Altered Jaw Posture and Occlusal Disruption Patterns Following Mandibular Advancement Therapy for Sleep Apnea: A Preliminary Study of Cephalometric Predictors

Brian D. Monteith, BChD, MChD[a]

Purpose: Reports of irreversible alteration in jaw posture and destructive occlusal contact relationships in individuals using mandibular advancement devices for obstructive sleep apnea are beginning to appear. This study sought cephalometric means of identifying such individuals before commencing therapy. ***Materials and Methods:*** Cephalograms of 34 obstructive sleep apnea sufferers who had worn mandibular advancement devices for 2 years were compared retrospectively with baseline films taken at commencement of therapy and analyzed for signs of morphologic changes in jaw position and occlusal relationship. In affected patients, two distinct morphologic species of mandibular reposturing became evident: *(1)* bilateral posterior open bite with destructive incisal attrition; and *(2)* less destructive intermediate open bite over the premolar and first molar regions. From the observed morphology patterns, gonial angle and maxillary-mandibular plane angle were analyzed as possible vertical cephalometric risk predictors, with newly defined pterygoid advancement proportion (PtAP) as a horizontal predictor. ***Results:*** Three patients displayed the posterior open bite pattern and had gonial angles $\leqslant$ 119 degrees and maxillary-mandibular plane angles $\leqslant$ 16 degrees, with PtAP values $\geqslant$ 0.48. Prediction intervals for the five intermediate open bite cases were 118 degrees $\leqslant$ gonial angle $\leqslant$ 128 degrees, and 23 degrees $\leqslant$ maxillary-mandibular plane angle $\leqslant$ 32 degrees. PtAP values were $\geqslant$ 0.52. ***Conclusion:*** Cephalometric analysis can help practitioners identify which apnea patients might be likely to develop irreversible mandibular postural changes from wearing a jaw-repositioning device. *Int J Prosthodont 2004;17:274–280.*

Managing obstructive sleep apnea (OSA) through use of an intraoral device to advance the mandible is a relatively recent development.[1] Although such devices were initially held to be safe, evidence is starting to emerge that unexpected, dramatic, and possibly irreversible alterations in jaw posture can result from their use.[2]

Until the end of the 1970s, OSA sufferers had been treated traditionally with permanent tracheostomy.[3,4] However, an associative link between improvement of sleep apnea and surgical advancement of the mandible to treat retrognathism was noted around this time,[3–5] and various procedures were subsequently devised to effect surgical advancement of mandibles in the treament of OSA.[6] Nonsurgical approaches involving behavioral and medical modalities began to gain recognition.[1] However, it was not until 1995 that a surgically noninvasive, dentally driven alternative won recognition within the broader context of sleep medicine[7]; this development occurred with publication of practice parameters for the treatment of snoring and OSA using oral appliances.[8] The possibility of occlusal change being effected by these devices drew sparse comment in the literature for much of the 1990s.[9–11] Indeed, monitoring of intermaxillary tooth contacts using occlusal foil appeared to show that the occlusion remained constant throughout follow-up,[12] which led to the belief that dental appliances might be the preferred method of treatment for mild to moderate OSA.

Disconcertingly, papers that reflect growing concern as to possible side-effects of mandibular advancement device

[a]*Professor and Chair, Department of Oral Rehabilitation, School of Dentistry, University of Otago, Dunedin, New Zealand.*

Correspondence to: *Dr Brian D. Monteith, Department of Oral Rehabilitation, University of Otago, PO Box 647, Dunedin, New Zealand. Fax: + 64 3 479 5079. e-mail: brian.monteith@dent.otago.ac.nz*

