ORIGINAL ARTICLE

Stability of anterior openbite correction with multiloop edgewise archwire therapy: A cephalometric follow-up study

Young H. Kim, DMD, MS,[a] Unae Kim Han, DMD, MPH, MS,[a] Diana D. Lim, DMD, MSD,[b] and Ma. Laarni P. Serraon, DMD, MSD[b]

Weston, Mass

Successful treatment of anterior openbite malocclusion is considered one of the most challenging areas in orthodontics. This study was designed to evaluate the treatment effects of the multiloop edgewise archwire therapy in openbite correction and to investigate the stability of correction during a 2-year follow-up period. The subjects consisted of 55 white patients who presented with anterior openbite. The subjects were divided into 2 groups: the growing group included 29 patients and the nongrowing group included 26 patients. The lateral cephalograms were analyzed for skeletal, esthetic, and dentoalveolar changes. Analysis of the pretreatment and posttreatment cephalometric radiographs revealed that the overbite increased an average of 4 mm in both the growing and the nongrowing groups. Analysis of the posttreatment and follow-up cephalometric radiographs proved that the treatment results obtained by this therapy were very stable. The changes in overbite during the 2-year follow-up period were not significant. (Am J Orthod Dentofacial Orthop 2000;118:43-54)

Anterior openbite malocclusion is considered one of the most difficult problems to treat by any means. Proper diagnosis, successful treatment, and long-term retention of openbite malocclusion have been a constant subject of discussion and research studies. There have been numerous theories proposed for the cause of openbite malocclusion including inherited facial form, unfavorable growth pattern, posture, digital habits, nasopharyngeal airway obstruction, and tongue posture and function. Several aspects of function, including posture and environmental influences, most likely interact with inherent facial morphology to produce openbite in some persons.[1,2]

Various therapeutic modalities have been proposed for the treatment of anterior openbite malocclusion. Conventional orthodontic treatment has been directed at inhibiting the vertical maxillary growth with headgear, retarding the mandibular growth with chincups, or extruding anterior teeth with vertical elastics.[3-6] Some other methods that have been used for treatment and/or retention of anterior openbite malocclusion include tongue crib therapy,[7,8] posterior bite blocks,[9] posterior magnets,[10] magnetic active vertical corrector,[11] and functional appliances.[12]

Because problems of excessive facial height are usually associated with severe anterior openbite or apertognathia, a combination of orthognathic surgery and orthodontic treatment has been proposed.[13,14] The successful treatment of apertognathia represents one of the most challenging areas of orthognathic surgery. Patients with skeletal openbite are treated with either maxillary or mandibular surgery or a combination of the two. Potential complications include lip dysesthesia, paresis, hemorrhage, infection, and postoperative joint symptoms. In order to balance the risk versus the benefit, the stability of surgical correction should be scrutinized.[15-22] Even though some studies reported favorable results,[15,16] Denison et al[19] reported that the openbite relapsed in 42.9% of subjects who were treated with LeFort I osteotomy.

Skeletal and dentoalveolar characteristics of patients with anterior openbite have been investigated extensively.[2,7,23-29] The skeletal pattern of anterior openbite is characterized by steep mandibular plane angle, obtuse gonial angle, and long lower face height. It is also sometimes associated with the palatal plane pointing downward posteriorly. The dentoalveolar characteristics include divergent upper and lower occlusal planes, mesial inclination of posterior dentition, and the lack of a normal curve of Spee in the lower arch.[2,26,27] There is no consensus regarding the correlation between posterior vertical maxillary excess and anterior openbite.[23,26-29]

Since 1967, severe openbite malocclusion cases have been successfully treated with multiloop edgewise archwire (MEAW) therapy.[2,30-33] The diagnostic phase of anterior openbite correction includes a cephalometric evaluation of the overbite depth indicator (ODI),[24,34] the anteroposterior dysplasia indicator (APDI),[35-38] and the

[a]In private practice.
[b]Department of Orthodontics, College of Dentistry, University of the Philippines.
Reprint requests to: Young H. Kim, DMD, MS, 30 Colpitts Road, Weston, MA 02493.
Submitted, 6/99; accepted 12/99.

0889-5406/2000/$12.00 + 0 **8/1/104830**
doi.10.1067/mod.2000.104830

Table I. Average patient ages at T1, T2, and T3

	Growing group		*Nongrowing group*	
	Mean (year/month)	*SD (year/month)*	*Mean (year/month)*	*SD (year/month)*
Pretreatment (T1)	13/05	1/11	26/01	5/10
Posttreatment (T2)	15/09	1/09	27/09	5/00
Follow-up (T3)	18/08	2/03	30/00	5/00

