Original Article

Treatment effects of the mandibular anterior repositioning appliance in patients with Class II skeletal malocclusions

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ABSTRACT

Objective: To examine the changes produced by the mandibular anterior repositioning appliance (MARA) appliance and compare the treatment effects to an untreated Class II control group.

Materials and Methods: Thirty consecutively treated patients were matched with an untreated control group. Lateral cephalograms were taken at T1, 5 months pre-MARA (CVMS 2.7); T2, immediately after MARA removal and prior to placement of full fixed edgewise appliances (CVMS 4.2); and T3, at least 2 years after MARA removal and completion of edgewise treatment (CVMS 5.4). The mean age of the MARA patients was 11.9 years for boys and 10.8 years for girls. Repeated-measures analysis of variance (ANOVA) was used to assess if the samples were morphologically comparable at the outset and to test if there were significant differences between the groups for the various increments of change. Given a significant ANOVA, the source of the difference was explored via Tukey-Kramer tests.

Results: Restriction of maxillary growth and no significant mandibular growth were observed with the MARA appliance. The Class II correction was obtained mainly by slight maxillary molar distalization and intrusion, in addition to mesial migration of the lower molars and flaring of the lower incisors. No vertical effect was observed with this appliance.

Conclusion: The MARA appliance was effective in the treatment of Class II malocclusions. Restriction of maxillary growth and dentoalveolar changes in the maxillary and mandibular arches were responsible for the correction of the Class II malocclusion. Significant mandibular growth did not contribute to this correction. (*Angle Orthod.* 2012;82:971–977.)

KEY WORDS: MARA; Maxillary growth restriction; Dentoalveolar changes; Molar distalization

INTRODUCTION

Class II malocclusions present a major and common challenge to orthodontists. Based on an overjet greater than 4 mm, the Third National Health and Nutrition Examination Survey (NHANES III) data indicated an 11% prevalence of Class II malocclusion in the US population. It has been reported that this malocclusion accounts for 20% to 30% of all orthodontic patients.[1] Seventy-five percent of the Class II patients exhibit a retrusive chin position.[2,3] Once the skeletal Class II pattern has been established, it remains as such during the growing years and thereafter.[4–6]

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.

Four commonly used methods for Class II correction include (1) selective extraction therapy, (2) orthopedic forces delivered with headgear, (3) functional jaw orthopedics using functional appliances, and, more recently, (4) molar distalization with or without temporary anchorage devices.

The term *functional appliance* refers to a removable or fixed appliance designed to alter the mandibular position both sagittally and vertically, resulting in

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orthodontic and orthopedic changes in the jaws.[7] Despite their long history, functional appliances continue to be controversial in their use, effectiveness, and mode of action. Advocates of functional appliances cite stimulation of mandibular growth caused by forward positioning of the mandible.[8,9] Histologic studies on laboratory animals have consistently shown a significant increase in cellular activity when the mandible is hyperpropulsed,[10–12] and it has been speculated that a similar effect can be produced in humans, thus aiding in the correction of Class II malocclusions.[13–19] However, some investigators disagree with these findings, claiming that the changes might be only those expected with normal growth or conventional edgewise therapy.[20,21] Several researchers have proposed that the Class II correction observed with functional appliances was caused by a headgear effect restraining maxillary growth[20,22,23] along with a combination of dental changes, such as retroclination of the maxillary incisors and proclinaton of the mandibular incisors.[21,22] Anterior glenoid fossa remodeling and spontaneous anterior mandibular displacement that occurs after elimination of a functional retrusion also have been cited as contributors to Class II correction.[24,25]

The lack of success with functional appliance treatment has been attributed to a lack of patient compliance and the inability to control the amount and direction of mandibular growth.[26] One of the few fixed functional appliances that eliminate this compliance factor is the mandibular anterior repositioning appliance (MARA). This device can be used concomitantly with full fixed appliances while the skeletal correction is being achieved.

The purpose of this study was to use cephalometrics to evaluate the overall changes produced by the MARA and to compare its treatment effect to an untreated Class II control group.

