ORIGINAL ARTICLE

Evaluation of the modified maxillary protractor applied to Class III malocclusion with retruded maxilla in early mixed dentition

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The purpose of this study was to evaluate the effects of orthodontic treatment with a maxillary protraction bow appliance on anterior crossbite patients with Class III malocclusion in the mixed dentition. The 29 patients treated with a maxillary protraction bow appliance (11 boys, 18 girls) were compared with 25 matched, untreated controls with anterior crossbite (10 boys, 15 girls). The mean age before treatment was 8 years 7 months (range, 6 years 3 months to 11 years 6 months). The mean treatment period to achieve a normal overjet was 10.2 months (range, 5 to 18 months). Fifty-nine cephalometric angular and linear parameters were compared between the treated group and the untreated controls using the analysis of variance and the paired *t* test to evaluate the effect of gender and the maxillary protraction bow appliance treatment. Skeletal and dentoalveolar advancement of the maxilla and retrusion of the mandible contributed significantly to the improvement of Class III malocclusion in the treated group. These results suggest that a maxillary protraction bow appliance is effective for correcting anterior crossbite with a retruded maxilla in the early mixed dentition. (Am J Orthod Dentofacial Orthop 2000;118:549-59)

Class III malocclusion has been reported to develop in from 5% to 10% of whites and is characterized by either a large mandible, a retruded maxilla, or both.[1-3] Among Japanese people, the incidence of such malocclusion is significantly higher,[4,5] and a retruded maxilla is more often encountered than a large mandible with skeletal Class III malocclusion.[6] In such cases, orthodontic treatment is needed to correct the skeletal discrepancy.

Mandibular prognathism was previously believed to be unalterable, and skeletal discrepancy difficult to correct.[7-12] As a result, some patients with skeletal Class III malocclusion were observed, and their orthodontic treatment postponed until their dentofacial growth and development had ceased. The only therapy for these patients was thought to be orthognathic surgery. This therapy forces patients to go through their psychologically and physically formative years with the handicap of facial disfigurement.

In order to eliminate such a handicap and promote the development of the maxillary complex in juveniles, we have developed a modified maxillary protractor called the maxillary protractor bow appliance (MPBA).[13] This appliance is characterized by its simplicity in design, stability when worn, and ease in adjustment in comparison with other types of maxillary protractors. The purpose of this study was to evaluate the skeletal and dentoalveolar effects produced by MPBA treatment in patients in the mixed dentition with Class III malocclusion.

MATERIAL AND METHOD

Twenty-nine patients (11 boys, 18 girls) with Class III malocclusion (treatment group) were actively treated with the MPBA. The control group consisted of 25 children (10 boys, 15 girls) with Class III malocclusion who received no active treatment. The criteria for selecting the patients was as follows: (1) anterior crossbite (negative overjet), (2) stage III-B of Hellman's developmental stages (4 maxillary and mandibular incisors have erupted), (3) Angle Class III molar relationship, and (4) no previous orthodontic treatment. All patients in the treatment group were treated at the orthodontic clinic, Kyushu University Dental Hospital. Two cephalographs from each subject were taken, 1 before and 1 after treatment with MPBA. Two cephalographs of each of the 25 control subjects were taken from the records of the same clinic. Because monitoring their craniofacial growth without providing orthodontic treatment would have posed a serious ethical problem, we previously obtained their parents' consent.

Table I shows the age distribution of the 29 subjects in the treatment group and the 25 subjects in the control group. The mean age at the start of treatment with the MPBA (TT1) was 8 years 7 months ± 1 year 5

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Table I. Age of MPBA-treated Class III subjects and untreated controls

	Treatment group				*Control group*			
	TT1 (SD)	*TT2 (SD)*	*Treatment period (SD)*	*Number of cases*	*CT 1 (SD)*	*CT2 (SD)*	*Observation period (SD)*	*Number of cases*
Boys	8y 10m (±1y 3m)	9y 10m (±1y 8m)	1y 4m (±4.8m)	11	9y 2m (±1y 9m)	10y 0m (±1y 9m)	9.6m (±1.2m)	10
Girls	8y 5m (±1y 8m)	9y 1m (±1y 3m)	8.9m (±3.7m)	18	8y 8m (±1y 0m)	9y 4m (±1y 1m)	8.1m (±2.6m)	15
Boys and girls	8y 7m (±1y 5m)	9y 5m (±1y 6m)	10.2m (±4.5m)	29	8y 10m (±1y 4m)	9y 7m (+1y 4m)	8.4m (±2.3m)	25

TT1, Mean age before MPBA therapy; *TT2,* mean age after MPBA therapy; *CT1,* starting observations in untreated subjects; *CT2,* ending growth observations in untreated subjects.