Table II. Extractions required as part of treatment plan

Growing group		*Nongrowing group*	
Case	*Teeth extracted*	*Case*	*Teeth extracted*
1	None	1	UR8, UL8, LR8, LL8
2	None	2	UR7, UL7
3	None	3	None
4	None	4	UR4, 8; UL4, 8; LR4, 8; LL4, 8
5	UR7, UL7, LR8, LL8	5	None
6	None	6	LL8
7	UR7, UL7, LR7, LL7	7	UL8
8	UR7, UL7, LR8, LL8	8	None
9	UR4, 7; UL4, 7; LR4, 7; LL4, 7	9	None
10	UR7, UL7	10	None
11	None	11	None
12	None	12	UR7, UL7, LR7, LL7
13	UR4, UL4, LR4, LL4	13	UR8, UL8, LR8, LL8
14	UR4, UL4, LR4, LL4	14	LR8, LL8
15	None	15	UR8, UL5, LR8, LL8
16	UR7, UL7, LR8, LL8	16	None
17	UR7, UL7, LR8, LL8	17	UL8, LL8
18	None	18	None
19	UR7, UL7, LR8, LL8	19	UR8, UL8, LR8, LL8
20	UR7, UL7, LR8, LL8	20	UR8, UL8, LR8, LL8
21	None	21	None
22	None	22	UR8, UL8, LR8, LL8
23	None	23	None
24	UR7, UL7	24	None
25	UR7, UL7, LR8, LL8	25	UR8, UL8
26	UR7, UL7, LR8, LL8	26	UL8, LL8
27	UR7, UL7, LR8, LL8		
28	None		
29	UR7, UL7, LR8, LL8		

UR8: upper right third molar
LR8: lower right third molar
UR7: upper right second molar
LR7: lower right second molar
UL5: upper left second premolar
UR4: upper right first premolar
LR4: lower right first premolar
UL8: upper left third molar
LL8: lower left third molar
UL7: upper left second molar
LL7: lower left second molar
UL4: upper left first premolar
LL4: lower left first premolar

presence of posterior crowding.[2] The objectives of the treatment include proper vertical positioning of maxillary incisors, compatible cant of the upper and lower occlusal planes, and uprighted inclination of posterior teeth. Detailed descriptions of the treatment mechanics are published elsewhere.[2,30,39-41]

The purpose of this study was to evaluate the treatment effects of the MEAW therapy in openbite correction and to investigate the stability of correction during a 2-year follow-up period. The lateral cephalograms were analyzed for skeletal, esthetic, and dentoalveolar changes.

Fig 1. Intraoral photographs of a 33-year-old man (case 25) with a severe anterior openbite malocclusion. Pretreatment (**A**), MEAW mechanism in place (**B**), posttreatment (**C**), and 23 months after appliance removal (**D**).

MATERIAL AND METHODS

Subjects

The sample consisted of 55 white subjects who presented with anterior openbite. The subjects were divided into 2 groups. The growing group included 29 patients (21 females and 8 males) who were 16 years of age and younger. The ages ranged from 10 years 5 months to 16 years 7 months with the mean of 13 years 5 months. The nongrowing group included 26 patients (21 females and 5 males) who were 17 years of age and older. The ages ranged from 17 years 4 months to 37 years 3 months with the mean of 26 years 1 month (Table I). The criteria for case selection were as follows:

1. Anterior openbite with the minimum of 0.5 mm.
2. Complete cephalometric records at pretreatment and posttreatment with optional records at 2-year follow-up period.
3. Treatment included the MEAW therapy with anterior vertical elastics.

All 55 subjects were selected from our practices.

Treatment

Complete diagnostic records including cephalogram, pantomogram, study models, and facial and intraoral photographs were prepared for each patient. After a thorough evaluation of the records for skeletal pattern, dentoalveolar condition, and facial esthetics, a detailed

