

# Treatment effects of the mandibular anterior repositioning appliance on patients with Class II malocclusion

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The mandibular anterior repositioning appliance (MARA) is a tooth-borne functional appliance for use in patients with Class II malocclusions; it positions the mandible forward into a Class I occlusion. The aim of this study was to investigate the MARA's dental and skeletal effects on anterior, posterior, and vertical changes in 30 Class II patients. The treatment group consisted of 12 boys with an average age of 11.2 years and 18 girls with an average age of 11.3 years. A pretreatment cephalometric radiograph was taken 2 weeks before treatment, and a posttreatment cephalometric radiograph was taken 6 weeks after removal of the MARA, with an average treatment time of 10.7 months. The mean and standard deviation were calculated for each cephalometric variable, and Student *t* tests were performed to determine the statistical significance of the changes. The results of the study showed that the MARA produced measurable treatment effects on the skeletal and dental elements of the craniofacial complex. These effects included a considerable distalization of the maxillary molar, a measurable forward movement of the mandibular molar and incisor, a significant increase in mandibular length, and an increase in posterior face height. The effects of the MARA treatment were then compared with those of the Herbst and Fränkel appliances. The treatment results of the MARA were very similar to those produced by the Herbst appliance but with less headgear effect on the maxilla and less mandibular incisor proclination than observed in the Herbst treatment group. (Am J Orthod Dentofacial Orthop 2003;123:286-95)

**T**he term *functional appliance* refers to a variety of removable or fixed appliances designed to alter the mandibular position both sagittally and vertically, resulting in orthodontic and orthopedic changes.<sup>1</sup>

Despite the long history of functional appliances,<sup>2-10</sup> there continues to be much controversy related to their use, effectiveness, and mode of action. The decision as to which is the most effective technique to use in the treatment of growing patients with skeletal and dental Class II malocclusions has long been the source of considerable debate in the orthodontic literature. Advocates of functional appliances cite stimula-

tion of mandibular growth caused by forward positioning of the mandible.<sup>11-27</sup> Histologic studies on laboratory animals have consistently shown a significant increase in cellular activity when the mandible is hyperpropulsed,<sup>28-32</sup> and it has been speculated that a similar effect can be produced in humans, thus aiding the correction of Class II malocclusions.<sup>5,12-25,33,34</sup>

Other investigators have disagreed with these statements, believing that greater mandibular growth does not occur in humans as had been demonstrated in animals.<sup>35-37</sup> It has been suggested that the changes might be only those expected with normal growth or conventional edgewise therapy.<sup>38-41</sup> Several researchers have proposed that the Class II correction observed with functional appliances was caused by a "headgear" effect restraining maxillary growth,<sup>38,42,43</sup> along with a combination of dental changes such as retroclination of the maxillary incisors and proclination of the mandibular incisors.<sup>41,42,44</sup>

The lack of success of functional appliances has in some circumstances been attributed to lack of patient compliance in appliance wear. In addition, failure to achieve optimum results has also sometimes been attributed to the inability to control the amount and

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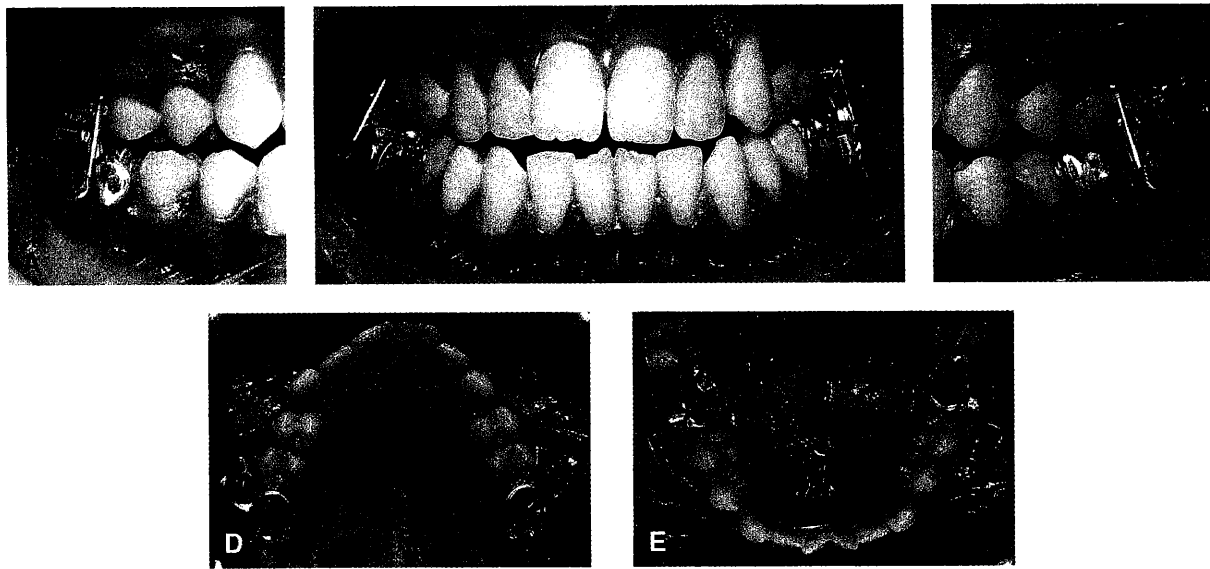