MATERIALS AND METHODS

This retrospective cephalometric study examined 30 consecutively treated patients involving 12 boys with a mean age of 11.9 years (range, 10 years 2 months to 14 years 4 months) and 18 girls with a mean age of 10.8 years (range, 8 years to 13 years 6 months). All patients complied with the following inclusion criteria: SNA: 80° to 84°, SNB $<76^\circ$, ANB $>4.5^\circ$, SN-GoGn 30° to 35°, Class II molar relation, and easily identifiable cephalometric landmarks. Two orthodontists, who shared the same treatment approach with the MARA, treated these patients.

This study was approved by the Institutional Review Board of the University of Detroit Mercy.

Lateral cephalometric x-rays were taken at T1, a maximum of 5 months pre-MARA treatment cervical vertebral maturation stage (CVMS 2.7); T2, immediately after MARA removal and prior to placement of full fixed edgewise appliances (CVMS 4.2); and T3, at least 2 years after MARA removal and after completion of edgewise treatment (CVMS 5.4). The mean treatment time interval with the MARA (T1–T2) was 1.3 years $\pm$ 6 months, the mean T2–T3 interval with full edgewise treatment was 1.5 years $\pm$ 3.2 months, and the mean T1–T3 time interval was 3.5 years $\pm$ 6 months. Some patients were treated with upper partial fixed appliances to increase the overjet and decrease the overbite prior to the MARA therapy. A stepwise advancement protocol of 2–3 mm every 2–3 months was used until the overjet was slightly overcorrected.[27] Full edgewise brackets were placed at the time of the MARA removal.

The control group was composed of 21 subjects from the Michigan Growth Study who conformed to the inclusion criteria. They were matched to the MARA group by skeletal age and their skeletal characteristics.

The cephalometric radiographs were digitized and corrected to 0% magnification. The Dolphin Imaging 10 software (Dolphin Imaging, 9200 Eton Avenue, Chatsworth, Calif) was used to obtain the cephalometric measurements. The measurements used were maxillary skeletal measurements: SNA, Apt-Nperp, and Co-Apt; maxillary dental measurement: U1-FH, U6-PTV, and U6-PP; mandibular skeletal measurement: SNB, Pog-Nperp, gonial angle (Ar-Go-Me), Co-Go, Go-Gn, Co-Gn, and SN-GoGn; mandibular dental measurement: IMPA and L6-Crown-symphysis (mesial contact point of L6 to a line tangent drawn to the lingual aspect of the symphysis and perpendicular to the mandibular plane); and intermaxillary measurements: ANB, Wits appraisal, SN-Occ plane, and overjet.

Statistical Analysis

Repeated-measures analysis of variance (ANOVA) was used to assess if the samples were morphologically comparable at the outset and to test if there were significant differences between the groups for the various increments of change. Given a significant ANOVA, the source of the difference was explored via Tukey-Kramer tests. A Bonferroni correction was made to determine the significance of the findings, and the P value was calculated at $P \leq .003$

The records of 10 patients were randomly selected, and intraclass correlations were used to calculate the reliability of the various cephalometric measurements. The correlation value was 97% for the overjet and for ANB and 99% for all the other measurements.

RESULTS

The experimental and the control samples were compared before treatment to determine the similarities

Table 1. Comparison of Starting Forms: Mandibular Anterior Repositioning Appliance (MARA) vs Controls

Measurement	T1 MARA	T1 Control	MARA vs Controls		
			Mean	*t* Value	*P* Value
Maxillary skeletal					
SNA, °	82.47	82.7	0.2	0.23	.82
Co-A pt, mm	81.4	81.2	−0.2	−0.11	.9
A-Nperp, mm	1.67	1.62	−0.04	−0.05	.9
Maxillary dental					
U1-FH, °	112.3	114.9	2.6	1.31	.1
U6-PTV, mm	14.3	11.9	−2.95	−2.47	.14
U6-PP, mm	17.1	14.8	−2.2	−3.16	.001*
Mandibular skeletal					
SNB, °	76.9	76.5	−0.39	−0.36	.7
Gonial angle, °	124.4	123.7	−0.6	−0.3	.7
Go-Gn, mm	71.3	72.2	0.8	0.39	.6
Co-Gn, mm	105.7	104.9	−0.82	−0.35	.72
SN-GoGn, °	30.3	32.2	1.9	1.14	.2
Pog-Nperp, mm	−5.3	−4.9	0.3	0.16	.8
Co-Go, mm	53.8	48.09	−5.7	−3.35	.001*
Mandibular dental					
IMPA, °	96.3	93.8	−2.5	−1.3	.1
L6-Crown-symphysis, mm	19.38	19.29	0.09	−0.12	.91
Intermaxillary skeletal					
ANB, °	5.5	6.2	0.6	1.36	.17
Wits, mm	2.7	4.3	1.6	3.39	.0001*
Intermaxillary dental					
Overjet, mm	6.3	6.6	0.2	0.11	.9
SN-Occl Pl, °	17.2	15.9	−1.3	−1.07	.2