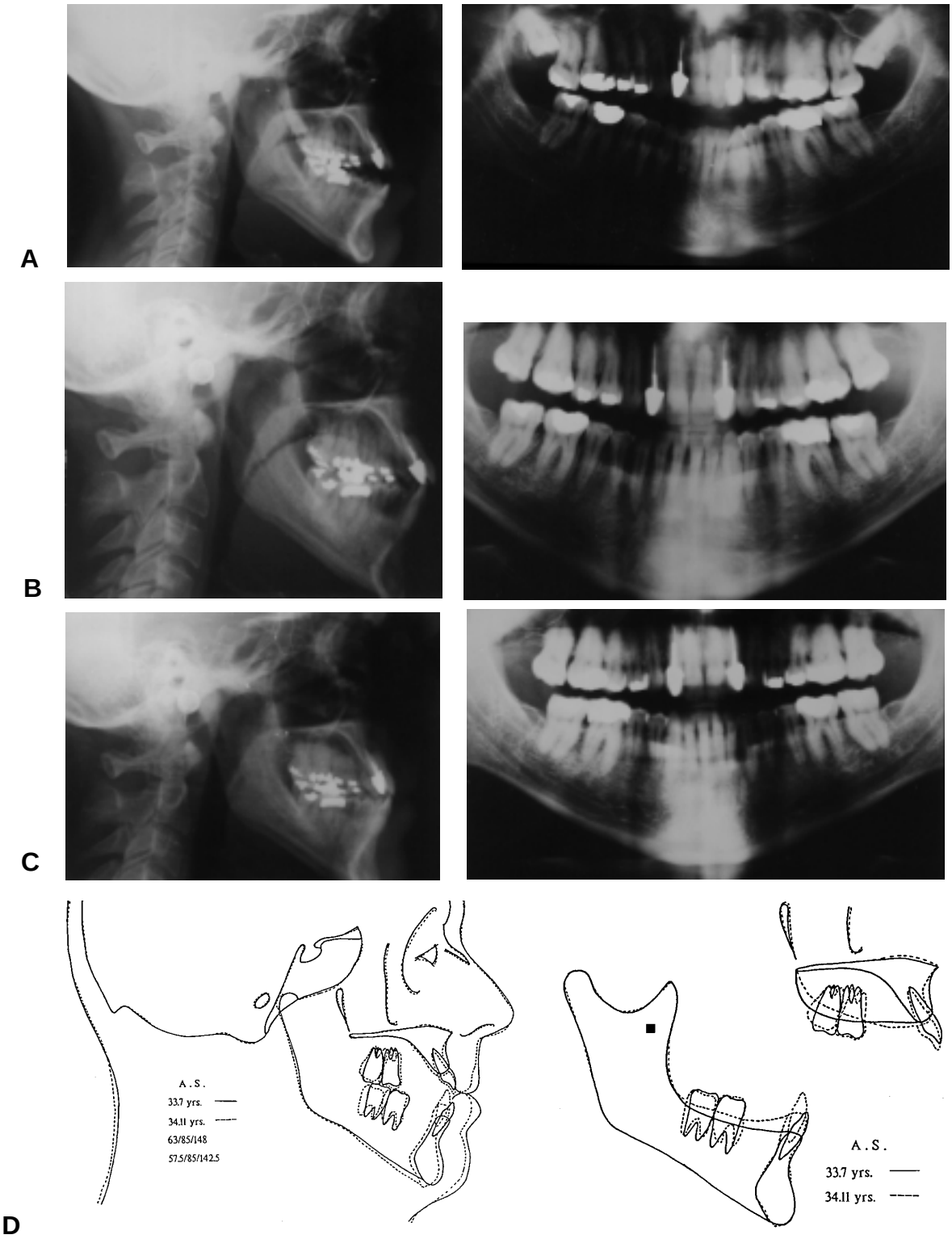

Fig 2. Cephalograms and pantomograms of the patient at pretreatment (**A**), posttreatment (**B**), and 23 months after appliance removal (**C**). Superimposition tracings from pretreatment to posttreatment (**D**). Craniofacial tracings were superimposed along the outlines of the cranial base and registered at the Sella; maxillary tracings were superimposed on the key ridge, pterygomaxillary fissure, and the floor of the nose, and mandibular tracings were superimposed on the mandibular border and the symphysis.

Table III. Skeletal changes during treatment (growing group N = 29)

Variables	*Mean ± SD (T1)*	*Mean ± SD (T2)*	*Difference (T2-T1)*	*P value*
Sagittal skeletal				
ANB	3.79 ± 2.30	3.59 ± 2.22	–0.20	NS
Facial angle	85.93 ± 2.69	85.86 ± 2.70	–0.07	NS
APDI	81.59 ± 4.47	82.29 ± 4.64	0.70	NS
Vertical skeletal				
FH-PP	1.66 ± 2.47	2.52 ± 2.39	0.86	*
FH-MP	30.66 ± 4.61	31.00 ± 4.66	0.34	NS
FH-UOP	7.45 ± 3.44	12.41 ± 3.57	4.96	***
FH-BOP	9.91 ± 3.77	11.09 ± 3.32	1.18	NS
FH-LOP	12.43 ± 4.44	9.66 ± 3.34	–2.77	**
Anterior LFH	72.62 ± 6.64	75.33 ± 6.52	2.71	***
Anterior TFH	123.48 ± 9.19	127.50 ± 8.84	4.02	***
Posterior LFH	42.91 ± 4.66	45.24 ± 4.83	2.33	***
AB to MP	69.62 ± 4.86	69.40 ± 4.55	–0.22	NS
Gonial angle	125.81 ± 5.69	125.60 ± 5.53	–0.21	NS
ODI	71.26 ± 5.27	71.91 ± 5.07	–0.65	NS
Miscellaneous				
Y-axis	61.83 ± 2.88	62.43 ± 2.98	0.60	NS
Upper lip to E-line	–0.90 ± 2.60	–2.21 ± 2.19	–1.31	***
Lower lip to E-line	0.48 ± 3.18	–0.17 ± 2.56	–0.65	NS
CF (ODI + APDI)	152.84 ± 6.13	154.21 ± 6.12	1.37	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

treatment plan was proposed. Extraction of permanent teeth was required for some patients to relieve anterior and/or posterior crowding as listed in Table II.

All the patients were treated with a .018 slot standard edgewise appliance system. Maxillary and mandibular dentitions were first prepared by eliminating all rotations, spaces, or crowding. Maxillary and mandibular MEAWs were then prepared and inserted. Patients were instructed to wear anterior vertical elastics. The treatment was completed when positive overbite was obtained, proper cant of occlusal planes was restored, and mesial inclinations of the dentition were corrected. A maxillary retainer with a full circumferential labial wire was used for 6 weeks on a full-time basis followed by half-time wear.[2,30]