Fig 1. Intraoral photographs of MARA.

direction of mandibular growth.<sup>45</sup> Thus, the ideal appliance for correcting Class II skeletal problems would eliminate the need for patient cooperation, allow stimulation of the overall amount of mandibular growth, and direct this growth in the appropriate direction.<sup>46</sup>

Recently a new fixed functional appliance, the mandibular anterior repositioning appliance (MARA) has been added to the orthodontist's armamentarium (Fig 1). The purposes of the present study were to evaluate, with cephalometric measurements, the overall changes during treatment with the MARA; to compare the treatment effects of the MARA with an untreated Class II control group; and to compare the results of the MARA with published results of treatment with the banded Herbst and Fränkel appliances.

#### MATERIAL AND METHODS

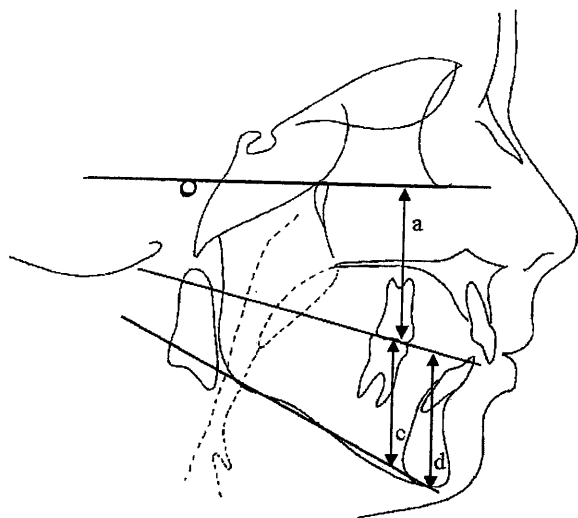
The study involved the cephalometric evaluation of 30 patients treated with the MARA from 1 private practice. The sample consisted of 12 boys (average age, 11.2 years; range, 9.5-15.8 years) and 18 girls (average age, 11.3 years; range, 9.9-15.0 years). The first cephalometric record was taken 2 weeks before the start of treatment, and the second was taken 6 weeks after the completion of treatment. The following criteria were established for the sample: (1) the patient exhibited continued growth, (2) ANB angle was greater than  $4.5^\circ$ , (3) the mandible was retrognathic, (4) malocclusion was Class II with at least an end-to-end molar and canine relationship, (5) landmarks were readily identifiable on the radiograph, and (6) the appliance was not

removed prematurely due to breakage. Average treatment time was 10.7 months (range, 8-17 months).

The experimental MARA subjects were compared with 21 Class II control subjects (13 girls and 8 boys) from the Michigan Elementary and Secondary School Growth Study for whom longitudinal cephalometric records were available for the age ranges studied.<sup>47</sup> The MARA group was also compared with Fränkel and Herbst groups that have been previously reported.<sup>48</sup> The MARA patients were closely matched for age and dentoskeletal characteristics with the patients in the Fränkel, Herbst, and historical control groups.<sup>48</sup> The mean ages were 11.1 years for the historical control subjects, 11.6 years for the Fränkel patients, and 12.0 years for the Herbst patients. The time intervals for the Fränkel, Herbst, and MARA groups were consistent with the pretreatment and posttreatment cephalometric radiographs of the MARA group.

Each cephalometric headfilm was traced by 2 investigators to verify anatomic outlines and landmark placements. The effect of functional appliance treatment on the growth of the craniofacial region was determined by cephalometric analysis (Figs 2 and 3).<sup>48,49</sup> The mean and standard deviation were calculated for each cephalometric variable, and Student *t* tests were performed to determine the statistical significance of the changes. In addition, there was no difference in cephalometric magnification between the groups.