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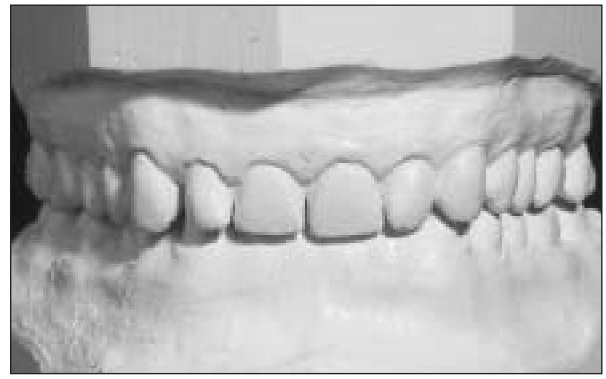
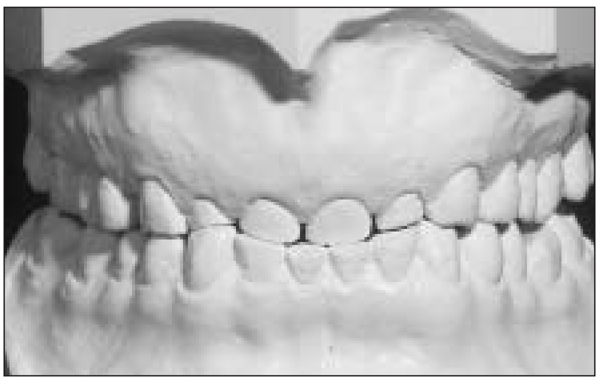
Fig 1 *(right)* Coronal view of pretreatment study models.

Fig 2 *(below)* Comparative view of study models demonstrates occlusal changes after 2 years of wearing a mandibular advancement device.

Fig 3 *(below right)* Sagittal view of study casts demonstrates mandibular reposturing and posterior open bite pattern of occlusal separation after 2 years of wear.





(MAD) use, in particular those affecting the teeth and jaw, began to appear with the turn of the millennium.[13,14] Occlusal changes observed involved decreases in overjet of 1 to 3 mm, with the proportion of patients affected appearing to increase up to 2 years but thereafter remaining constant. Follow-up studies[15] reported a mesial shift in intermaxillary sagittal relationship with a minor yet significant decrease in overbite as well as overjet. The fact that patients' teeth were firmly locked into their appliances caused authors to discount dentoalveolar changes as a cause for the occlusal discrepancies, with the speculation that remodeling of the temporomandibular joints or neuromuscular adaptation of mandibular posture might provide a more probable explanation of the observed changes in occlusal relationship.

Cephalometric analyses began to appear, initially as individual case reports[16,17] and later as more substantive follow-up studies.[2,18] Superimposition of initial and follow-up cephalograms demonstrated a downward and forward displacement of the mandible in affected cases, again prompting speculation as to whether the changes might be linked to direct osseous adaptation in the temporomandibular region. Data from one of these studies,[2] which involved follow-up of 30 subjects over a 2-year period of mandibular advancement therapy, revealed a significant mean increase in mandibular length of 0.3 mm, with a maximum value of 2.5 mm. However, a similar study[18] (involving 100 consecutively treated patients) also reported significant mandibular reposturing in certain instances, but was unable to demonstrate any bony increase in mandibular length at all. Common observations in both studies were that only certain patients appeared to have undergone permanent alteration of mandibular posture; the phenomenon, when it did occur, was unexpected, unpredictable, and apparently unrelated to intermaxillary relationship or other cephalometric variables. A disconcerting finding was that the disruption of occlusal relationships, particularly in relation to a posterior open bite pattern of mandibular reposturing, was associated with alarming degrees of attrition of anterior teeth[18] (Figs 1 to 3). In view of this—and given that the treatment of snoring and OSA is likely to be lifelong—the present study was undertaken with the research objective of finding a way to predict, cephalometrically, whether a patient wearing an MAD will be at risk of undergoing permanent mandibular postural change of a type that is likely to lead to occlusal destruction. This would test the hypothesis that the nature of the occlusal disruption pattern seen in some patients undergoing MAD therapy can be predicted by analyzing their craniofacial characteristics.

