Original Article

Skeletal and Dental Effects During Observation and Treatment with a Magnetic Device

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Abstract: The aim of this study was to evaluate the effects of a magnetic appliance, MAD IV, on the treatment of anterior open bites in growing patients. The study material included the lateral cephalograms and hand-wrist radiographs of 16 patients who had an anterior open bite malocclusion. The radiographs were taken at the beginning (T_1) and at the end of observation period (T_2) and at the end of MAD IV application (T_3). At the beginning of the study, the mean age of the subjects was 11 years two months. To define the direction of facial growth, the patients were first observed for nine months without any orthodontic or orthopedic approach. At the end of the observation period, patients who had shown a vertical growth direction, resulting in an increase in open bite, were given an MAD IV appliance and were instructed to wear the appliance 18 hours a day for 7.5 months. Thirty-two different parameters were evaluated from the lateral cephalograms. Paired *t*-tests were used for statistical evaluation of differences that occurred during the periods and between the periods. During the observation period, the patients continued their mandibular posterior rotation resulting in an increase in lower facial height ($P < .001$) and an open bite ($P < .01$). During the treatment period, the patients showed an anterior mandibular rotation with statistically important decreases in lower facial height and open bite ($P < .001$). In the treatment of anterior open bite with the MAD IV appliance, skeletal changes played a role along with dental and dentoalveolar effects. (*Angle Orthod* 2003;73:716–722.)

Key Words: High angle; Open bite; MAD IV appliance; Anterior mandibular rotation

INTRODUCTION

The diagnosis and treatment of skeletal open bite malocclusion continue to be one of the most difficult problems for orthodontists. Skeletal open bites are mainly caused by overeruption of the posterior teeth or vertical overgrowth of the posterior dentoalveolar structures. Either of these implies a posterior rotation of the mandible,[1–5] superior repositioning of the glenoid fossa due to underdevelopment of the middle cranial fossa[1,6] and underdevelopment of the anterior portion of the maxilla, or a combination of these effects.[4,7,8] These growth patterns could be associated with tongue and orofacial muscular imbalance or with habits.[8–11]

In adults, severe skeletal open bite deformities are best treated with orthognathic surgical procedures combined with orthodontic therapy, if possible.[12] However, orthodontists and individuals usually prefer early correction of the malocclusion. In the early treatment approach, the goal is based on the inhibition of the vertical development of the posterior dentoalveolar structures or intrusion of the posterior teeth by means of a high pull headgear,[13,14] activator,[15,16] combined headgear and upper plate,[17] open bite bianotor,[18] activator-headgear combination,[19] vertical chin cup,[20] or passive and active bite blocks.[21–24]

A recent approach to this problem is the use of the active vertical corrector (AVC), introduced by Dellinger.[25] The AVC consists of upper and lower bonded bite blocks containing four pairs of occlusally placed repelling magnets in the posterior region. Dellinger[25] reported rapid intrusion of the posterior teeth and an anterior rotation of the mandible.

Animal and clinical studies comparing magnetic and nonmagnetic bite blocks have shown that open bite corrections are more effective when magnets are used.[26–30] Comparative clinical studies with magnetic and acrylic posterior bite blocks have demonstrated that the therapeutic effect of magnetic bite blocks is characterized by anterior mandibular rotation, significant intrusion of the posterior teeth, and open bite closure associated with maxillary incisor eruption and lingual tipping.[27,30] These effects are especially marked

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Accepted: January 2003. Submitted: December 2002.
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in growing individuals. However, because magnetic bite blocks provide lateral shearing forces as well as vertical ones, transverse problems (ie, unilateral crossbite) were sometimes observed during treatment. To avoid adverse lateral vectors, the use of magnets with a lower force threshold[27] or use of a vertical chin cup has been proposed.[25]

Darendeliler and Joho,[31] introduced a removable appliance with posterior repelling and anterior attracting magnets termed MAD IV. This arrangement provided them with the advantage of guiding the mandible to a midline centric position, but they did not report any results. Darendeliler et al[32] presented different kinds of MAD IV appliance usage in case reports. They showed that the effects of MAD IV appliances with posterior as well as anterior magnets did add an anterior closing effect that accentuated and facilitated the anterior rotation of the mandible.