To determine the accuracy of the method, 10 cephalograms were retraced by an original investigator,



**Fig 2.** Measurements used to compare vertical changes in untreated and MARA treated groups: a, maxillary molar eruption; c, mandibular molar eruption; d, mandibular incisor eruption (after McNamara<sup>49</sup>).

and the variables were recalculated. The interjudge reliability study indicated 73% agreement in the cephalometric measurements. All recalculated measures were within 1 mm of the original, and the average discrepancy was 0.4 mm. The test-retest reliability coefficient overall was greater than .99. For individual measures, it was between .97 and 1.00 accuracy. This indicated an extremely high level of consistency in tracing and calculating the cephalometric measurements.

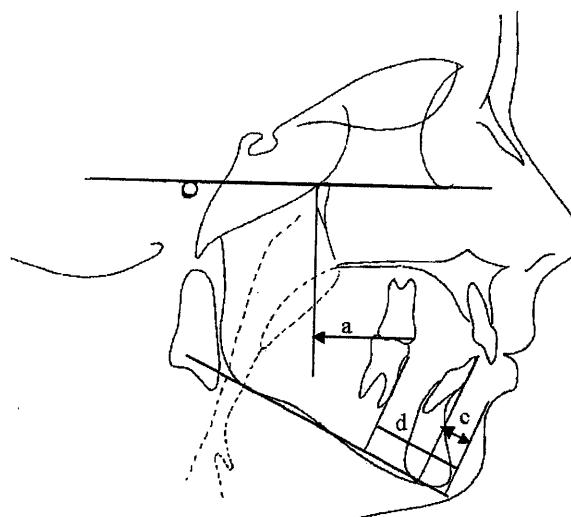
## RESULTS

Comparison between the MARA and control group was separated into starting forms (Table I) and annualized forms (Table II). In addition, an analysis was made between each of the MARA, Herbst, and Fränkel groups and the control group (Table III). The analysis used the same variables to compare each category, and the results were tabulated as a percentage of skeletal and dentoalveolar changes (Fig 4).

### Comparison of starting forms

The experimental and control samples were compared before treatment to determine the similarities between them and to assist in interpreting the results.

Although the experimental and control groups were reasonably well matched (Table I), some differences in skeletal measurements were noted. The control group had a less protrusive maxilla when measured from Co-ANS and a more retrognathic mandible as shown by



**Fig 3.** Measurements used to compare sagittal changes in untreated and MARA treated groups: a, maxillary molar change; c, mandibular incisor change; d, mandibular molar change (after McNamara et al<sup>49</sup>).

the reduced lengths of Co-Gn and Go-Pog. These measurements were statistically significant at  $P < .002$ .

There were no significant differences in any mandibular dental measurements between the groups. However, a statistically significant difference was noted in the horizontal and vertical position of the maxillary molar. The maxillary molar in the experimental group was found to be slightly more distal and inferior than in the control group. In addition, the inclination of the occlusal plane was significantly different between the 2 groups ( $P < .002$ ).

Overall comparison of the starting forms of the 2 groups showed a high level of similarity. Of the 21 variables, only 6 showed statistical differences.

### Comparison of annualized treatment effects between the experimental and control forms

The analysis of the effects of treatment was derived from cephalometric measurements taken 6 weeks after the removal of the MARA. These data were then compared with data from the control sample by using the same variables that were used in analyzing the starting forms. The data were annualized to provide a more direct comparison of growth changes (Table II).

In all 3 maxillary skeletal measurements (Co-ANS, SNA, and NA perp/Apt), there were no statistically significant differences between the experimental and control groups. Thus, the maxilla grew downward and forward at the same basic rate as in the control group.