Materials and Methods

Access was provided to the orthodontic records of 100 patients who had been treated sequentially for habitual snoring or OSA. Each patient had been provided with an

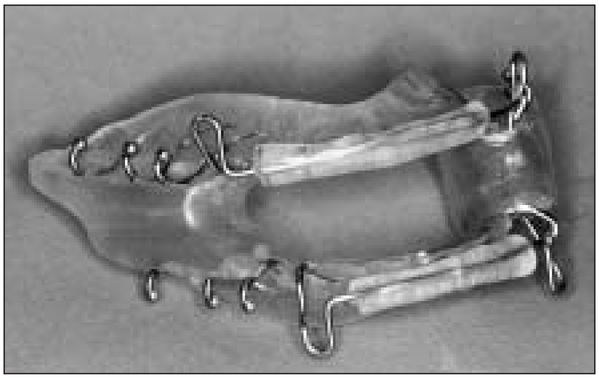


Fig 4 Monoblock splint designed to advance mandible over 75% of its protrusive range at increased opening.

Fig 5 Intermediate open bite pattern on follow-up cephalogram demonstrates typical occlusal separation over premolars and first molars, with retained intermaxillary contact at anterior and posterior of arch.

MAD of a monoblock type (Fig 4), featuring complete occlusal coverage and designed to advance the mandible over 75% of the protrusive range using the method advocated by George.[19]

The literature seems to indicate a minimum of 2 years as being necessary for mandibular reposturing to occur; accordingly, an exclusion criterion of 2 years of regular MAD use was applied to the patient base. This resulted in 34 patients being identified for further investigation (29 men and five women, with a mean age of 47.9 years). Standardized pre- and posttreatment lateral cephalograms of these subjects were available and were retraced in the conventional way.

Morphologic Considerations: Vertical Influences

Superimposition of pre- and posttreatment tracings revealed that certain individuals had undergone mandibular reposturing sufficient to cause loss of intermaxillary occlusal contacts. It was immediately evident, however, that two distinctly different patterns of interocclusal separation were at issue. The first displayed a posterior open bite that featured heavy incisal contact anteriorly, with a distally diverging wedge-shaped space between the posterior occlusal surfaces (Fig 3). The second disruption pattern was typified by an intermediate open bite that featured occlusal separation over the premolar and first molar regions, but with maintained contacts on the incisors and second molars (Fig 5).

A striking feature of both occlusal separation patterns was that each appeared to be associated with a particular pattern of mandibular rotation. These, in turn, were closely reminiscent of the two craniofacial types originally described in a series of growth studies that used implants to track mandibular growth directions in children.[20,21] One type was associated with an anterior rotation of the mandible, with a demonstrated superior/anterior curvilinear path of condylar cartilage development. Associated effects in this type were an increased posterior facial height relative to anterior height, with maxillary and mandibular planes tending toward parallelism and a characteristically acute gonial angle (GA). Those authors termed this pattern a forward rotation type. In the present study, this was a common feature of all subjects who presented with the posterior open bite pattern of occlusal separation, almost as if the use of the MAD had caused a previously established juvenile pattern of forward rotation to be reasserted. As seen in the right-side cephalometric profile in Fig 6, this would involve counterclockwise rotation of the mandible, a further relative increase in posterior face height, and a resultant separation of the most posterior occlusal surfaces.

In similar fashion, the intermediate pattern of occlusal disruption was strongly reminiscent of the second developmental rotation pattern in the earlier studies,[20,21] which was termed the backward rotation type. This features a more horizontal, posteriorly directed path of condylar development, with an increase in anterior facial height relative to the posterior height, convergent maxillary and mandibular planes, and a more obtuse GA. Characteristically, this type appeared to be a common feature of all of the intermediate open bite subjects in the present study and involved a flatter, clockwise pattern of mandibular rotation. Given their apparent link to forward and backward mandibular rotation types (Figs 6 and 7), the maxillary-mandibular plane angle (MMPA) and GA were investigated as possible vertical cephalometric risk predictors.