The purpose of this study is to evaluate the skeletal and dental effects during observation and treatment with a magnetic device (MAD IV) on subjects demonstrating an anterior open bite with a Class I or II skeletal malocclusion.

MATERIALS AND METHODS

Sample selection

The sample in this study consisted of 16 patients (eight boys, eight girls) with anterior open bites and with Class I or Class II, division 1 malocclusions between the ages of nine years six months and 13 years six months. According to their hand-wrist radiographs' evaluation, determined using the atlas of Greulich and Pyle,[33] their skeletal ages ranged between nine years six months to 13 years one month. The following criteria were considered in the selection of patients.

- Existence of an anterior open bite with a skeletal component, verified by at least one of the following cephalometric values, ie, a steep mandibular plane, increased lower anterior facial height, and a large gonial angle.
- The presence of a sagittal Class 1 or Class 2 skeletal type.
- The presence of fully erupted upper and lower permanent incisors, no records of sucking habits within recent years, and no need for tonsillectomy or adenoidectomy on examination by an otorhinolaryngologist.

Observation period (T_2-T_1)

At the beginning of this period, lateral cephalograms and hand-wrist radiographs were obtained from all subjects (T_1). The subjects were observed for a period of 9.25 months without any orthodontic or orthopedic treatment. During the observation period no extraction of deciduous or permanent teeth was performed. At the end of this period, lateral cephalograms and hand-wrist radiographs were taken to evaluate the changes in skeletal and dental structures to see the growth direction and amount of growth potential (T_2).

MAD IV appliance

The MAD IV consists of removable upper and lower plates, each of which contains three cylindrical neodymium iron boron ($Nd_2Fe_{17}B$) magnets coated with stainless steel[30] (Figure 1a,b). The four posterior magnets, embedded in a repelling configuration, generate an intrusive force of 300 g per side with a bite opening of five mm at the posterior teeth. The two anterior midline magnets, embedded in an attractive configuration with a force of 300 g, are positioned with a vertical opening of two mm to three mm, whereas the posterior magnets are placed in full contact (Figure 1c,d).

Treatment period (T_3-T_2)

The subjects were instructed to wear the MAD IV appliances full time except during meals and were checked every month. No extraction of deciduous or permanent teeth was performed. When a normal dental relationship was obtained with a reasonably well-corrected open bite, treatment was ended and the posttreatment records were taken (T_3) (Figure 2a,b).

Cephalometric and statistical analyses

Lateral cephalograms and hand-wrist radiographs used for this study were exposed at the beginning of the study and before and after treatment for all 16 patients. All cephalograms were taken with the patients in a standing position with relaxed lips and teeth in occlusion. All cephalometric radiographs were traced by the same investigator (Dr Meral). All radiographs were traced, digitized, and evaluated with RMO JOE Jiffy 5.0 (Denver) program. Fifteen linear, 16 angular, and one ratio were determined (Figure 3).

The method error was assessed by retracing and redigitizing 24 randomly selecting cephalometric radiographs after 15 days. Method error coefficients for all measurements were calculated and were within acceptable limits (range 0.98–0.99).[34]

The average differences at the beginning and end of observation, at the beginning and end of treatment, and the comparison of the observation and treatment periods were evaluated with the paired *t*-test.

RESULTS

A comparison of the chronological and skeletal age at T_1, T_2, and T_3 and changes during observation and treatment periods are shown in Table 1. The means and standard error of the means of skeletal and dental measurements at T_1, T_2, and T_3 and the mean changes during the observation and treatment periods are presented in Tables 2 through 4.