* $P < .003$.

between them and to assist in interpreting the results (Table 1). Although the experimental and the control groups were well matched, some differences in skeletal measurements were found. The Wits appraisal was larger in the control group ($P < .001$). The posterior face height (Co-Go) and U6-PP were significantly larger in the MARA group ($P < .001$).

Maxillary Skeletal Measurements

Comparison of treatment effects: MARA vs control (Table 2). When comparing the differences between the MARA and the control groups, all of the maxillary skeletal measurements showed no statistically significant differences at any of the time intervals studied. However, a slight growth restriction was observed over time.

Maxillary Dental Measurements

The upper incisors were flared after MARA treatment (T2–T1), but their inclination was not significantly different from the controls after edgewise therapy (T3–T2) and over the entire observation period (T3–T1).

The horizontal position of the upper molars (U6-PTV) was not significantly different between the treatment and control groups after MARA therapy (T2–T1). When the differences were examined long-term (T3–T1), the control group showed a larger mesial displacement of the upper molars (6.19 mm), which paralleled the anterior growth of the maxilla (Co-Apt, 5.94 mm). In the MARA sample, the mesial displacement of the molars (3.23 mm) was less than that of the anterior displacement of the maxilla (Co-Apt, 4.26 mm), thus indicating a restrictive effect on anterior molar movement.

The vertical distance of the upper molars to the palatal plane (U6-PP) was significantly larger in the MARA group than the controls at T1. This difference decreased 1.3 mm after MARA treatment (T2–T1) when compared with the controls. Therefore, a restraining effect on molar eruption occurred during MARA treatment. This effective intrusion was maintained during the edgewise phase (T3–T2) and long-term (T3–T1).

Mandibular Skeletal Measurements

The SNB angle decreased 1.04° during MARA treatment (T2–T1) for an overall decrease of 1.5° (T3–T1). The mandibular length (Co-Gn) showed a slight decrease during the MARA treatment (T2–T1). A

Table 2. Differences Between Control and Treatment Groups[a]