Because most of the patients were treated with the

Table I. Starting forms

Starting forms	MARA (n = 30)		Control (n = 21)		Significance MARA/control
	$\bar{X}$	SD	$\bar{X}$	SD	
Maxillary skeletal					
Co-ANS (mm)	95.6	3.1	91.8	3.8	*
SNA (°)	80.6	3.0	81.2	2.6	NS
Nasion perp/point A (mm)	0.8	3.2	-0.3	3.2	NS
Maxillary dental					
Molar horizontal (mm)	28.4	3.8	26.0	2.7	*
Molar vertical (mm)	46.2	3.0	43.3	2.6	*
Molar to PP (mm)	21.3	4.0	22.4	2.2	NS
Mandibular dental					
Molar horizontal (mm)	31.7	3.4	31.9	2.5	NS
Molar vertical (mm)	32.9	2.9	31.8	1.6	NS
Incisor horizontal (mm)	6.6	2.2	7.6	3.1	NS
Incisor vertical (mm)	44.0	2.8	42.0	2.5	NS
IMPA (°)	94.0	4.8	94.5	6.4	NS
Mandibular skeletal					
Length (Co-Gn) (mm)	113.6	4.3	110.7	3.4	*
Pog/N perp. (mm)	-6.4	6.8	-9.5	5.7	NS
SNB (°)	75.1	3.0	75.6	4.7	NS
ANB (°)	5.4	1.8	5.7	1.9	NS
Corpus length (Go-Po) (mm)	74.1	3.2	71.9	2.6	*
Vertical					
Anterior face height (ANS-Me) (mm)	65.2	4.4	65.2	3.4	NS
Posterior face height (Co-Go) (mm)	52.5	3.9	52.9	3.1	NS
Occlusal plane (°)	6.8	3.2	10.3	3.7	*
Mandibular plane angle (°) (SNGoGn)	34.3	4.9	34.1	5.2	NS
Frankfort mandibular plane (°) (FMA)	24.0	4.9	25.0	3.7	NS

NS, Not significant;  $\bar{X}$ , mean.

\* $P < .002$ .

MARA in conjunction with a partial maxillary strap-up, the position of the maxillary incisors was not measured in this study. Only the changes in maxillary molar position were measured to assess maxillary dental changes. The change in the horizontal position of the maxillary molar was measured by dropping a line from the most posterior superior point on the pterygomaxillary fissure perpendicular to the Frankfort horizontal. A direct linear measurement was then made from the pterygoid perpendicular to the mesial contact point of the maxillary first molar (Fig 3).<sup>47</sup> Unlike the maxillary skeletal measures, there was a statistically significant difference ( $P < .002$ ) in the horizontal position of the maxillary molar. In the control group, the molar migrated forward about 1.3 mm on average. In contrast, the experimental group had on average a 1.1 mm backward movement of the maxillary molar—a net difference of 2.4 mm of annualized change.

The vertical movement of the maxillary first molar was measured from its mesial cusp tip to Frankfort horizontal (Fig 2).<sup>47</sup> The MARA group showed only an inferior movement of 0.1 mm a year versus 0.9 mm in

the control sample. Although this was not statistically significant, the MARA results suggested a tendency toward restricting eruption of the maxillary molars.

The average horizontal movements of the mandibular molar and the mandibular incisor were measured by drawing a line perpendicular to the mandibular plane through Pog. Measurements were made from the mesial contact point of the mandibular molar and the most labial surface of the mandibular incisor to the constructed Pog perpendicular (Fig 3). A forward movement of the mandibular molar or incisor relative to the Pog perpendicular was reported as a positive value.<sup>47</sup> There was a statistically significant greater forward movement of both the mandibular molar and incisor in the experimental group compared with the control group ( $P < .002$ ). In the MARA group, the mandibular molar and incisor moved forward 1.2 and 0.6 mm, respectively, versus the control group of 0.5 and -0.4 mm, respectively. In addition to this, IMPA was measured, and the results showed a statistically significant difference between the 2 groups. The experimental group had an annualized increase of 3.9° compared

Table II. Annualized change

Annualized forms	MARA (n = 30)		Control (n = 21)		Significance MARA/control
	$\bar{X}$	SD	$\bar{X}$	SD	
Maxillary skeletal					
Co-ANS (mm)	1.8	2.2	1.3	0.8	NS
SNA (°)	-0.4	1.4	0.0	0.8	NS
Nasion perp/point A (mm)	-0.2	1.4	0.2	0.8	NS
Maxillary dental					
Molar horizontal (mm)	-1.1	2.1	1.3	0.7	**
Molar vertical (mm)	1.6	2.3	1.6	0.6	NS
Molar to PP (mm)	0.1	2.9	0.9	0.5	NS
Mandibular dental					
Molar horizontal (mm)	1.2	1.3	0.5	0.7	**
Molar vertical (mm)	1.3	1.6	0.8	0.5	NS
Incisor horizontal (mm)	0.6	0.8	-0.4	0.5	**
Incisor vertical (mm)	0.5	1.7	0.9	0.5	NS
IMPA (°)	3.9	3.2	0.3	0.9	**
Mandibular skeletal					
Length (Co-Gn) (mm)	4.8	4.4	2.1	1.0	**
Pog/N perp (mm)	2.3	2.9	0.3	0.9	**
SNB (°)	1.1	1.4	0.1	0.5	**
ANB (°)	-1.4	1.4	-0.1	0.5	**
Corpus length (Go-Po) (mm)	1.7	2.4	1.6	0.7	NS
Vertical					
Anterior face height (ANS-Me) (mm)	2.5	2.0	1.0	0.8	**
Posterior face height (Co-Go) (mm)	4.0	3.4	1.3	0.9	**
Occlusal plane (°)	0.4	2.5	-0.9	1.2	*
Mandibular plane angle (°) (SNGoGn)	-0.1	1.7	-0.3	0.1	NS
Frankfort mandibular plane (°) (FMA)	-0.1	1.6	-0.3	0.7	NS