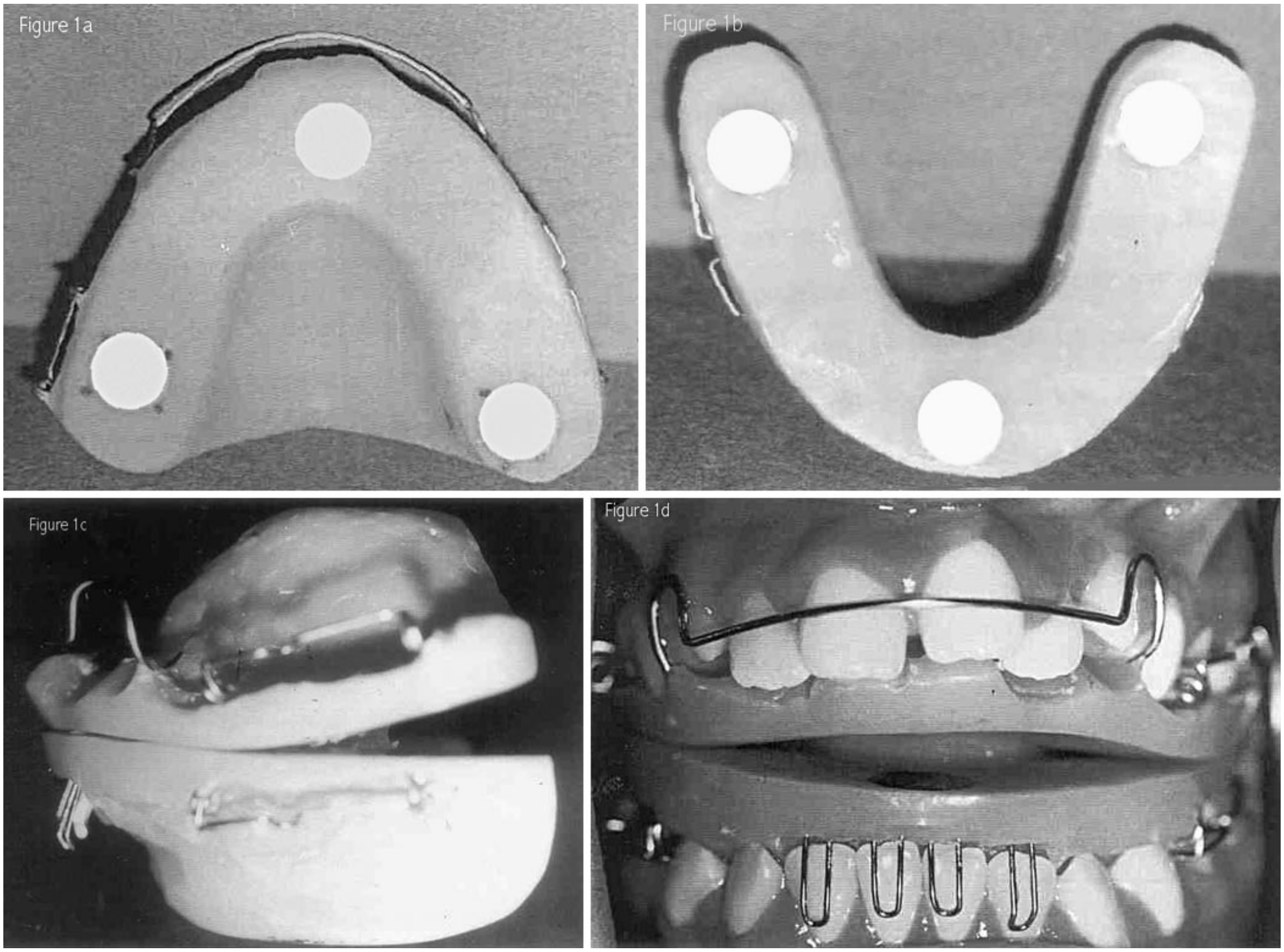

FIGURE 1. (a) Upper and (b) lower plates of MAD IV appliance. (c,d) Attractive configuration of anterior magnets.