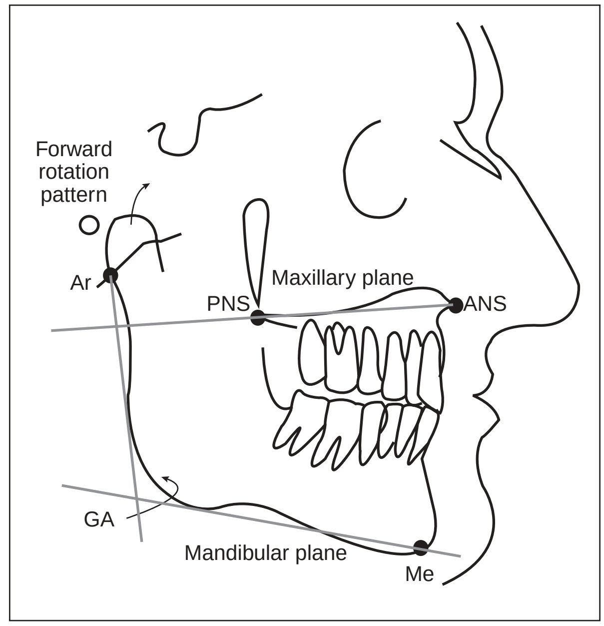
Morphologic Considerations: Horizontal Influences

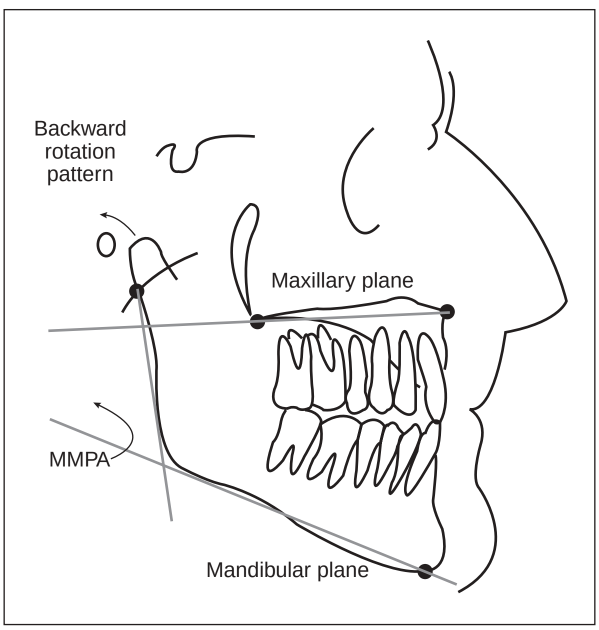
All subjects who had developed either type of open bite appeared to conform to an associated craniofacial pattern. Yet, some subjects in the sample who, despite possessing a craniofacial pattern that ought to have predisposed them

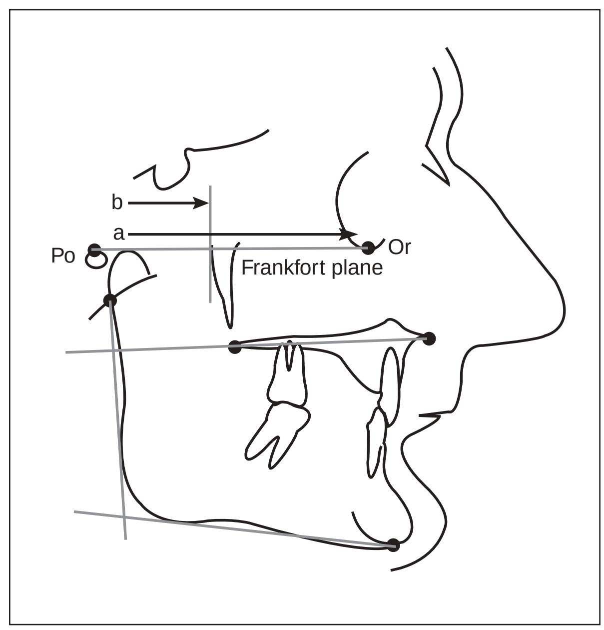
Fig 6 *(right)* Forward rotation pattern of mandibular reposturing results in posterior open bite. Closed gonial angle and small maxillary-mandibular plane angle typify this pattern of reposturing. Cephalometric points and lines used in the study are illustrated; *Ar* = articulare; *PNS* = posterior nasal spine; *ANS* = anterior nasal spine; *GA* = gonial angle; *Me* = menton.

Fig 7 *(below)* Backward rotation pattern of mandibular reposturing results in intermediate open bite. More open gonial angle and greater maxillary-mandibular plane angle *(MMPA)* typify this pattern of reposturing.