The case shown in Figs 1 and 2 was one of the subjects treated with the MEAW therapy. This 33-year-old man (case 25) presented with a severe anterior openbite (Fig 1*A*). Surgical correction of his openbite had been previously recommended, but he refused to have it done. Cephalometric analysis indicated a mild Class III openbite skeletal pattern with an ODI of 63° and an APDI of 85° (Fig 2*A*). The impacted upper third molars were extracted. After the upper and lower arches were aligned, MEAW therapy was initiated (Fig 1*B*). A normal occlusion was obtained 5 months after the onset of MEAW therapy (Fig 1*C*). The entire treatment took 15 months. The posttreatment cephalogram and the superimposition tracing revealed that there were marked changes in the dentition, especially in the lower occlusal plane that moved upward anteriorly (Fig 2*B* and 2*D*). The correction was well maintained after 23 months with a small amount of reduction in overbite and return of Class III tendency (Fig 1*D*). Abnormal tongue function and posture as well as inherent Class III skeletal tendency may have caused this small amount of relapse.[8] In addition, poor quality restorations in the posterior dentition and small size crowns on the upper lateral incisors may have contributed to the initial changes after treatment. The occlusion, however, stabilized and a positive overbite has been maintained during the follow-up period.

The average duration of active treatment was 27 months (SD, 11 months) for the growing group and 17 months (SD, 9 months) for the nongrowing group. The average length of the follow-up period was 35 months (SD, 17 months) for the growing group and 28 months (SD, 4 months) for the nongrowing group.

Cephalometric Analysis

Lateral cephalograms were obtained before treatment (T1), immediately after completion of treatment (T2), and after a 2-year follow-up period (T3). The 2-year follow-up records were available on 17 patients from the growing group and on 10 patients from the nongrowing group. All the lateral cephalograms were taken with the same cephalostat, under the same conditions, and with standardized settings. One investiga-

Table IV. Dentoalveolar changes during treatment (growing group N = 29)

Variables	*Mean ± SD (T1)*	*Mean ± SD (T2)*	*Difference (T2-T1)*	*P value*
Overbite	–2.27 ± 2.10	1.58 ± 0.81	3.85	***
Overjet	5.09 ± 2.45	2.03 ± 0.69	–3.06	***
Angular measurements				
U1 - BOP	55.41 ± 6.04	63.00 ± 5.32	7.59	***
U6 - PP	97.88 ± 5.28	98.60 ± 7.12	0.72	NS
U6 - BOP	90.66 ± 3.96	89.60 ± 5.96	–1.06	NS
L1 - BOP	68.31 ± 6.06	70.93 ± 5.48	2.62	*
L1 - MP	0.76 ± 7.02	–0.68 ± 7.24	–1.44	NS
L6 - BOP	102.53 ± 7.44	98.50 ± 3.94	–4.03	*
L6 - MP	94.48 ± 17.03	97.93 ± 20.40	3.45	**
Interincisal angle	123.41 ± 8.67	134.03 ± 8.29	10.62	***
Vertical distance measurements				
U1 - PP	25.95 ± 2.89	28.67 ± 3.11	2.72	***
U6 - PP	22.62 ± 3.07	23.31 ± 2.67	0.69	NS
L1 - MP	47.55 ± 5.12	50.95 ± 5.78	3.40	***
U1 - lip line	2.84 ± 1.45	4.32 ± 1.67	1.48	***
L6 - MP	38.07 ± 4.28	40.10 ± 3.90	2.03	***
Horizontal distance measurement				
U1 to A-Pog	7.22 ± 2.64	4.34 ± 2.05	–2.88	***

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

Table V. Skeletal changes during treatment (nongrowing group N = 26)

Variables	*Mean ± SD (T1)*	*Mean ± SD (T2)*	*Difference (T2-T1)*	*P value*
Sagittal skeletal				
ANB	3.94 ± 2.56	3.88 ± 2.54	–0.06	NS
Facial angle	84.69 ± 3.69	84.23 ± 3.54	–0.46	NS
APDI	80.94 ± 5.91	80.77 ± 5.54	–0.17	NS
Vertical skeletal				
FH-PP	2.63 ± 3.40	2.81 ± 3.14	0.18	NS
FH-MP	32.73 ± 6.45	32.58 ± 5.61	–0.15	NS
FH-UOP	8.38 ± 4.54	13.21 ± 4.92	4.83	***
FH-BOP	10.37 ± 4.17	11.25 ± 5.02	0.88	NS
FH-LOP	12.44 ± 4.59	9.10 ± 5.39	–3.34	**
Anterior LFH	79.69 ± 6.53	79.44 ± 6.23	–0.15	NS
Anterior TFH	131.90 ± 8.52	132.42 ± 8.41	0.52	NS
Posterior LFH	45.69 ± 6.05	45.75 ± 6.47	0.06	NS
AB to MP	68.63 ± 4.60	69.17 ± 5.73	0.54	NS
Gonial angle	125.73 ± 6.98	125.40 ± 7.27	–0.33	NS
ODI	71.63 ± 6.77	71.92 ± 6.88	0.29	NS
Miscellaneous				
Y-axis	64.06 ± 3.72	64.40 ± 3.41	0.34	NS
Upper lip to E-line	–2.04 ± 3.30	–2.79 ± 3.11	–0.75	*
Lower lip to E-line	0.12 ± 3.37	–0.42 ± 3.06	–0.54	NS
CF (ODI + APDI)	153.38 ± 7.55	152.67 ± 7.32	–0.71	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

tor traced all the lateral cephalograms using matte acetate paper, and 2 examiners recorded all the cephalometric measurements. The angular measurements were recorded to the nearest 0.5°, and the linear measurements were recorded to the nearest 0.5 mm.