Maxillary, maxillomandibular, and facial height changes (Table 2)

Among the maxillary measurements, only the SN ⊥ ANS showed a significant increase during the treatment period ($P < .001$). The ANB angle increased during the observation period and was significantly different as compared with the decrease in this angle during treatment ($P < .01$). ANS-PNS/Go-Me increased during observation, decreased during treatment, and a significant change was observed between the periods ($P < .001$).

During the observation period, the anterior (N-Me) and posterior (S-Go) facial heights increased significantly ($P < .05$); however, increases in the posterior-anterior facial height ratio (S-Go/N-Me × 100) were not significant. A significant increase was observed in lower facial height (ANS-Me) ($P < .001$). During the treatment period, the posterior facial height (S-Go) increased significantly, whereas the anterior facial height (N-Me) and the posterior-anterior facial height ratio (S-Go/N-Me × 100) did not show significant increases. The increase in lower facial height (ANS-Me) during the observation period changed to a decrease during treatment with a significant difference between the periods ($P < .001$).

Changes in the mandible (Table 3)

A decrease in the SNB angle changed to an increase from the observation to the treatment period and showed significant difference between the periods ($P < .05$). A significant difference was found between the periods in the Y-axis (S-Gn/SN) and the mandibular plane angle (SN/Go-Gn) ($P < .01$, $P < .05$).

There was a significant difference between the increase in lower gonial angle (N-Go-Me) and the increase in gonial angle (Ar-Go-Me) during the observation period as compared with the decreases during treatment, respectively ($P < .001$, $P < .05$).

The ramal inclination angle (SN/Go-Ar) showed a significant decrease during the treatment period ($P < .05$). Increases in Ar-Go and Go-Me were statistically significant

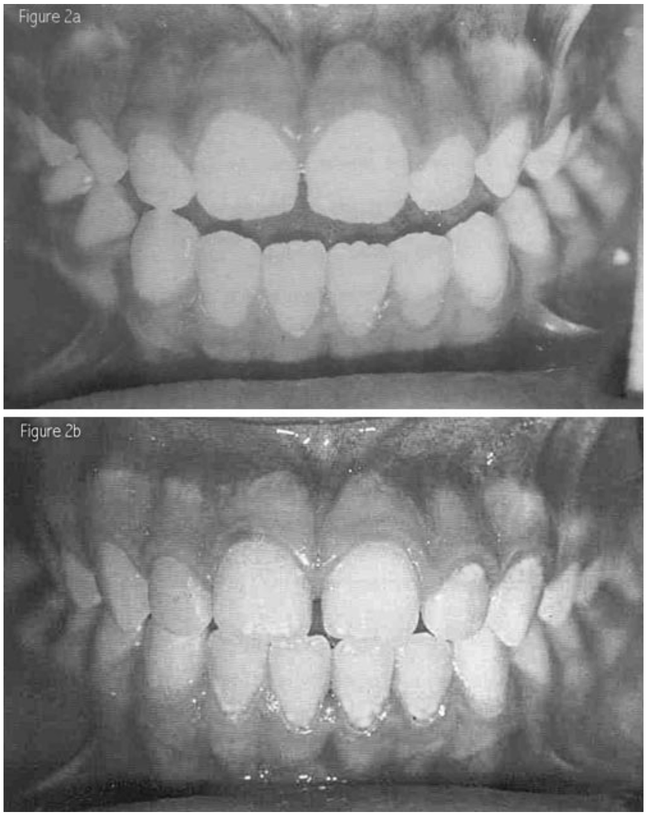

FIGURE 2. Intraoral views of a patient (a) before and (b) after treatment.

during the observation and treatment periods ($P < .05$, $P < .001$)

Dental changes (Table 4)

An increase in the overjet during the observation period was significantly different when compared with the decrease during treatment ($P < .01$). Overbite and U1-NA (°) showed significant differences between the observation and treatment periods ($P < .001$). A significant increase in the upper anterior dentoalveolar height (U1 ⊥ ANS-PNS) was observed during the treatment period ($P < .01$). When the increase in the SN/lower occlusal plane angle during observation was compared with the decrease during treatment, a significant difference was present ($P < .001$).