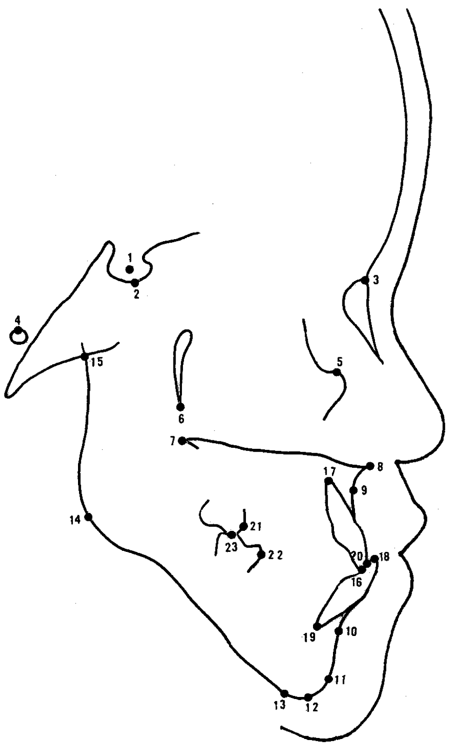

Fig 1. Cephalometric reference points. *1,* Sella (S); *2,* contact tangency from nasion to lower contour of sella turcica (point U); *3,* nasion (N); *4,* porion (PO); *5,* orbita (OR); *6,* pterygomaxillary fissure (Ptm); *7,* posterior nasal spine (PNS); *8,* anterior nasal spine (ANS); *9,* point A; *10,* point B; *11,* pogonion, (Poy); *12,* gnathion (Gn); *13,* menton (Mn); *14,* gonion (G0); *15,* articulare (AR); *16,* maxillary central incisor tip (Max1); *17,* maxillary central root apex (MaxR1); *18,* mandibular central incisor tip (Mand1); *19,* mandibular central incisor root apex (MandR1); *20,* middle point of Max1 and Mand1 (I); *21,* mesial surface of maxillary first molar (Max6); *22,* mesial surface of mandibular first molar (Mand6); *23,* molar point (point M).

months, and the mean age at correction of the anterior crossbite (TT2) was 9 years 5 months ± 1 year 6 months. The average treatment time was 10.2 months ± 4.5 months. For the control group, the mean age at the start of the observation period (CT1) was 8 years 10 months ± 1 year 4 months, and the mean age at the end of the observation period (CT2) was 9 years 10 months ± 1 year 4 months. The mean observation period was 8.4 months ± 2.3 months.

Analysis of Lateral Cephalographs

Lateral cephalographs were traced by the same investigator to avoid interoperator error and 23 landmarks (Fig 1) were identified on the tracing films. The landmarks were digitized 3 times, and the average values were used for the analyses. The cephalometric landmarks and constructed reference lines and angles are shown in Figs 2 and 3. The point U is defined as a point of contact tangency from nasion (N) to the lower contour of sella turcica. Nineteen angular and nine linear measurements were calculated from the x, y coordinates of the landmarks (Fig 2).