The lateral cephalograms were analyzed for skeletal, dentoalveolar, and esthetic changes. Selection of the cephalometric variables was determined by their frequent use to evaluate vertical skeletal and dental relationships before, during, and after orthodontic treatment. Thirty-four cephalometric variables were evaluated: 21 angular and 13 linear parameters. They included 16 skeletal, 16 dentoalveolar, and 2 esthetic variables.

Table VI. Dentoalveolar changes during treatment (nongrowing group N = 26)

Variables	*Mean ± SD (T1)*	*Mean ± SD (T2)*	*Difference (T2-T1)*	*P value*
Overbite	–2.23 ± 2.10	1.78 ± 0.84	4.01	***
Overjet	3.81 ± 2.58	2.65 ± 0.60	–1.16	**
Angular measurements				
U1 - BOP	60.12 ± 4.08	63.94 ± 3.62	3.82	***
U6 - PP	93.77 ± 5.65	98.23 ± 6.50	4.46	***
U6 - BOP	94.11 ± 7.37	90.28 ± 5.46	–3.83	***
L1 - BOP	68.33 ± 9.21	69.60 ± 7.91	1.27	NS
L1 - MP	–0.25 ± 8.21	–1.67 ± 9.66	–1.42	NS
L6 - BOP	104.73 ± 7.56	100.27 ± 4.41	–4.46	**
L6 - MP	93.85 ± 20.97	98.31 ± 20.07	4.46	**
Interincisal angle	126.98 ± 8.78	133.81 ± 9.19	6.83	***
Vertical distance measurements				
U1 - PP	28.92 ± 2.34	30.21 ± 1.97	1.29	***
U6 - PP	26.08 ± 2.51	25.42 ± 2.62	–0.66	*
L1 - MP	53.27 ± 7.38	55.13 ± 5.89	1.86	*
U1 - lip line	3.96 ± 2.27	4.65 ± 1.90	0.69	NS
L6 - MP	43.00 ± 6.18	43.48 ± 4.74	0.48	NS
Horizontal distance measurement				
U1 to A-Pog	6.73 ± 2.91	5.52 ± 2.86	–1.21	**

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

Table VII. Skeletal changes during follow-up (growing group N = 17)

Variables	*Mean ± SD (T2)*	*Mean ± SD (T3)*	*Difference (T3-T2)*	*P value*
Sagittal skeletal				
ANB	4.54 ± 2.60	4.59 ± 2.20	0.05	NS
Facial angle	88.58 ± 2.87	89.46 ± 3.45	0.88	NS
APDI	79.50 ± 4.94	80.38 ± 5.36	0.88	NS
Vertical skeletal				
FH-PP	2.47 ± 2.58	1.91 ± 2.97	–0.56	NS
FH-MP	30.21 ± 4.74	30.47 ± 4.85	0.26	NS
FH-UOP	11.65 ± 3.66	11.21 ± 3.96	–0.44	NS
FH-BOP	10.47 ± 3.55	10.29 ± 3.61	–0.18	NS
FH-LOP	9.21 ± 3.61	9.38 ± 3.89	0.17	NS
Anterior LFH	75.97 ± 7.65	76.47 ± 7.61	0.50	NS
Anterior TFH	128.59 ± 10.16	129.65 ± 9.75	1.06	NS
Posterior LFH	46.03 ± 5.48	45.47 ± 5.28	–0.56	NS
AB to MP	69.03 ± 4.62	67.97 ± 4.94	–1.06	**
Gonial angle	125.00 ± 5.97	123.65 ± 6.42	–1.35	NS
ODI	71.50 ± 5.43	69.64 ± 6.28	–1.56	*
Miscellaneous				
Y-axis	61.82 ± 2.53	61.79 ± 2.13	–0.03	NS
Upper lip to E-line	–2.91 ± 2.46	–3.15 ± 2.40	–0.24	NS
Lower lip to E-line	–0.76 ± 3.03	–1.38 ± 2.83	–0.62	*
CF (ODI + APDI)	155.15 ± 6.43	154.38 ± 7.92	–0.77	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

Reliability

Tests for intraexaminer and interexaminer reliability were performed for angular and linear measurements. During data collection, each examiner obtained and recorded 2 cephalometric measurements (overbite and SNA angle), and 4 weeks later, the same examiner repeated the same procedure. In order to test for bias, the intraexaminer correlation coefficient of reliability was calculated. Interexaminer reliability was also evaluated, and correlation coefficients were obtained for both angular and linear measurements.