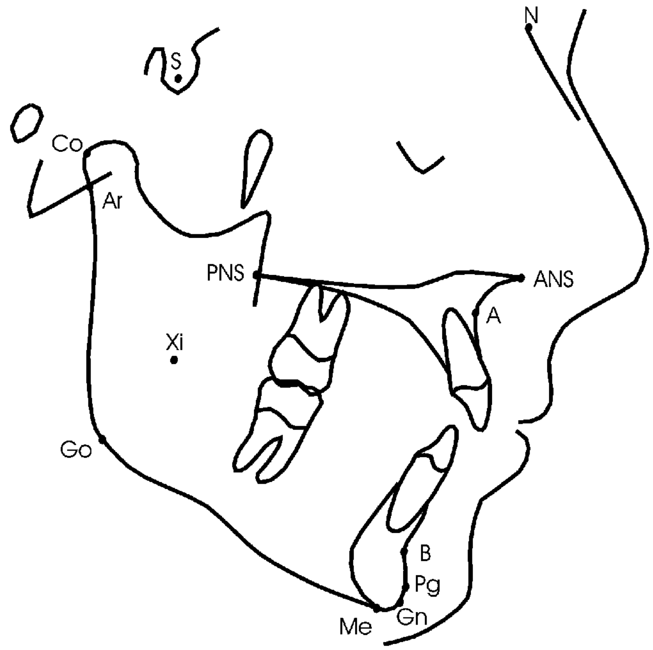

FIGURE 3. 1) SNA angle; 2) SN/ANS-PNS angle; 3) SN ⊥ ANS distance; 4) SN ⊥ PNS distance; 5) ANB angle; 6) ANS-PNS/Go-Me angle, palatal plane-mandibular plane; 7) S-Go distance, posterior facial height; 8) N-Me distance, anterior facial height; 9) S-Go/N-Me × 100%, posterior-anterior facial height ratio; 10) ANS-Me distance, lower facial height; 11) SNB angle; 12) S-Gn/SN angle, Y-axis; 13) SN/Go-Gn angle, mandibular plane angle; 14) S-Ar-Go angle, articular angle; 15) Ar-Go-N angle, upper gonial angle; 16) N-Go-Me angle, lower gonial angle; 17) Ar-Go-Me angle, gonial angle; 18) SN/Go-Ar angle, ramal inclination; 19) Ar-Go distance, ramal height; 20) Go-Me distance, mandibular corpus length; 21) overjet; 22) overbite; 23) U1-NA (mm), upper incisors protrusion; 24) U1-NA (°), upper incisor proclination; 25) L1-NB (mm), lower incisor protrusion; 26) L1-NB (°), lower incisor proclination; 27) SN/upper occlusal plane angle; 28) SN/lower occlusal plane angle; 29) U1 ⊥ ANS-PNS, upper anterior dentoalveolar height; 30) L1 ⊥ Go-Gn, lower anterior dentoalveolar height; 31) U6 ⊥ ANS-PNS, upper posterior dentoalveolar height; 32) L6 ⊥ Go-Gn, lower posterior dentoalveolar height.

When the increase in the lower anterior dentoalveolar height (L1 ⊥ Go-Gn) during treatment was compared with the observation period, a significant increase was present ($P < .001$).

When the extrusion of the lower first molar (L6 ⊥ Go-Gn) during observation was compared with the intrusion

TABLE 1. The Comparison of the Chronological and Skeletal Ages in Years at T_1, T_2, and T_3, and Changes During Observation Period (T_2–T_1) and Treatment Period (T_3-T_2) (n = 16)[a]

	T_1		T_2		T_3		T_2-T_1		T_3-T_2		(T_2-T_1)-(T_3-T_2)
Measurements	X	Sx	X	Sx	X	Sx	D	Sd	D	Sd	*P*
Chronological age	11.20	3.08	11.97	3.06	12.62	3.25	0.77***	1.77	0.63***	1.86	**
Skeletal age	11.07	2.92	11.82	2.88	12.53	3.21	0.72***	2.86	0.71***	2.03	

[a] X indicates the mean value; Sx, standard error; D, the mean value of the difference; and Sd, Standard deviation; * $P < .05$; ** $P < .01$; *** $P < .001$.