As point U is reported to be a more stable and distinguishable point than point S,[14] the U-N line was used as the horizontal reference line in this study. The U-N line served as the x-axis, and the perpendicular line to it passing through point U was defined as the y-axis. The depths of 16 landmarks and the heights of 15 landmarks were obtained, respectively, from the x values and y values in the x, y coordinates of the landmarks. As the observation period differed for each subject, the dentofacial changes on cephalometric measurements were annualized.

$$\text{The annual change} = 12 \times \text{the actual change/treatment period (in months)}$$

The analysis of variance (ANOVA) was carried out to determine whether the effects of MPBA therapy or gender explained any differences in the cephalometric

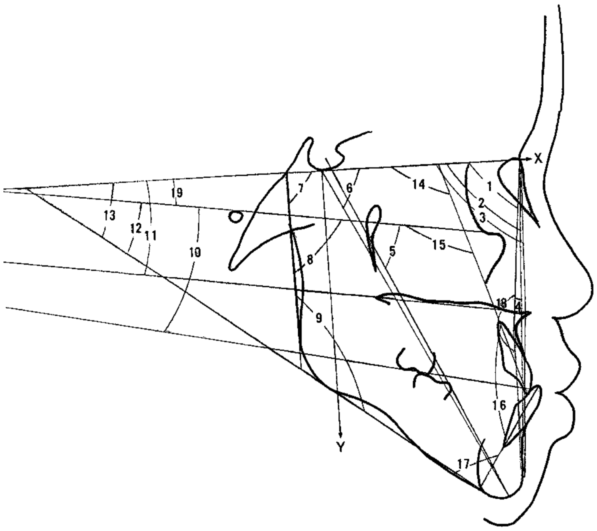

Fig 2. Angular measurements for assessing the jaw relationship: *1,* UNA; *2,* UNB; *3,* UNPog; *4,* ANB; *5,* y-axis; *6,* UNGn; *7,* ramus plane/UN; *8,* ramus plane/FH plane; *9,* Go angle; *10,* occlusal plane angle; *11,* nasal flow/UN; *12,* mandibular plane angle; *13,* mandibular plane/UN; *14,* maxillary 1/UN; *15,* maxillary 1/FH; *16,* interincisor angle; *17,* mand1/mandibular plane, *18,* convexity; *19,* FH plane UN.

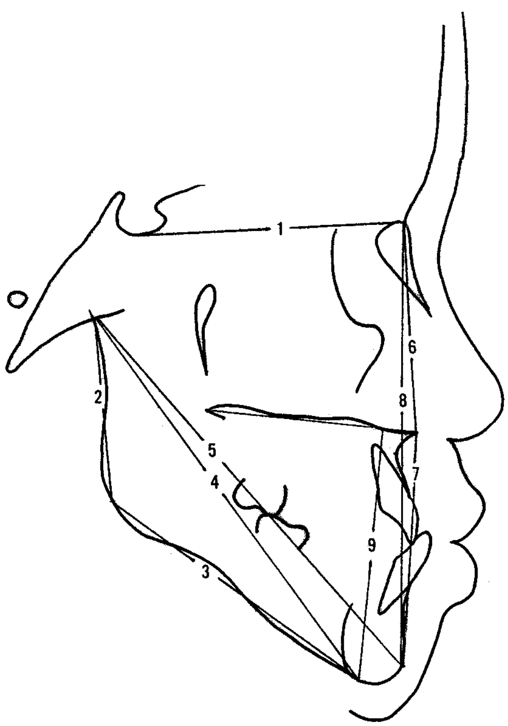

Fig 3. Linear measurements for assessing the jaw relationship: *1,* U-N; *2,* Ar-Go; *3,* Go-Me; *4,* Ar-Me; *5,* Ar-Pog; *6,* N-ANS; 7, ANS-Me; *8,* N-Me; *9,* Me-nasal floor.

Table II. Comparison of angular measurements between treatment and control groups at beginning of treatment/observation

	Treatment group		*Control group*		
Variables (°)	*Mean*	*SD*	*Mean*	*SD*	*t test*
UNA	77.08	4.10	77.28	3.22	—
UNB	77.68	3.81	76.28	3.56	—
ANB	–0.60	2.55	1.00	2.27	*
Conv	181.75	5.80	176.70	4.96	*
FH/UN	9.45	2.35	10.27	2.81	—
NF/UN	11.78	2.71	12.90	3.21	—
Max l/UN	97.90	8.10	98.56	8.48	—
Max 1/FH	107.36	7.20	108.83	9.14	—
RP/UN	91.40	4.50	93.09	5.26	—
RP/FH	81.93	3.94	82.82	5.72	—
UN/UGn	70.11	4.22	72.44	3.03	*
Y-axis	60.65	3.50	62.17	3.20	—
UNP	77.86	3.96	75.72	3.42	*
MP/UN	37.69	5.45	40.99	4.31	*
MP/FH	28.21	4.94	30.72	4.13	—
Gonial angle	126.28	5.80	127.89	7.79	—
Mand 1/MP	87.33	6.97	90.66	7.11	—
Int Inc A	137.09	11.41	129.77	9.29	*
Occ plane	11.98	4.13	13.82	4.22	—