NS, Not significant;  $\bar{X}$ , mean.\* $P < .01$ ; \*\* $P < .002$ .

with a  $0.3^\circ$  increase in the control group with a significance level of  $P < .002$ .

The average vertical movements of the mandibular molar and incisor were measured by the perpendicular distance relative to the functional plane through the tip of the mesial cusp to the intersection of the mandibular plane (Fig 2).<sup>47</sup> There was no significant difference between the experimental and control groups in the vertical movement of either the mandibular molar or the incisor.

In the 5 different mandibular skeletal variables measured, all, except for corpus length, showed a statistically significant difference between the MARA and the control groups ( $P < .002$ ). Mandibular length (Co-Gn) increased annually 4.8 mm in the experimental group but only 2.1 mm in the control group. The chin point (Pog/N perp) moved forward an average of 2.3 mm in the experimental group, while the control group showed only a 0.3 mm change. Finally, ANB decreased an average of -1.4 mm annually in the experimental group versus -0.1 mm in the control group.

In the vertical measures, a statistically significant

difference was seen in the anterior and posterior face heights between the experimental and control groups. The mandibular anterior face height increased an average of 2.5 mm annually in the MARA patients and only 1.0 mm in the control group. An even greater difference was seen in the posterior face height, with the MARA group having an average increase of 4.0 mm, while the control group increased 1.3 mm ( $P < .002$ ). In addition, a significant difference was observed in the inclination of the occlusal plane between the 2 groups at the onset of treatment and after treatment. The statistical significance was more after treatment ( $P < .001$ ) than before ( $P < .002$ ). The MARA group did not show a significant difference in change of the mandibular plane angle when compared with the control group, and there was no change in the mandibular plane (SNGoGn and FMA) angles with treatment.

#### Comparison of the MARA, Herbst, and Fränkel groups

The treatment results of these 3 appliances were compared with the control sample to study the treat-

Table III. Comparisons

Comparisons	MARA (n = 30)		Herbst (n = 45)		Fränkel (n = 41)		Control (n = 21)		Significance		
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	M	H	F
Maxillary skeletal											
Co-ANS (mm)	1.8	2.2	0.9	1.4	1.6	1.0	1.3	0.8	NS	NS	NS
SNA (°)	-0.4	1.4	-0.4	1.3	-0.4	0.7	0.0	0.8	NS	NS	NS
Nasion perp/point A (mm)	-0.2	1.4	-0.5	1.2	-0.3	0.7	0.2	0.8	NS	*	NS
Maxillary dental											
Molar horizontal (mm)	-1.1	2.1	-1.4	1.9	0.7	1.1	1.3	0.7	**	**	NS
Molar vertical (mm)	1.6	2.3	0.5	1.3	1.6	1.0	1.6	0.6	NS	**	NS
Molar to PP (mm)	0.1	2.9	NA	NA	NA	NA	0.9	0.5	NS	NA	NA
Mandibular dental											
Lower molar horizontal (mm)	1.2	1.3	1.4	1.3	0.1	0.7	0.5	0.7	**	**	NS
Lower molar vertical (mm)	1.3	1.6	1.3	1.5	1.7	0.9	0.8	0.5	NS	NS	*
Lower incisor horizontal (mm)	0.6	0.8	1.6	3.2	0.1	1.1	-0.4	0.5	**	**	NS
Lower incisor vertical (mm)	0.5	1.7	-1.1	1.6	0.6	0.9	0.9	0.5	NS	**	NS
IMPA (°)	3.9	3.2	NA	NA	NA	NA	0.3	0.9	**	NA	NA
Mandibular skeletal											
Length(Co-Gn) (mm)	4.8	4.4	4.8	2.3	4.3	1.3	2.1	1.0	**	**	**
Pogonion/N perp (mm)	2.3	2.9	2.7	3.4	1.2	1.5	0.3	0.9	**	**	NS
SNB (°)	1.1	1.4	1.7	1.7	0.6	0.7	0.1	0.5	**	**	NS
ANB (°)	-1.4	1.4	-2.1	1.6	-1.0	0.7	-0.1	0.5	**	**	*
Corpus length (Go-Po) (mm)	1.7	2.4	1.8	1.6	1.9	1.1	1.6	0.7	NS	NS	NS
Vertical											
Anterior face height (ANS-Me) (mm)	2.5	2.0	1.8	1.9	2.2	1.1	1.0	0.8	**	*	**
Posterior face height (Co-Go) (mm)	4.0	3.4	3.4	2.0	3.1	1.4	1.3	0.9	**	**	NS
Occlusal plane (°)	0.4	2.5	2.9	3.5	0.4	1.9	-0.9	1.2	*	**	NA
Mandibular plane angle (°) (SNGOGN)	-0.1	1.7	NA	NA	NA	NA	-0.3	0.1	NS	NA	NS
Frankfort mandibular plane (°) (FMA)	-0.1	1.6	-0.3	2.1	-0.4	1.0	-0.3	0.7	NS	NS	NS