Fig 8 *(below right)* Cephalometric tracing of case noted as resistant to mandibular postural change. Posteriorly placed maxilla relative to Frankfort plane is expressed by a pterygoid advancement proportion (PtAP) < 0.45 as derived by dividing dimension *a* into dimension *b* (described in text); *Po* = porion; *Or* = orbitale.







to mandibular change, did not appear to have been so affected. One such example is illustrated in Fig 8, where a more posteriorly positioned maxillary base (compared to the affected individual in Fig 6) suggested that an additional horizontal influence might act as a codeterminant of mandibular postural change.

Reference Points, Planes, and Angles

The reference points and planes used in the investigation of vertical determinants are illustrated in Fig 6. For clarification in the face of certain descriptive differences likely to be encountered in the literature, the following definitions are also provided.

The maxillary plane is a line that passes through the tip of the anterior and posterior nasal spines of the maxilla.[22] The mandibular plane is a tangent to the lower border of the mandible passing through the menton (defined as the most inferior point on the mandibular symphysis).[22,23] MMPA is the angle formed between the maxillary and mandibular planes.[22] GA is the angle formed between the mandibular plane (as defined above) and a tangent to the posterior border of the mandible passing through the articulare (defined as the point of intersection of the

Table 1 Descriptive Statistics (n = 34)

	Age (y)	Gonial angle (°)	Maxillary-mandibular plane angle (°)
Mean	47.9	120.9	23.4
Standard deviation	8.6	7.0	6.4
Maximum	74.0	132.0	36.5
Minimum	33.0	99.0	8.0

posterior border of the mandible and the inferior border of the basilar part of the occipital bone[24]).

The cephalometric reference points and planes relating to horizontal predictors are illustrated in Fig 8. The Frankfort horizontal plane is constructed by joining points porion (Po) and orbitale (Or), which at their extremes represent the ear and eye and provide an expression of distance as well as spatial orientation. Po is defined as the most superior point of the external auditory meatus,[23] while Or is a point located at the lowest point on the external border of the orbital cavity.[23] The pterygoid vertical plane is constructed by drawing a line tangent to the posterior margin of the pterygomaxillary fissure and at right angles to the Frankfort horizontal. The pterygoid advancement proportion (PtAP) is a newly defined entity to express the anteroposterior orientation of the pterygoid vertical (and, by extension, the maxillary base) along the Frankfort plane. It is determined by measuring, in millimeters, the distance between Po and Or on the Frankfort plane and dividing this into the distance between Po and the pterygoid vertical plane's point of intersection with the Frankfort plane (ie, b/a).

Cephalometric points were identified, and planes were constructed using the pretreatment tracing of each subject. MMPA and GA values were then measured to the nearest 0.5 degree using a protractor. Linear measurements in determining PtAP were made with a ruler to the nearest 0.5 mm, and PtAP was calculated as described above. Tracings and measurements were repeated on separate occasions by the author to optimize intraexaminer reproducibility.

Data Analysis

The GA and MMPA values of each subject were examined for any distinctive grouping pattern that might link to either of the two distinct occlusal separation patterns that had been observed within the patient base. The PtAP value for each subject was included in the hope of enhancing the precision of the overall prediction by factoring in any influence that the anteroposterior position of the maxillary base might have on the predictive power of the model. The hope was to identify a risk predictor that might be useful to clinicians about to commence OSA therapy for patients using an MAD. To this end, decision matrix analysis[25] was applied to calculate sensitivity, specificity, and positive predictive value. In addition, logistic regression analysis was undertaken using the "entry" method of the SPSS, version11.5.0, statistical package's (SPSS) binary logistic regression function, with the cutpoint set at 0.5. Acting on the supposition that two distinct populations were involved, separate analyses were conducted for the forward rotator pattern and backward rotator pattern cases. In each instance, the complete set of GA, MMPA, and PtAP values were investigated as explanatory variables; the dependent variable was coded as 1 if occlusal separation was found to have occurred and 0 if no separation had been observed.