TABLE 2. The Comparison of the Maxillar, Maxillomandibular, and Facial Height Measurements at T_1, T_2, and T_3, and Changes During Observation Period (T_2-T_1) and Treatment Period (T_3-T_2) (n = 16)[a]

	T_1		T_2		T_3		T_2-T_1		T_3-T_2		(T_2-T_1)–(T_3-T_2)
Measurements	X	Sx	X	Sx	X	Sx	D	Sd	D	Sd	*P*
1. SNA (°)											
2. SN/ANS-PNS (°)	76.98	0.9	77.04	0.8	77.32	0.8	0.07	0.3	0.28	0.3	
3. SN ⊥ ANS (mm)	10.00	0.9	10.09	0.9	9.72	0.9	0.09	0.2	−0.38	0.3	
4. SN ⊥ PNS (mm)	53.44	1.2	54.00	1.3	55.66	1.3	0.56	0.5	1.65***	0.2	
5. ANB (°)	44.63	0.8	45.25	0.7	45.59	0.8	0.63	0.3	0.34	0.2	
6. ANS-PNS/Go-Me (°)	4.69	0.5	4.79	0.5	3.61	0.5	0.10	0.2	−1.18	0.5	**
7. S-Go (mm)	34.25	1.3	35.38	1.1	33.69	1.2	1.12**	0.3	−1.68**	3.7	***
8. N-Me (mm)	73.09	1.3	74.22	1.2	75.31	1.5	1.13*	0.4	1.03*	0.5	
9. S-Go/N-Me × 100	124.71	1.8	126.53	1.9	127.34	2.0	1.82*	0.6	0.82	0.5	
(%)	58.69	1.2	58.92	1.1	59.12	1.3	0.23	0.2	0.20	0.4	
10. ANS-Me (mm)	73.51	1.1	75.06	1.0	73.90	1.1	1.54***	0.3	−1.15***	0.3	***

[a] X indicates the mean value; Sx, standard error; D, the mean value of the difference; and Sd, Standard deviation; * $P < .05$; ** $P < .01$; *** $P < .001$.

TABLE 3. The Comparison of the Morphologic Changes in the Mandible at T_1, T_2, and T_3, and Changes During Observation Period (T_2-T_1) and Treatment Period (T_3-T_2) (n = 16)[a]

	T_1		T_2		T_3		T_2-T_1		T_3-T_2		(T_2-T_1)–(T_3-T_2)
Measurements	X	Sx	X	Sx	X	Sx	D	Sd	D	Sd	*P*
11. SNB (°)	72.30	3.4	72.25	0.8	73.56	0.9	−0.05	0.3	1.31***	0.3	*
12. S-Gn/SN (°)	75.77	3.8	76.39	0.9	74.63	0.9	0.62	0.4	−1.75***	0.4	**
13. SN/Go-Gn (°)	44.39	6.9	45.11	1.6	43.47	1.8	0.73	0.4	−1.64**	0.5	*
14. S-Ar-Go (°)	146.46	8.1	146.22	1.8	144.99	1.9	−0.24	0.9	−1.23	0.6	
15. Ar-Go-N (°)	49.13	5.1	49.44	1.2	50.19	1.3	0.31	0.5	0.75	0.4	
16. N-Go-Me (°)	81.44	4.8	82.38	1.2	81.25	1.2	0.93**	0.3	−1.12*	0.4	**
17. Ar-Go-Me (°)	130.56	8.0	131.81	2.0	131.44	2.0	1.25*	0.4	−0.38	0.5	*
18. SN/Go-Ar (°)	92.50	4.8	92.53	1.2	91.41	1.4	0.03	0.6	−1.12*	0.5	
19. Ar-Go (mm)	42.95	3.8	43.77	0.9	44.67	1.0	0.81*	0.3	0.9*	0.3	
20. Go-Me (mm)	66.88	3.3	67.54	0.8	69.03	0.9	0.66*	0.3	1.48***	0.3	

[a] X indicates the mean value; Sx, standard error; D, the mean value of the difference; Sd, and Standard deviation; * $P < .05$; ** $P < .01$; *** $P < .001$.