Statistical Analysis

The software program Microsoft Excel was used

Table VIII. Dentoalveolar changes during follow-up (growing group N = 17)

Variables	*Mean ± SD (T2)*	*Mean ± SD (T3)*	*Difference (T3-T2)*	*P value*
Overbite	1.41 ± 0.75	1.18 ± 1.01	–0.23	NS
Overjet	1.94 ± 0.66	2.74 ± 1.22	0.80	*
Angular measurements				
U1 - BOP	62.15 ± 5.39	61.12 ± 4.50	–1.03	NS
U6 - PP	99.56 ± 6.69	97.71 ± 8.12	–1.85	NS
U6 - BOP	88.79 ± 6.15	90.66 ± 6.66	1.87	NS
L1 - BOP	71.62 ± 5.98	73.15 ± 5.11	1.53	NS
L1 - MP	–0.74 ± 7.85	–2.64 ± 7.56	–1.90	NS
L6 - BOP	97.32 ± 3.54	100.03 ± 3.93	2.71	*
L6 - MP	96.32 ± 26.52	94.38 ± 25.14	–1.94	NS
Interincisal angle	134.26 ± 8.43	134.32 ± 6.41	0.06	NS
Vertical distance measurements				
U1 - PP	28.18 ± 2.74	28.41 ± 3.58	0.23	NS
U6 - PP	23.47 ± 2.84	23.59 ± 3.09	0.12	NS
L1 - MP	50.50 ± 5.90	50.79 ± 6.05	0.29	NS
U1 - lip line	4.06 ± 1.70	3.71 ± 1.33	–0.35	NS
L6 - MP	39.62 ± 3.97	40.15 ± 4.35	0.53	NS
Horizontal distance measurement				
U1 to A-Pog	4.23 ± 2.15	4.88 ± 2.38	0.65	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

for data management and statistical analysis. Statistical analysis involved the calculation of mean differences and SDs for the cephalometric variables. Paired *t* tests were used to determine the mean differences between pretreatment (T1) and posttreatment (T2) and between posttreatment (T2) and follow-up (T3) to evaluate the treatment effects of MEAW therapy and the stability during the follow-up period.

RESULTS

Reliability

The outcome of the test for intraexaminer and interexaminer reliability showed good reliability (R^2 = 0.99) for both linear and angular measurements. They were statistically satisfactory at the .05 level or less, and the results revealed little evidence of bias. This made the further examination of this study valid.

Changes During Treatment (T1 to T2)

For the growing group, the skeletal variables showed significant changes in upper occlusal plane, anterior LFH, anterior TFH, and posterior LFH, moderate changes in lower occlusal plane and mild changes in palatal plane. The upper occlusal plane moved downward anteriorly and the lower occlusal plane moved upward anteriorly. The posterior and anterior facial heights increased and the palatal plane moved downward anteriorly. The upper lip was retracted (Table III). There were some significant dentoalveolar changes during active treatment for this group. The overbite increased by about 4 mm, and the overjet decreased by about 3 mm. The upper and lower incisors were retracted and extruded. The interincisal angle changed from an average of 123° to an average of 134°. The upper and lower molars were significantly uprighted and the lower molars erupted an average of 2.03 mm (Table IV).

For the nongrowing group, upper and lower occlusal planes moved toward each other during treatment, and the upper lip was retracted. The skeletal variables did not exhibit any changes (Table V). The dentoalveolar changes for this group included an increase in overbite by about 4 mm and a decrease in overjet by 1 mm. The upper and lower incisors were retracted and extruded. The interincisal angle changed from an average of 127° to an average of 134°. The upper molars were uprighted 4°, and the lower molars were uprighted 4.5° relative to bisected occlusal plane (BOP). The upper molars were also intruded slightly (Table VI).

Changes During Follow-up (T2 to T3)

The skeletal variables for the growing group showed small changes in the AB to MP angle and ODI. All the other skeletal variables remained unchanged. The lower lip retracted slightly (Table VII). The dentoalveolar variables showed only small changes in the overjet and in the lower molar inclination (Table VIII).

There were absolutely no significant changes in both the skeletal and dentoalveolar variables for the nongrowing group during the follow-up period (Tables IX and X).

Table IX. Skeletal changes during follow-up (nongrowing group N = 10)

Variables	*Mean ± SD (T2)*	*Mean ± SD (T3)*	*Difference (T3-T2)*	*P value*
Sagittal skeletal				
ANB	3.63 ± 2.75	3.38 ± 2.35	–0.25	NS
Facial angle	88.66 ± 3.38	89.16 ± 3.97	0.50	NS
APDI	81.28 ± 6.26	81.47 ± 5.31	0.19	NS
Vertical skeletal				
FH-PP	2.45 ± 3.44	1.95 ± 3.35	–0.50	NS
FH-MP	33.30 ± 4.19	33.45 ± 5.06	0.15	NS
FH-UOP	13.15 ± 4.75	11.75 ± 4.86	–1.40	NS
FH-BOP	10.85 ± 4.70	10.20 ± 3.95	–0.65	NS
FH-LOP	8.40 ± 4.59	8.85 ± 3.38	0.45	NS
Anterior LFH	79.75 ± 7.86	79.05 ± 7.33	–0.70	NS
Anterior TFH	132.50 ± 10.29	132.05 ± 10.13	–0.45	NS
Posterior LFH	44.45 ± 6.77	44.60 ± 6.39	0.15	NS
AB to MP	69.40 ± 5.02	69.15 ± 4.67	–0.25	NS
Gonial angle	125.50 ± 6.18	126.05 ± 6.50	0.55	NS
ODI	71.75 ± 6.68	71.10 ± 5.89	–0.65	NS
Miscellaneous				
Y-axis	64.05 ± 2.28	63.90 ± 3.52	–0.15	NS
Upper lip to E-line	–2.65 ± 3.32	–2.95 ± 3.53	–0.30	NS
Lower lip to E-line	–0.15 ± 3.05	0.05 ± 3.14	0.20	NS
CF (ODI + APDI)	151.35 ± 7.47	150.75 ± 6.13	–0.60	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