Results

Table 1 presents the global angular and linear descriptive statistics of the full group of 34 patients in the study. Of these, 3 individuals were found to have developed posterior open bite, and 5 had developed intermediate open bite. In view of the dramatic degree of occlusal damage that characterized the former group and the perceived need to find some sort of predictive pattern, it was notable that all three affected cases demonstrated GA values that did not exceed 119 degrees (mean 112.7 degrees). Likewise, their MMPA values were also on the small side, with none exceeding 16 degrees (mean 15 degrees). Subjects who had developed intermediate open bites showed GA values of between 119 and 128 degrees (mean 121.6 degrees) and MMPA values of between 23.5 and 32.0 degrees (mean 26.6 degrees). Thus, each type of observed occlusal separation pattern appeared to correspond to a numerically distinct data interval of GA and MMPA values, constituting, in effect, two circumscribed subsets within the global range of values shown in Table 1. Consequently, by analyzing these values for a particular patient, it would seem possible to determine not only whether there might be a risk of that patient experiencing occlusal disruption when wearing an MAD, but also the type of occlusal separation pattern that might be likely to arise.

PtAP values ranged from 0.44 to 0.53; however, only when one views these values within the context of separate rotator pattern species giving rise to a particular occlusal separation type does any meaningful predictor pattern emerge. Thus, forward rotator pattern patients appeared to display a risk threshold at PtAP $\geqslant$ 0.48, at and beyond which a posterior open bite occurred in all cases with this pattern. Notable, however, is that cases ostensibly at risk appeared to be immune from change if they had PtAP values $\leqslant$ 0.45. The backward rotator pattern patients displayed a comparable phenomenon. In these cases, the risk threshold occurred at a PtAP value of 0.52, at and beyond which intermediate open bites were observed; the immunity threshold for this group occurred at a PtAP value of 0.49.

Applying decision matrix analysis, use of the vertical and horizontal predictors in combination was shown to predict both species of jaw reposturing pattern correctly in all cases. Thus, sensitivity, specificity, and positive predictive power relative to predicting both forward and backward rotator pattern species all returned a value of 1.

Logistic regression analysis supported these results and permitted regression coefficients to be derived for each species of rotator pattern. Combination of coefficients with their respective explanatory variable values provided a regression equation relative to forward rotator pattern analysis:

$$z = -18{,}742.4 + (157.176 \times \mathrm{GA}) - (12.437 \times \mathrm{MMPA}) + (39{,}974.8 \times \mathrm{PtAP}) - (331.713 \times \mathrm{GA} \times \mathrm{PtAP})$$

In similar fashion, analysis of the backward rotator pattern species yielded an equation for determining z:

$$-2{,}527.827 - (8.823 \times \mathrm{GA}) + (19.44 \times \mathrm{MMPA}) + (6{,}029.17 \times \mathrm{PtAP})$$

These equations are clinically useful in that they can be applied to prospective case analysis using a standard spreadsheet application, with no need for sophisticated statistical software packages.[26]

Discussion

The clinical importance of these results is in their prosthodontic implication: Repositioning of the mandible is likely to lead to a redirection of functional stresses on relatively limited regions of the occlusal table, which, in terms of force per unit area, is capable of inducing devastating degrees of hard tissue destruction in certain cases. The prevalence of such events is as yet unclear from the literature. Apart from case reports, reporting of study samples of statistically useful size has tended to proceed from an orthodontic perspective.[2,18,27] This has concentrated on quantitative analysis of the change in mean values of multiple cephalometric parameters. Categoric considerations have been ignored, so the plight of those individual patients who require prosthodontic rehabilitation as the only means of redressing an occlusal disorder becomes effectively obscured. It is therefore important to be able to identify such individuals; the cephalometric analysis described in this article appears to make this possible. However, further work will be necessary by way of a prospective study in a far larger patient base to ensure the creation of a maximally robust diagnostic model.

Conclusion

Cephalometric analysis of affected patients' GA, MMPA, and PtAP values provides a means of predicting which of two jaw reposturing patterns might be likely to occur when an MAD is used in OSA management. Because each of these patterns is associated with a distinct type of occlusal change, this provides a method of flagging those patients who would be likely to develop the more destructive type of occlusal pattern. This might assist clinicians in identifying ahead of time those patients who might be at risk of developing destructive tooth wear and for whom use of an MAD would be contraindicated.

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