Measurement	Group	DT T2–T1	Control-Treatment Mean	*P* Value	DT T3–T2	Control-Treatment Mean	*P* Value	DT T3–T1	Control-Treatment Mean	*p Value*
Maxillary skeletal										
SNA, °	Control	−0.03	2.47	.01	−0.82	−0.04	.97	−0.84	2.43	0.01
	MARA	−2.50			−0.78			−3.28		
Co-A pt, mm	Control	2.39	−0.44	.99	3.54	2.12	.57	5.94	1.68	0.78
	MARA	2.84			1.42			4.26		
A-Nperp, mm	Control	0.07	1.15	.27	−0.55	−0.43	.68	−0.47	0.72	0.49
	MARA	−1.08			−0.12			−1.20		
Maxillary dental										
U1-FH, °	Control	−2.43	−4.36	.03	1.88	2.13	.28	−0.55	−2.23	0.26
	MARA	1.93			−0.25			1.69		
U6-PTV, mm	Control	2.25	0.59	.99	3.94	2.38	.09	6.19	2.96	0.02
	MARA	1.66			1.57			3.23		
U6-PP, mm	Control	1.66	1.29	.04	0.87	−0.51	.43	2.52	0.78	0.22
	MARA	0.36			1.38			1.74		
Mandibular skeletal										
SNB, °	Control	0.52	1.04	.15	0.07	0.43	.55	0.60	1.47	0.04
	MARA	−0.51			−0.36			−0.87		
Gonial angle, °	Control	1.73	0.54	.71	−3.26	−1.42	.32	−1.53	−0.88	0.54
	MARA	1.19			−1.84			−0.65		
Co-Go, mm	Control	1.27	2.11	.28	−0.42	−1.87	.34	0.85	3.99	0.19
	MARA	3.39			1.45			4.84		
Go-Gn, mm	Control	2.97	−0.30	.92	1.91	−2.75	.33	4.88	−3.05	0.28
	MARA	3.26			4.66			7.92		
Co-Gn, mm	Control	4.44	−1.28	.28	2.21	−0.57	.63	6.65	1.84	0.55
	MARA	5.72			2.77			8.49		
SN-GoGn, °	Control	−0.77	−1.92	.03	0.54	0.80	.36	−0.22	−1.12	0.21
	MARA	1.15			−0.26			0.89		
Pog-Nperp, mm	Control	0.35	−1.43	.63	1.01	−3.05	.31	1.36	−4.47	0.14
	MARA	1.78			4.06			5.83		
Mandibular dental										
IMPA, °	Control	0.10	4.78	.002*	−0.72	1.97	.19	−0.62	2.81	0.06
	MARA	4.88			−2.69			2.19		
L6-Crown-symphysis, mm	Control	−0.22	2.08	.02	−0.89	0.04	.96	−1.11	2.12	0.01
	MARA	−2.29			−0.93			−3.23		
Intermaxillary skeletal										
ANB, °	Control	−0.38	1.08	.0001*	−0.41	−0.29	.23	−0.40	0.22	0.35
	MARA	−1.46			−0.12			−0.63		
Wits, mm	Control	−0.27	0.68	.20	−0.34	−0.34	.52	−0.61	0.34	0.52
	MARA	−0.95			0.00			−0.95		
Intermaxillary dental										
Overjet, mm	Control	−0.60	2.33	.0001*	−0.24	−0.40	.48	−0.84	1.93	0.0007*
	MARA	−2.93			0.16			−2.77		
SN-Occl Pl, °	Control	−0.86	−2.62	.003*	−1.25	−0.26	.77	−2.10	−2.88	0.001*
	MARA	1.76			−0.99			0.77		

[a] MARA indicates mandibular anterior repositioning appliance.

* $P < .003$.

larger increment of growth (1.9 mm) was observed during the edgewise phase (T3–T2), resulting in a slight nonsignificant increase in total mandibular length of 1.0 mm from T3–T1. However, corpus length (Go-Gn) increased during all the time points studied for a total change of 3.05 mm. The distance of Pog-Nperp decreased 4.47 mm, indicating an anterior displacement of the mandible. The SN-GoGn showed an increase of 1.92° after MARA therapy (T2–T1). This initial increase was reduced at T3 for a total overall change of 1.12° (T3–T1). The 1.5° decrease in SNB could be attributed to the opening of the mandibular plane angle.

Mandibular Dental Measurements

The lower incisors (IMPA) flared significantly 4.88° during MARA treatment (T2–T1). This initial flaring was corrected during the edgewise phase (T3–T2) and remained stable thereafter (T3–T1), for a nonsignificant difference of 2.81° from the controls. A 2-mm mesial movement of the lower molars (L6-Crown-symphysis) was observed with the MARA treatment (T2–T1) and at the end of the observation period (T3–T1), which paralleled the flaring of the lower incisors.

Intermaxillary Skeletal Measurements

The ANB angle had a statistically significant reduction with the MARA treatment (T2–T1). No statistically significant differences were found between the groups overtime. The Wits appraisal did not change significantly from the controls at all time points studied, during MARA treatment (T2–T1).

Intermaxillary Dental Measurements

The overjet showed a statistically significant decrease of 2.3 mm immediately after MARA treatment (T2–T1), for a total decrease of 1.93 mm long-term (T3–T1) when compared with the controls. The SN-Occ Pl increased significantly during MARA treatment (T2–T1). During the edgewise phase (T3–T2), there were no statistically significant differences in the amount of change between the groups. When the changes in the occlusal plane were evaluated long-term (T3–T1), a significantly steeper occlusal plane remained in the MARA sample.