Table X. Dentoalveolar changes during follow-up (nongrowing group N = 10)

Variables	*Mean ± SD (T2)*	*Mean ± SD (T3)*	*Difference (T3-T2)*	*P value*
Overbite	1.90 ± 0.57	1.55 ± 1.09	–0.35	NS
Overjet	2.70 ± 0.68	2.30 ± 1.09	–0.40	NS
Angular measurements				
U1 - BOP	64.30 ± 3.15	66.45 ± 5.27	2.15	NS
U6 - PP	98.15 ± 4.91	95.35 ± 5.23	–2.80	NS
U6 - BOP	89.65 ± 4.74	93.55 ± 4.41	3.90	NS
L1 - BOP	68.60 ± 8.32	67.70 ± 7.78	–0.90	NS
L1 - MP	–1.15 ± 9.25	–0.35 ± 7.08	0.80	NS
L6 - BOP	100.95 ± 4.27	101.75 ± 7.25	0.80	NS
L6 - MP	101.75 ± 7.50	101.35 ± 8.18	–0.40	NS
Interincisal angle	132.65 ± 8.75	133.10 ± 6.25	0.45	NS
Vertical distance measurements				
U1 - PP	30.35 ± 2.20	30.65 ± 2.27	0.30	NS
U6 - PP	25.80 ± 3.13	26.15 ± 2.56	0.35	NS
L1 - MP	55.65 ± 5.71	54.80 ± 6.83	–0.85	NS
U1 - lip line	4.65 ± 1.96	4.25 ± 1.89	–0.40	NS
L6 - MP	43.65 ± 5.09	43.70 ± 5.78	0.05	NS
Horizontal distance measurement				
U1 to A-Pog	5.85 ± 2.30	5.80 ± 2.50	–0.05	NS

NS, $P > .05$; *$P < .05$; **$P < .01$; ***$P < .001$.

Changes in Overbite

The overbite before treatment (T1) for the growing group ranged from –0.5 mm to –10.0 mm with the mean of –2.27 mm. The overbite for this group after treatment (T2) ranged from 0.5 mm to 4.5 mm with the mean of 1.58 mm. The mean overbite after a 2-year follow-up period (T3) was 1.18 mm, and the overbite ranged from –1 mm to 2.5 mm. One subject (case 24) had –1 mm overbite at T3. Her overbite was –5 mm at T1 and 1.5 mm at T2. The overbite before treatment (T1) for the nongrowing group ranged from –0.5 mm to –7.0 mm with a mean of –2.23 mm. The overbite for this group after treatment (T2) ranged from 0.5 mm to 3.5 mm with a mean of 1.78

mm. The mean overbite after a 2-year follow-up period (T3) was 1.55 mm, and the overbite ranged from –1 mm to 3.0 mm. One subject (case 20) had –1 mm overbite at T3. Her overbite was –1.5 mm at T1 and 2.0 mm at T2. She had a persistent nail-biting habit.

DISCUSSION

The results of this study illustrated that mild-to-severe anterior openbite cases can be successfully treated and retained after the MEAW therapy. In openbite treatment, the cant of occlusal planes must be corrected and the teeth must be uprighted in relation to the bisecting occlusal plane to secure stability and function. A thorough diagnostic phase includes an evaluation of skeletal and dentoalveolar patterns and facial esthetics. Cephalometric indicators such as ODI and APDI provide important diagnostic information regarding an individual's skeletal pattern. The biomechanical system provided by the multiloop edgewise archwire makes it possible to obtain the objectives stated earlier.[2]

The pretreatment skeletal pattern of the subjects in both the growing and the nongrowing groups presented an openbite tendency as indicated by an increased mandibular plane angle, increased lower facial height, low ODI, and obtuse gonial angle. There were some significant changes in the skeletal variables for the growing group during the active treatment period. Because this study did not include a control group for this age group, it was difficult to ascertain whether the skeletal changes were due to growth alone or due to growth and treatment. The number of changes in anterior total facial height and anterior lower facial height was compatible to previously reported growth changes for this age group.[1,42-44] In a longitudinal study of subjects with long and short faces, Nanda[45] reported a small amount of decrease in the SN-MP angle, 34.00° to 33.69° in openbite females from age 13 to 15 years. He reported a small amount of decrease in gonial angle, 118.83° to 118.04° and he stated that the palatal plane remained constant throughout growth. In this study the changes in mandibular plane and gonial angles were not statistically significant and the palatal plane angle increased from 1.66° to 2.52° at $P < .05$ level of significance (Table III).

