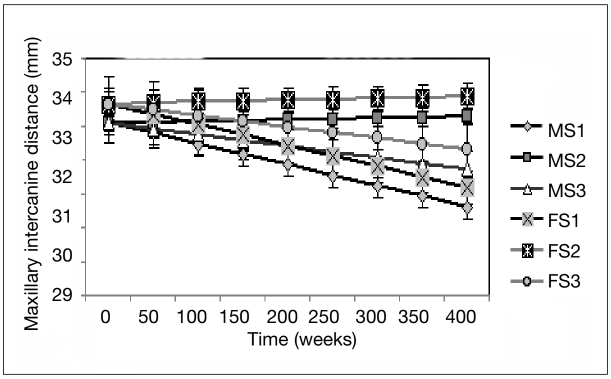

Figure 6. Mean value changes for the maxillary intercanine distance following treatment using the 3 MAS systems.
MS1: Males using monoblock appliance
MS2: Males using twinblock appliance
MS3: Males using a monoblock followed by a twinblock appliance
FS1: Females using monoblock appliance
FS2: Females using twinblock appliance
FS3: Females using a monoblock followed by a twinblock appliance

plaster first molars which produced a fine radiopaque line to facilitate measurement. The bitewing films were held in position on the articulated models with a modified Snapex (Dentsply Pty Ltd., Mt. Waverley, Victoria, Australia) film holder. A customised flat metal ruler was placed on the occlusal surface of the mandibular first molars as a horizontal guide plane for the positioning the Snapex holder and radiographic machine cone (Figures 3 and 4). A metal wire attached to the Snapex holder, acted as a radiographic horizontal reference line (Figure 5).

Ten per cent (5 pretreatment, 5 follow-up) of the models were remeasured and assessed using a paired *t*-test and Dahlberg statistics to determine the presence of systematic and random errors.

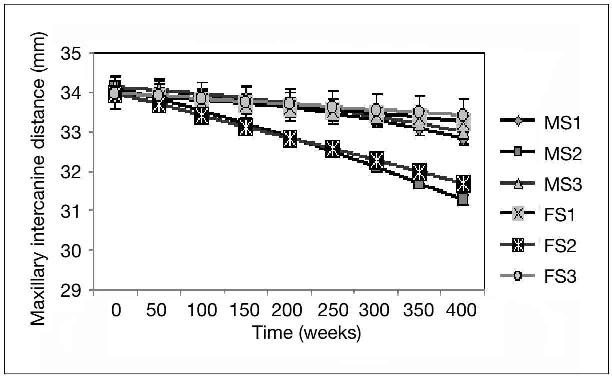

Figure 7. Mean value changes for the mandibular intercanine distance following treatment using the 3 MAS systems.
MS1: Males using monoblock appliance
MS2: Males using twinblock appliance
MS3: Males using a monoblock followed by a twinblock appliance
FS1: Females using monoblock appliance
FS2: Females using twinblock appliance
FS3: Females using a monoblock followed by a twinblock appliance

The data were analysed using linear models and were first adjusted for a number of effects a priori, using the following models: variable prior to treatment = cast material + maxillary tooth number + mandibular tooth number + error; variable at the follow-up assessment (while still undergoing treatment) = cast material x operator + maxillary tooth number + mandibular tooth number. Appliance material and operator were class variables and tooth number was a covariate. Subsequent analysis of predicted values was then undertaken using the fixed linear model: variable = gender + age + time + gender x time + age x time + splint x time + error. Gender and splint type were class variables, age was a covariate, and treatment duration was a continuous measure of repetition modelled using a spatial covariance structure (sp[pow]). Least squares variable estimates were derived for each gender by splint type combination and plotted against the maximum duration of treatment to construct graphs illustrating the significant model effects.

Results

None of the paired *t*-tests comparing 10 per cent of the models with repeat measurements showed a significant difference ($p > 0.05$), indicating that there were no systematic errors due to the equipment used in the study. The random experimental error was less than 10 per cent of the observed population variation for all measured variables, which suggested that the measurement approach had little influence.

Table I. Study model measurements, expressed values are the follow-up minus the pretreatment measurements.