NS, Not significant; NA, not applicable; M, MARA; H, Herbst; F, Fränkel.  
\* $P < .01$ ; \*\* $P < .002$ .

ment effects of the appliances. The data were annualized in the same manner as previously stated with the MARA (Table III).

The only significant difference in maxillary skeletal measurements was seen in the Herbst group compared with the control group, in which Nperp/Apt was distalized 0.7 mm in the Herbst patients ( $P < .01$ ). The remaining variables showed no measurement differences among the MARA, Herbst, Fränkel, and control groups. This indicates a restriction of maxillary growth by the Herbst appliance.

Both the MARA and the Herbst measurements showed significant changes from the control for the horizontal position of the maxillary molar, while the Fränkel group did not ( $P < .002$ ). Only the Herbst group had a significant difference from the control in the vertical position of the maxillary molar ( $P < .002$ ). In the Herbst group, the molar intruded 1.1 mm more than it did in the control group, and the MARA and the Fränkel results were identical to the control sample.

In the vertical and horizontal changes of the man-

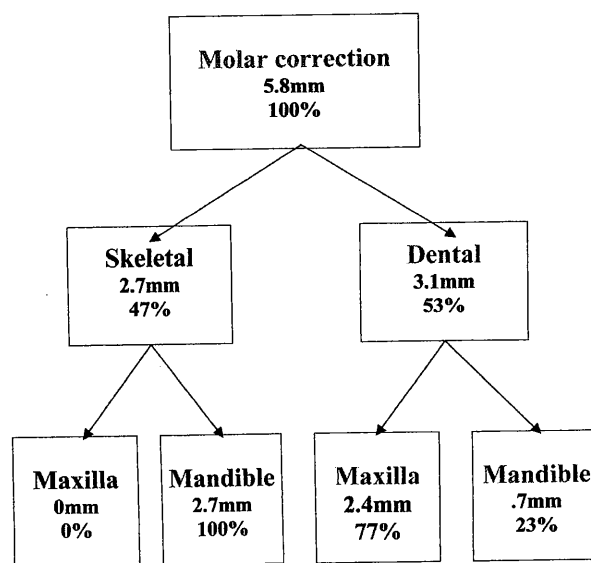


Fig 4. Maxillary and mandibular skeletal and dental changes.

dibular molar and incisor, the MARA and Herbst measurements showed similar results: significantly greater forward movement in the horizontal position of the mandibular molar and incisor than in the control group ( $P < .002$ ). The Fränkel group did not show significant dental changes ( $P < .002$ ). The vertical position of the mandibular molars was similar in the MARA, Herbst, and control groups. However, the Fränkel group showed a statistical significant difference ( $P < .01$ ). The only other vertical measurement to be significantly different was the vertical position of the mandibular incisor in the Herbst group versus the control group. The Herbst group had a 1.1 mm intrusion of the mandibular incisors while the MARA, Fränkel, and control groups all had a slight extrusion of the mandibular incisors.