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

Table III. Comparison of linear measurements between treatment and control groups at beginning of treatment/observation

	Treatment group		*Control group*		
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*t test*
U-N	65.05	3.71	65.91	2.95	—
Ar-Go	42.79	3.54	41.72	3.94	—
Go-Me	67.41	4.15	65.77	5.49	—
Ar-Me	100.69	5.26	98.61	7.34	—
Ar-Pog	101.84	5.05	100.54	7.15	—
N-ANS	50.18	3.07	52.35	4.18	*
ANS-Me	61.67	3.49	63.89	4.51	—
N-Me	111.01	5.60	114.64	7.95	—
Me-NF	60.52	3.30	61.74	4.60	—

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

measurements. In order to evaluate the effects of the MPBA therapy, Student *t* test was performed between the treatment and control groups regarding the cephalometric measurements that showed no significant differences between gender.

RESULTS

A few measurements showed significant differences ($P < .05$) in the cephalometric analysis at the start of MPBA therapy and observation (Tables II and III).

Table IV. Descriptive statistics and results of ANOVA of annual angular changes by group and gender

	Boys				*Girls*					
	Treatment group		*Control group*		*Treatment group*		*Control group*		*Main effect*	
Variables (°)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*MPBA*	*Gender*
UNA	1.86	1.50	0.48	2.32	1.25	2.15	-0.24	1.91	**	—
UNB	–1.07	1.14	1.55	1.46	–1.55	2.29	0.32	1.74	***	—
ANB	2.93	1.99	–1.06	1.18	2.80	3.24	–0.57	1.24	***	—
Conv	–2.58	5.90	–0.34	3.47	1.22	4.55	–1.18	2.07	***	—
FH/UN	0.31	2.29	1.61	2.14	1.20	4.30	–0.31	2.91	—	—
NF/UN	–0.70	2.10	–1.63	1.92	–0.99	2.45	0.21	1.78	—	—
Max l/UN	–9.91	6.58	–3.99	4.19	–8.60	8.16	–1.93	5.43	***	—
Max 1/FH	–9.60	6.94	–2.37	5.43	–7.40	6.04	–2.25	5.83	***	—
RP/UN	1.90	2.43	–1.06	2.80	2.16	2.48	0.52	2.54	**	—
RP/FH	2.20	3.90	0.55	3.21	3.36	5.15	0.20	3.87	*	—
UN/UGn	1.90	1.61	–1.52	1.75	1.90	2.49	–0.28	1.57	***	—
Y–axis	2.22	3.05	0.08	2.12	3.10	3.75	–0.60	2.48	***	—
UNP	–1.08	1.35	1.83	1.62	–1.45	2.01	0.16	1.50	***	*
MP/UN	2.48	2.18	–1.32	2.39	1.50	3.38	–0.58	1.65	***	—
MP/FH	2.79	3.16	0.28	2.47	2.70	4.07	–0.90	2.56	***	—
Gonial angle	0.58	1.70	–0.27	2.84	–0.66	3.97	–1.11	3.42	—	—
Mand 1/MP	–2.27	6.73	–0.46	4.09	–5.97	7.13	–2.00	4.45	—	—
Int Inc A	–10.11	6.50	–2.19	7.14	–4.13	8.90	0.66	7.92	**	*
Occ plane	–0.22	2.55	0.22	1.97	0.22	4.07	–1.26	2.80	—	—

*P < .05; **P < .01; ***P < .001; —, not significant.