Variables	Combined (N = 52)			MB (N = 17)		DB (N = 29)		MB-DB (N = 6)		
	Mean	SD	*p*	Mean	SD	Mean	SD	Mean	SD	*p*
Maxillo-mandibular relationship										
Left posterior open bite (mm)[a]	1.4	0.9	0.05	1.4	1.0	1.4	0.8	1.9	1.0	0.24
Right posterior open bite (mm)[a]	1.0	1.2	0.13	1.0	1.1	1.1	1.2	1.2	1.1	0.11
Overbite (mm)	-1.4	1.2	0.08	-1.3	1.2	0.3	0.5	-2.5	1.5	0.31
Overjet (mm)	-1.1	1.7	**0.00**	-0.9	1.4	-0.8	1.1	-2.2	1.3	**0.03**
Left canine relationship (mm)[b]	-1.1	1.5	**0.03**	-0.7	1.5	-1.1	1.3	-1.4	1.5	0.38
Right canine relationship (mm)[b]	-0.6	1.4	0.73	0.1	1.5	-1.1	1.0	-0.4	1.7	0.42
Left molar relationship (mm)[b]	-1.5	1.7	**0.02**	-1.5	1.6	-1.3	1.4	-1.5	2.2	**0.00**
Right molar relationship (mm)[b]	-1.3	1.8	0.30	-0.8	1.5	-1.2	1.3	-1.3	2.2	0.15
Maxillary arch										
Intercanine distance (mm)[c]	0.0	0.4	0.52	0.2	0.5	-0.1	0.4	0.0	0.4	**0.03**
Intermolar distance (mm)[c]	0.1	0.6	0.90	0.3	0.4	0.0	0.6	0.0	0.9	0.48
Arch length (mm)[c]	-1.3	2.0	0.26	-1.1	1.3	-0.8	1.8	-4.6	1.3	0.14
Arch depth (mm)[c]	0.1	0.7	0.54	-0.1	0.7	0.3	0.8	-0.2	0.5	0.84
Mandibular arch										
Intercanine distance (mm)[c]	0.1	0.6	0.44	0.0	0.4	0.0	0.7	0.3	0.5	**0.00**
Intermolar distance (mm)[c]	0.3	0.9	0.17	0.1	0.5	0.3	1.1	0.9	0.3	**0.01**
Arch length (mm)[c]	0.4	1.4	0.65	0.0	0.9	0.7	1.4	1.3	1.1	0.11
Arch depth (mm)[c]	-0.1	0.7	0.95	-0.2	0.9	-0.2	0.6	0.0	0.4	0.47

Significant values in bold
[a] Means calculated from scores: overbite = -1, cusp-to-cusp relationship = 0, open bite = +1
[b] Means calculated from scores: Class I = 0, Class II = +1, Class III = −1
[c] Means calculated from scores: decrease = −1, no change = 0, increase = +1

Subjectively, subjects in general coped well with their appliances and reported a reduction in sleep apnoea symptoms. Repeat polysomnograph tests were conducted for most subjects and indicated successful control of OSA by the appliances.

Prior to treatment, a normal bilateral posterior overbite was observed for all subjects. At recall, all subjects had bilateral posterior open bites attributed to the appliances. Changes in the left side posterior open bite approached significance as treatment duration increased ($p = 0.05$), while changes in the right posterior open bite were not statistically significant.

A significantly greater decrease in overjet was observed in MB and MB-DB subjects compared with the DB subjects ($p < 0.05$). There was a tendency for anterior overbite to decrease with the length of time the appliances were worn ($p = 0.08$). However, there were no apparent statistically significant differences between splint categories.

With treatment, a mesial shift of the mandibular canine relative to the maxillary canine and first premolar was observed in all patients, resulting in bilateral changes to the canine relationships. Changes in the canine relationships on the left side were statistically significant ($p < 0.05$) for all splint categories. In comparison, changes to the right canine relationship were not statistically significant.

A mesial shift of the mandibular molar relative to the maxillary molar was also noted, causing a bilateral change in the molar relationships. The shift was significantly different between splint categories ($p < 0.05$) for the left molar relationship, with MB and MB-DB users having greater change compared with DB users. In contrast, changes to the right molar relationship were not statistically significant.

The maxillary intercanine distance decreased with appliance wear. The decrease was statistically significant between splint categories ($p < 0.05$), with DB users experiencing the greatest decrease (Figure 6). In comparison, MB and MB-DB and users had less change.

Changes in the mandibular intercanine distance were statistically significant between splint categories over time ($p < 0.05$). MB and MB-DB users experienced a reduction in mandibular intercanine distance, with a greater decrease apparent in MB users (Figure 7). In contrast, mandibular intercanine distance remained stable or increased slightly for all DB users.

The maxillary and mandibular intermolar distances also increased as treatment progressed. This change was statistically significant between splint categories ($p < 0.05$) for the mandibular intermolar distance, with all DB patients experiencing the greatest increase in comparison with MB and MB-DB users. In comparison, the increase in maxillary intermolar distance was not statistically significant between splint categories. A trend was observed such that the increase in maxillary intermolar distance was greatest in DB subjects.

Discussion

Previous long-term cephalometric and study model investigations have indicated that extended use of MAS is associated with dentofacial changes.[9,10,12,15,16] The orthodontic effects of the MAS observed in adults differ from functional appliances used in growing children in which a dentoskeletal growth alteration is desired.[9] While skeletal changes noted often involved a rotation and/or transposition of the mandible,[17–19] other studies have reported changes in overbite and overjet, arch widths, and the canine and molar relationships.[9,10,15,16] However there has been no comparative study which has examined the side effects of various MAS appliances. This may be important for the clinician when selecting an appropriate appliance for a patient. This study therefore aimed to investigate the dental changes associated with the use of MB and DB appliances and to compare the extent of the changes induced by both appliances.

MAS-induced posterior open bite is a variable that is not commonly assessed in OSA studies. In the present study, standardised bitewing radiographs of the study models were taken, enabling the measurement of the posterior open bite. Barium liquid provided an excellent radiopaque marker because it produced a thin layer on study models from which accurate measurements could be made. Anatomical anomalies, such as mandibular tori, which prevented optimal positioning of the Snapex film holder were the same for each patient. The potential radiographic magnification did not influence the difference (delta value) between the pretreatment and follow-up measurements and did not therefore affect statistical assessment of the variables.