DISCUSSION

Maxillary Changes

A slight restriction of maxillary growth was observed in the treatment group. This finding is similar to those reported in other studies using the Herbst and MARA appliances.[28–30]

The upper incisors flared initially in the MARA group. This finding contrasts with the results found in the literature, which report retroclination of the maxillary anterior teeth after functional appliance therapy.[19,23] The utilization of partial anterior maxillary braces to flare the incisors prior to mandibular advancement with the MARA appliance explains this finding. This initial flaring of the upper incisors was resolved during the fixed edgewise appliance phase.

The anterior-posterior position of the maxillary molars in the MARA group was not significantly different after MARA treatment (T2–T1) and overall (T3–T1) from that of the controls. However, when evaluated long-term, a difference of 3 mm from the controls was observed. This could be explained by the relative restriction of maxillary growth observed with the MARA. This result is similar to those of others previously reported.[26,28–31]

The MARA produced a significant intrusion of the upper molars. This may be due to both the thickness of the cementing medium and stainless-steel crowns involved in the construction of the appliance and the forces of occlusion acting on them.[26] It is interesting to note that long-term, there were no differences from the controls, indicating that the upper molars erupted after the appliance was removed and full fixed appliance was used. This could be considered an overall intrusion effect since the molars in the MARA patients had a significantly larger measurement from the palatal plane than the controls at the onset of treatment.

Mandibular Changes

The size of the mandible, as measured from Co-Gn, did not show a statistically significant change in the MARA group, leading one to conclude that there was no skeletal effect on the mandible. However, the corpus length had a 3.05-mm increase in the MARA group, suggesting an overall mandibular remodeling in response to functional appliance treatment. This contrasts with the findings of other investigators[28,30,31] who reported a significant increase in mandibular length. Ghislanzoni et al.[30] reported a significant increase of 2.2 mm in mandibular length after MARA treatment. However, the 1.84-mm total increase in mandibular length in the present study was not statistically significant. The discrepancy between these two studies could be explained by the difference in the statistical analysis used and differences in the level of significance chosen by the authors. The findings of this investigation are in agreement with those previously reported by randomized clinical trials and other clinical studies, which showed insignificant change in mandibular length with functional appliances.[32–35] The anterior displacement of Pog could be due to a combination of slight mandibular growth and glenoid fossa remodeling.[36,37] One could speculate that according to the Servo system mechanism of Petrovic, the restriction of maxillary growth produced by functional appliances could affect the increase in the length of the mandible.[38]

The lower molars moved mesially in the MARA group when compared with the controls. Similar findings have been reported after Herbst therapy.[28,29,31] The mesial migration of the molars and the increase in IMPA could explain the dentoalveolar effect of the MARA appliance.

Intermaxillary Changes

The initial reduction of the ANB angle and Wits appraisal was similar to that previously reported.[26,29,30]

The controls experienced a similar reduction when evaluated long-term, thus reducing the initial differences. The initial reduction of the Wits appraisal could have been a function of the increase in the occlusal plane. As the occlusal plane returned to its initial dimension, after MARA removal, the Wits reduction was eliminated. These findings are consistent with those previously reported with the MARA and acrylic Herbst appliances.[26,28]

The overjet was similar in both groups at the onset. The control sample showed an insignificant decrease over time. The MARA subjects experienced a larger reduction. This decrease in the overjet could be attributed to the significant flaring of the lower incisors, maxillary growth restriction, and a combination of spontaneous anterior mandibular displacement, slight mandibular growth, and glenoid fossa remodeling.[25,36,37]

CONCLUSIONS

The MARA was effective in the treatment of the Class II malocclusions by:

- Maxillary growth restriction, slight maxillary molar distalization, and intrusion
- No significant effect on mandibular growth
- Mesial migration of the lower molars and flaring of the lower incisors
- No significant vertical changes
- Restriction of maxillary growth and dentoalveolar changes in the maxillary and mandibular arches, without a significant effect on mandibular growth, were responsible for the correction of Class II malocclusion.

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