The dentoalveolar changes during treatment for the growing group illustrated that the openbite correction was obtained by increased dentoalveolar heights in upper and lower anterior teeth, uprighting movement in posterior teeth, retraction of anterior teeth, and changes in occlusal planes. Simple extrusion of anterior teeth to correct openbite has been criticized as being unstable, and Ellis and McNamara[27] even reported that the vertical heights of the anterior maxilla were already increased in the openbite group. Betzenberger et al,[46] however, studied the compensatory mechanisms in high-angle malocclusions and reported that deep bite high-angle cases exhibited extrusion of upper and lower incisors and downward inclination of the maxilla anteriorly. This study was in agreement with the findings of Chang and Moon[31] that the dentoalveolar changes produced by the MEAW therapy closely mimic this natural compensatory mechanism.

Ricketts[47] reported lower molar eruption of 1.5 mm on average during the 30 months of observation from the average age of 8.1 years without treatment. Creekmore[48] reported 1.98 mm of upper molar eruption and 1.59 mm of lower molar eruption in the untreated group during a 30-month follow-up period from the average age of 10.14 years. In this study, the upper and lower first molars erupted an average of 0.69 mm ($P > .05$) and 2.03 mm ($P < .001$), respectively, during treatment for the growing group. Dougherty[49] reported lower molar eruption of 3.03 mm in 96 treated cases that ranged in age from 9 to 18 years. Gardner et al[50] reported that the vertical height of upper and lower first molars increased an average of 2.03 mm and 4.0 mm, respectively, during orthodontic treatment of adolescents. They attributed this change in vertical height to compensatory changes in the alveolus as a result of condylar growth. It is apparent from this comparison that the vertical control of upper and lower molars was an important aspect of the MEAW therapy in openbite correction.

The MEAW therapy, as expected, minimally changed the skeletal pattern of the subjects in the nongrowing group. The dentoalveolar changes were similar to the growing group, and the upper and lower occlusal planes moved toward each other. The lower molars, however, did not show any significant amount of eruption, and the upper molars were intruded an average of 0.66 mm ($P < .05$). Chang and Moon[31] presented similar findings and provided evidence that these treatment changes were similar to natural dentoalveolar compensatory mechanisms. Denison et al[19] reported that the increase in facial height did not always produce a concomitant decrease in incisal overbite. The eruption of the upper incisors, as a compensatory mechanism, maintained the overbite despite the increase in facial heights.

One of the objectives of the openbite correction with the MEAW therapy is proper vertical positioning of upper incisors relative to lip line at or near 4 mm as measured cephalometrically. For the growing group, the upper incisors were positioned below the lip line an average of 2.84 mm at T1, 4.32 mm at T2, and 3.71 mm at T3. For the nongrowing group, the upper incisors were positioned below the lip line on average of 3.96 mm at T1, 4.65 mm at T2, and 4.25 mm at T3.

The objective of proper positioning of upper incisors has, therefore, been successfully met.

Some subjects in this study required extraction of permanent teeth. It can be argued that the treatment effects are influenced by the extractions. As stated earlier, the proper diagnosis of an openbite malocclusion includes evaluation of anterior and/or posterior crowding. The treatment plan must include elimination of the anterior and/or posterior crowding. If necessary, appropriate extraction of permanent teeth, including the third molars, is an important aspect of the MEAW therapy, and it does not present bias in the interpretation of the treatment effects.

As part of the treatment plan to eliminate posterior crowding, maxillary second molars were extracted in some subjects. The usefulness of the third molars as a replacement of the second molars has been challenged. Moffit[51] studied the eruption and function of maxillary third molars after the extraction of second molars. He studied 56 consecutively treated cases of maxillary second molar extraction and reported that most maxillary third molars erupted successfully into an acceptable position by the late teens. Our clinical experience coincides with his findings.

It should be noted that the MEAW therapy provides an efficient mechanism to treat openbite malocclusion. The duration of active treatment was on average 27 months for the growing group and 15 months for the nongrowing group. Robb et al[52] studied the duration of orthodontic treatment and reported an average of 29.4 months for adolescents and 30.6 months for adults. Beckwith et al[53] sampled 140 cases from 5 private offices and reported that the duration of treatment ranged from 23.4 months to 33.4 months with a mean of 28.6 months.

Some limitations of this study should be discussed. Problems with cephalometric studies include difficulties in identifying landmarks, in making accurate measurements, and in delineating bilateral images that are often confusing. This study was retrospective in design, and the limitations of a retrospective study are primarily due to bias that may arise from inclusion criteria of subjects. Finally, inclusion of a control group would have helped to delineate the changes from growth or treatment for the growing group.

CONCLUSIONS

The following conclusions can be made from this study:

1. The multiloop edgewise archwire therapy was shown to be an effective and efficient method to treat openbite malocclusion. As a result of treatment, the overbite increased an average of 4 mm in both the growing and the nongrowing groups.
2. The openbite was corrected by retraction and extrusion of the anterior teeth and the uprighting movement of the posterior teeth. The upper and lower occlusal planes moved toward each other.
3. There were some significant changes in the skeletal variables in the growing group. The anterior LFH, anterior TFH, and posterior LFH increased. The palatal plane moved downward anteriorly, and the gonial angle decreased. There were not any significant changes in skeletal variables for the nongrowing group. There was retraction of the upper lip in both the growing and the nongrowing groups.
4. The correction of openbite obtained by the MEAW therapy was proven to be very stable. The relapse in the overbite during the 2-year follow-up period was 0.23 mm for the growing group and 0.35 mm for the nongrowing group; these figures were not significant.

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