TABLE 4. The Comparison of the Dental and Dentoalveolar Changes at T_1, T_2, and T_3, and Changes During Observation Period (T_2-T_1) and Treatment Period (T_3-T_2) (n = 16)[a]

	T_1		T_2		T_3		T_2-T_1		T_3-T_2		(T_2-T_1)–(T_3-T_2)
Measurements	X	Sx	X	Sx	X	Sx	D	Sd	D	Sd	*P*
21. Overjet (mm)	4.27	0.5	4.88	0.5	2.87	0.5	0.61	0.3	−2.01***	0.4	**
22. Overbite (mm)	−3.58	0.4	−4.36	0.4	−0.42	0.3	−0.78**	0.2	3.94***	0.3	***
23. U1-NA (mm)	5.41	0.4	5.74	0.5	5.68	0.5	0.34	0.3	−0.07	0.2	
24. U1-NA (°)	24.67	1.4	26.19	1.4	23.58	1.3	1.51*	0.6	−2.63***	0.5	***
25. L1-NB (mm)	6.14	0.4	6.08	0.4	6.48	0.4	−0.06	0.2	0.41	0.2	
26. L1-NB (°)	29.44	1.6	27.98	1.5	28.98	1.6	−1.47	1.0	1.00	1.0	
27. SN/upper occlusal plane (°)	21.09	1.0	21.25	0.8	22.62	1.1	0.16	0.6	1.38	0.8	
28. SN/lower occlusal plane (°)	26.78	0.9	27.78	1.0	23.75	1.1	1.00	0.5	−4.03***	0.6	***
29. U1 ⊥ ANS-PNS (mm)	28.59	0.5	28.88	0.5	29.94	0.5	0.28	0.2	1.06**	0.3	
30. L1 ⊥ Go-Gn (mm)	39.50	0.8	39.84	0.8	41.56	0.9	0.34*	0.1	1.72***	0.2	***
31. U6 ⊥ ANS-PNS (mm)	21.25	0.5	21.75	0.6	21.81	0.6	0.50	0.3	0.06	0.3	
32. L6 ⊥ Go-Gn (mm)	30.19	0.7	30.84	0.6	30.09	0.7	0.66	0.3	−0.75*	0.3	*

[a] U1, indicates upper incisor; L1, lower incisor; U6, upper molar; L6, lower molar; X, the mean value; Sx, standard error; D, the mean value of the difference; Sd, and Standard deviation; * $P < .05$; ** $P < .01$; *** $P < .001$.

during treatment, a significant difference was present ($P < .05$).

DISCUSSION

Historically, bite block therapy has been shown to be very effective in the treatment of anterior open bites.[22–30,32,35,36] The MAD IV appliance couples an effective bite block with an adjustable magnetic field. The present study has shown that the use of this particular combination in the treatment of the anterior open bite produced an effective response in the dental and skeletal vertical relation in growing individuals. None of the patients treated with the MAD IV had developed the transverse problems associated with repelling posterior magnets.[27]

During the observation period, a nonsignificant increase in SNA and decrease in SNB led to a slight increase in ANB angle. Several authors reported that an increase in the ANB angle could be expected in open bite cases with increased face heights.[3,20,22,37,38] The forward movement of the mandible increased and the ANB angle decreased significantly during treatment with the MAD IV appliance. Similar results were demonstrated in studies with posterior bite blocks.[23–25,27,29,30,32] Kuster and Ingervall[30] reported that the increase in mandibular prognathism and the decrease in ANB were greater with magnetic bite blocks when compared with the spring bite blocks. They explained the difference by a greater and continuous force obtained by magnetic bite blocks.