The MARA and Herbst groups had similar mandibular skeletal measurements that were statistically different from the control group in all measurements ( $P < .002$ ). Mandibular length and SNB increased, while ANB decreased with respect to the control. Pog/N perpendicular decreased because of forward movement of Pog. The Fränkel group, on the other hand, was statistically different only in its increase in mandibular length ( $P < .002$ ) and its decrease in ANB ( $P < .01$ ). There was no change in corpus length in the 3 appliances when compared with the control group.

Mandibular plane changes were similar to the control in all 3 appliances. The anterior and posterior face heights were statistically different in the MARA, Herbst, and Fränkel groups when compared with the control group. All showed significant increases at the  $P < .002$  and  $P < .01$  levels. Finally, the MARA and Herbst groups showed significant changes in occlusal plane with respect to the control group. They both increased, with the Herbst ( $P < .002$ ) having a greater difference than the MARA ( $P < .01$ ).

## DISCUSSION

Although there was no maxillary skeletal effect in the patients treated with the MARA, there was a profound movement of the maxillary molar in a distal direction. The maxillary molars of the experimental group moved distally (-1.1 mm) while the control group moved forward (1.3 mm), giving a total net effect of 2.4 mm of maxillary molar distalization (Table II). This was significant in correcting the Class II malocclusion and provided most of the dental movement in the treated patients (Fig 4). There was no demonstrable difference in vertical movement of the maxillary molar between the experimental group and control group, suggesting that no extrusive or intrusive forces were applied to that molar during treatment. Because most

patients with the MARA also received a maxillary appliance, it was not possible to measure the movement of the MARA on the maxillary incisors. This should be considered a flaw in the study but as a possible treatment advantage because it permits one to align the dentition while advancing the mandible.

Dental movement in the mandible is also important in the correction of Class II malocclusions. The experimental group had a greater forward movement of the mandibular molar and incisor than did the control group (Table II). The mandibular molar moved forward an average of 1.2 mm in the experimental group versus only 0.5 mm in the control group, giving a treatment effect of 0.7 mm (Fig 4). This accounted for 23% of the total dental movement in correcting the Class II molar relationship. The mandibular incisor was also significantly affected by treatment, with a forward horizontal movement of 1.0 mm and a decrease in IMPA of approximately  $3.6^\circ$ , when compared with the values of the control sample. This dental effect of the mandibular incisor is evident with functional appliances.<sup>38,44</sup> There was no statistically significant difference in the vertical dental movement of the mandibular molar and incisor between the experimental groups, indicating that the mandibular teeth did not extrude with the MARA.

The greatest difference between the treatment and control groups was observed in the annualized changes for the mandibular skeletal measurements (Table II). All 4 variables measuring the changes in the growth of the mandible were significantly different between the experimental groups. In positioning the mandible forward, the chin point increased overall by 2.7 mm, the chin point to gonion distance forward 2.0 mm, SNB decreased  $1.0^\circ$ , and the angle of B-point increased  $1.3^\circ$  because of the overall forward movement of B-point. These findings suggest that the MARA successfully enhanced the growth potential of the mandible in the Class II patients.

Significant increases could be seen in the posterior face height and, especially, the posterior face height. The average treatment effect of the MARA on the lower anterior face height was 2.5 mm per year, while the control increased 1.0 mm per year. In the control group, posterior face height was an area of no change, with the posterior face height of the experimental group showing an annualized increase of 4.0 mm while the control group increased only 1.3 mm. One could speculate that this increase in posterior face height might be due to the MARA's stainless steel archwire on the molars that, when in occlusion, position the molars inferiorly in the glenoid fossa, thus stimulating the growth of the condyle in a superior and posterior direction. Previous studies have shown that Herbst patients