A recent paper by Chen et al.[20] used a 3-dimensional computerised analysis system to accurately measure conventional variables such as overbite and overjet, and to enable the measurement of formerly unassessed variables such as the posterior open bite. The reference points Chen and coworkers used to measure the posterior open bite were similar to the points we used.

The present study, as well as other studies,[10,12,15] demonstrated bilateral changes to the canine and molar relationships following MAS wear. However, changes in the left canine and molar relationships were statistically significant, while changes to the right side were not. Almeida and colleagues similarly observed a more significant mesial shift of the left mandibular molar.[21] These authors in their angled force theory suggested that the right side of the mandible was the preferred chewing side and this displaced the right condyle. Therefore, the resultant force from the MAS on the teeth was directed anteriorly and to the left.

In contrast to the present study, Almeida and colleagues reported a greater change in the right canine relationship.[21] This variation may be attributed to dentoalveolar changes associated with longer durations of treatment. The study by Almeida and associates reported dentoalveolar changes following a mean treatment duration of 7.4 years. In comparison, the present study (mean of 3.6 years) suggested changes in the positioning of the mandible as the maxillary and mandibular arch lengths remained stable throughout treatment.

The decrease in the maxillary and mandibular intercanine distances in the present study may possibly be due to a change in the forces exerted by the intra-oral and extra-oral musculature. As the mandible is postured forward during the day due to the nocturnally-induced mandibular advancement,[19,21–23] a change in tongue position[9] occurs. This may cause an imbalance of forces, leading to a greater influence of the extra-oral facial musculature compared to intra-oral musculature (i.e. tongue) on the canines. Palatal or lingual movements of the canines follow, resulting in reductions in the maxillary and mandibular intercanine distance.

Similarly, the force differential between the intra-oral and extra-oral musculature may also explain the increase in the mandibular intermolar distance, possibly from buccal movement of the mandibular molars. This buccal movement may be further encouraged due to reduced occlusal contact between opposing molars, which occurs as the posterior open bite develops over time.[9]

A major difference between MB and DB appliances was that the DB caused an overall increase in mandibular arch width (mandibular intercanine and intermolar distances),[9,10] while the MB appliance was associated with a reduction in mandibular intercanine distance, but an increase in mandibular intermolar distance.[12,15] Even within the MB category, there were statistically significant differences in the mandibular intermolar distances between the hard acrylic and soft elastomeric appliances.[12] The variation in findings suggests that differences in appliance design may have an effect on the distribution of forces affecting the alignment of the teeth. The disparity in design and material of the MAS used in the current study is possibly an important factor, which may account for the differences in mandibular arch width changes. The MB appliance in the current study was made of soft elastomeric material with a greater alveolar coverage, while the hard acrylic DB did not have any alveolar coverage. Alveolar coverage has been suggested to affect the force vectors on the dental arches.[12] The type of occlusal splint material used has been shown to affect the nocturnal activity of the masticatory muscles; muscle activity is decreased in 80 per cent of hard splint users, but increased in 50 per cent of those using soft splints.[24] It is possible that the hard DB and soft MB appliances, also used nocturnally in the present study, may lead to similar patterns in masticatory muscle activity. It is unclear how masticatory muscle activity may affect the mandibular arch width and this would benefit from further investigation.

There were limitations associated with the study which require future consideration. Because there was no objective measure of appliance wear, the patients' reporting of wear was relied upon. In addition, because of the long time scale (43 to 414 weeks), it was not possible to split the samples into two or three time groups for comparison. Doing so would have rendered group numbers too small for informative statistical assessment. Furthermore, it was difficult to perform any meaningful comparisons of mandibular advancement because data were not available for all subjects, and, had the combined MB-DB group been removed from the sample, it would have resulted in a reduction in statistical power. Future investigations should ideally include cephalometric measurements in conjunction with study model assessments to provide a better understanding of the dental changes associated with MAS.

Conclusions

A comparison of dental changes produced by the MB and DB appliance systems is important to aid the clinician in selecting an effective device that has minimal dental side effects. The present study indicated several statistically significant observations, including changes in the intercanine and intermolar distances which may possibly be explained by a daytime imbalance of forces between the intra-oral and extra-oral musculature due to nocturnally-induced mandibular advancement. A major difference between MB and DB appliances was that the DB caused an overall increase in mandibular intercanine and intermolar distances,[9,10] while the MB appliance was associated with a reduction in mandibular intercanine distance, but an increase in mandibular intermolar distance.[12,15] The variation in findings suggests that differences in appliance design (splint material, alveolar coverage) may have an effect on the distribution of forces affecting the alignment of the teeth.

While some of the orthodontic measurements demonstrated trends towards differences between the monoblock and duoblock systems, these were not significantly different. This indicates that both appliances may be used safely as they both produced similar, but mild, effects, and no particular recommendation can be made regarding the choice of appliance.

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