Increases in the SGn/SN (Y-axis), SN/GoGn, and ANS-PNS/GoMe angles during the observation period changed to decreases with treatment. Björk,[6] in his longitudinal study, reported that the mandibular plane angle decreases in patients with mesiodivergent and hyperdivergent growth patterns; however, several studies on patients with increased face heights pointed out an increase in the angle.[1–3,37–40] The anterior mandibular rotation that occurred during treatment showed a significant difference when compared with the observation period. This result is in agreement with the Frankel IV appliance therapy results that were compared with a control group.[16]

Evaluation of condyle and gonial regions showed a nonsignificant decrease in S-Ar-Go (articular angle) during the observation and treatment periods, although there was a greater decrease during treatment. Riolo et al[40] reported that the condyle showed an upward directed growth, and this could be an effective factor on the decrease of the articular angle.

The upper gonial angle (Ar-Go-N) showed no significant increases in both periods. Significant increases in the gonial angle (Ar-Go-Me) and the lower gonial (N-Go-Me) angle during the observation period changed to decreases during treatment, and both angles showed significant differences between periods. Björk and Skieller[2] and Björk[6] reported increases in the gonial angle during growth caused by differential local mandibular remodeling. The pattern of mandibular growth is thus generally characterized by an upward- and forward-curving growth at the condyles, while at the same time there is resportion on the lower aspect of the gonial angle. In an experimental study on growing baboons, a significant remodeling of the gonial region was observed when using magnetic bite blocks.[26]

Fränkel and Fränkel[16] reported an increase in mandibular corpus length during the Frankel IV treatment of open bite cases. The mandibular corpus length increased in both periods in this study, and no significant difference was observed between periods. The significant decrease in lower facial height during MAD IV treatment was in accordance with similar magnetic bite block studies.[27,29,30]

Upper incisor protrusion, lower incisor retrusion, forward maxillary growth, and posterior rotation of mandible all resulted in a no significant increase in overjet during the observation period. A significant decrease in overjet occurred during treatment with the palatal version of the upper incisors, labial version of lower incisors, and anterior rotation of mandible. The forward force vector (that forced the mandible to anterior rotation) applied by posterior repelling and anterior attracting magnets of the MAD IV appliance might be responsible for the labial version of the lower incisors.

A significant decrease in overbite during the observation period changed to a significant increase during treatment. The anterior rotation of the mandible was accompanied by an increase in lower anterior dentoalveolar height, and this led to closure of the open bite during treatment. These findings are in accordance with several studies.[23,24,29,30,35,36]

Increases in the occlusal plane angle were observed in the skeletal open bite cases.[1–3,39] Ellis et al[39] reported that the mandibular occlusal plane was steeper than the maxillary occlusal plane. Nahoum et al[4] suggested a normal upper occlusal plane and an increased lower occlusal plane angle in open bite cases. During observation, no significant tendency for an increase in the upper and lower occlusal plane angles was observed. With MAD IV treatment, the lower occlusal plane angle showed a significant decrease due to a lower posterior dentoalveolar decrease, lower anterior dentoalveolar height increase, and an anterior rotation of mandible.

This study indicates the short-term effects of the MAD IV appliance in the treatment of anterior open bites. The changes in the retention and the postretention periods will be assessed to be informed about stability in open bite patients showing aberrant growth.

CONCLUSIONS

- During the observation period, the patients showed a mandibular backward and downward rotation, resulting in an increase in the lower facial height and open bite.

- During the treatment period, the patients showed an anterior mandibular rotation with a significant decrease in the lower facial height and open bite.
- Besides the skeletal changes, dental and dentoalveolar effects played a role in the treatment of the anterior open bites.

ACKNOWLEDGMENT

We would like to thank Dr Mehmet Ali Darendeliler for his support in this study.

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