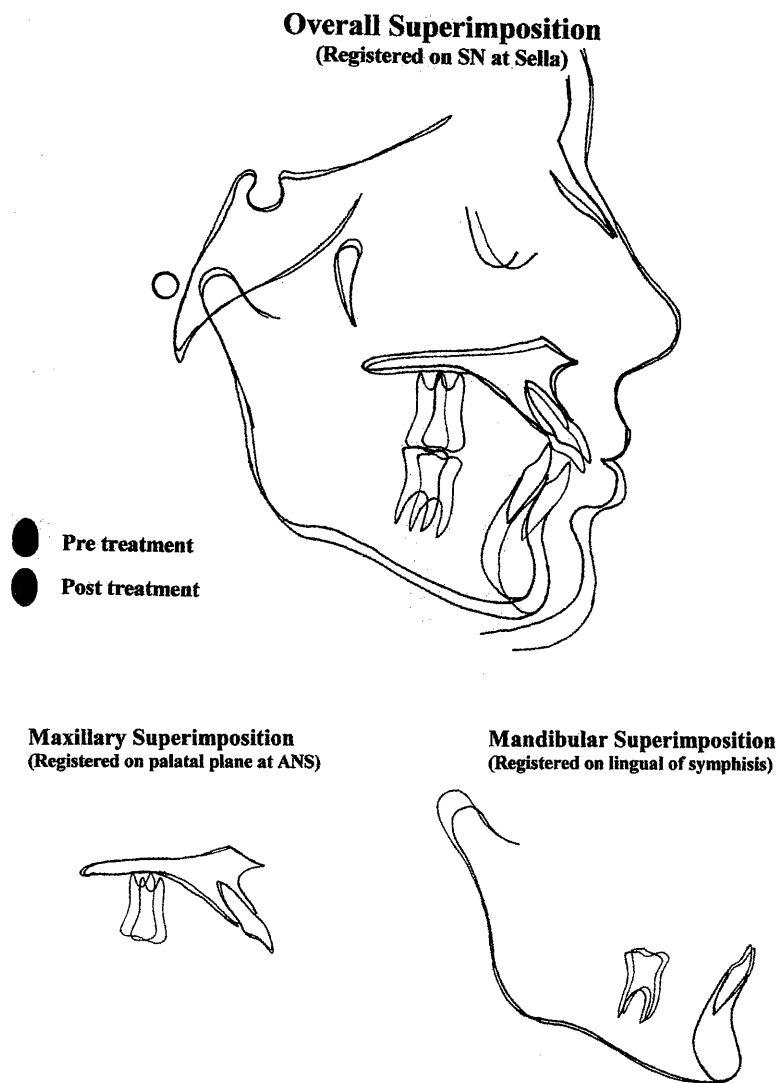


Fig 5. Cephalometric superimpositions.

rience a more posterior and superior condylar growth pattern than do those using a Fränkel appliance.<sup>50</sup> It has also been determined that vertical condylar distraction with the acrylic Herbst might contribute to a greater increase in posterior face height and result in a more upward and forward rotation of the mandible.<sup>51</sup> This could help to explain the larger effective mandibular length in the MARA and Herbst patients compared with the Fränkel and control groups. Even though anterior face height increased with treatment, there was no significant change in the mandibular plane angle. This could be explained by possible remodeling along the lower border of the mandible as a response to posterior vertical condylar growth.

The treatment effects of the MARA were compared

with the Herbst and Fränkel results of the study of McNamara et al.<sup>47</sup> The MARA seemed to produce the same treatment effects as the Herbst and a greater dentoalveolar effect than the Fränkel (Table III). This was not unexpected, because both the MARA and the Herbst are tooth-borne appliances, while the Fränkel is tissue-borne. Although the MARA and the Herbst had very similar results, some differences were noted. The Herbst had a greater restrictive effect on the maxilla, but the MARA results indicated no headgear effect. In measuring the vertical position of the maxillary molar, the Herbst had a greater intrusive effect than did the MARA; this could be due to a combination of dental intrusion and restrictive downward growth of the maxilla produced by the Herbst appliance. The final differ-



ence observed between the 2 appliances was in the vertical position of the mandibular incisors. The Herbst caused the mandibular incisor to move downward and forward during treatment. Although both the MARA and the Herbst produced a significant change with respect to the control group in the horizontal position of the mandibular incisor, the MARA produced much less movement, suggesting that it causes less incisor flaring.

## CONCLUSION

This study showed that the MARA is effective in treating patients with Class II malocclusions through dental and skeletal changes in the craniofacial complex. The annualized 5.8-mm Class II molar correction was obtained by a 47% skeletal change (2.7 mm) and a 53% dental change (3.1 mm). The 2.7-mm skeletal change was completely due to growth of the mandible. The skeletal changes indicated that the MARA produced increases in mandibular length and in posterior and anterior face heights but had no headgear effect on the maxilla (Fig 5). In contrast, the dental changes were mainly due to the distalization of the maxillary molar (2.4 mm), which accounted for 77% of the total dental correction. The mandibular molar moved forward about 0.7 mm, accounting for only 23% of the total dental correction. Therefore, dental changes included distalization of the maxillary molar, forward movement of the mandibular molar and incisor, and a slight proclination of the mandibular incisor (Fig 5). The MARA produced similar dentoalveolar changes as the Herbst and greater dentoalveolar changes than the Fränkel II appliance.

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