Table V. Annual linear changes of treatment and control groups

	Boys				*Girls*					
	Treatment group		*Control group*		*Treatment group*		*Control group*		*Main effect*	
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*MPBA*	*Gender*
U–N	0.57	0.70	0.19	1.19	1.00	1.26	1.35	1.57	—	*
Ar–Go	–1.67	7.18	1.00	2.24	0.48	3.37	1.16	2.20	—	—
Go–Me	2.51	2.41	1.02	3.13	1.26	3.21	0.98	2.05	—	—
Ar–Me	0.84	4.47	1.63	3.05	1.48	2.87	1.71	1.47	—	—
Ar–Pog	0.99	5.17	1.71	2.92	0.93	2.72	2.33	2.27	—	—
N–ANS	1.51	1.68	–0.06	2.31	1.31	2.06	1.62	1.23	—	—
ANS–Me	4.59	2.53	1.12	1.32	4.05	2.88	0.58	1.65	***	—
N–Me	5.62	2.22	1.35	2.22	4.73	3.02	2.30	1.64	***	—
Me–NF	3.83	2.00	1.40	0.98	3.15	2.29	0.66	1.68	***	—

*P < .05; **P < .01; ***P < .001; —, not significant.

Annual angular, linear, horizontal, and vertical changes of ANOVA are shown in Tables IV to VII. Except for a few measurements, no significant differences between genders were found. Therefore, most of the significant alterations were attributed to the appliance.

Student *t* tests of changes are shown in Tables VIII to X. The angles UNA and ANB in the treatment group increased significantly and the angle UNB in this group decreased more than in the control group. The angles of the y-axis, NUGn, ramus plane, and the mandibular plane increased more significantly in the treatment group. These changes suggest the clockwise rotation of the mandible. But neither the gonial angle nor the angle of nasal floor to FH showed any significant differences in annual change between the treatment and control groups.

The angles of Max 1 to UN and Max 1 to FH increased significantly more in the treatment group than in the controls; the angle of Mand 1 to the mandibular plane and interincisal angle decreased more. These changes suggest that the maxillary

Table VI. ANOVA of annual horizontal changes (x–axis values)

	Boys				*Girls*					
	Treatment group		*Control group*		*Treatment group*		*Control group*		*Main effect*	
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*MPBA*	*Gender*
X-axis										
Or	1.37	2.87	–0.38	3.06	2.04	3.18	0.87	3.30	—	—
Ptm	0.55	1.12	0.90	1.88	0.17	2.13	0.51	2.19	—	—
Pog	–2.48	2.76	3.24	4.46	–2.64	4.98	0.88	3.40	***	—
Me	–2.70	3.83	3.33	4.40	–2.27	5.27	0.75	3.12	***	—
Go	2.94	2.07	–1.41	2.48	2.22	2.23	0.26	2.63	***	—
Ar	1.29	0.80	–0.78	1.55	0.92	1.46	0.84	1.92	**	—
Max 1	5.95	2.37	2.62	3.18	5.27	4.91	2.36	2.99	**	—
Max E	1.93	2.46	2.48	2.81	1.85	4.41	0.59	3.89	—	—
Mand 1	–1.62	2.79	2.27	2.74	–2.71	3.81	1.21	2.85	***	—
Mand E	–0.52	1.38	3.10	3.13	–0.63	2.49	1.28	2.73	***	—
A	2.10	1.40	0.61	3.13	1.71	2.80	0.63	2.13	—	—
B	–2.24	2.10	1.87	3.62	–2.42	4.49	1.38	3.00	***	—
Gn	–2.28	2.83	4.15	3.74	–2.52	4.67	1.37	3.16	***	—
ANS	1.88	2.38	0.62	2.93	2.21	3.04	0.80	1.95	—	—
PNS	0.46	1.04	0.83	2.66	–0.34	2.59	1.11	2.13	—	—
N	0.57	0.70	0.19	1.19	1.00	1.26	1.35	1.57	—	*

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

Table VII. ANOVA of annual vertical changes (y–axis values)

	Boys				*Girls*					
	Treatment group		*Control group*		*Treatment group*		*Control group*		*Main effect*	
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*MPBA*	*Gender*
Y-axis										
Or	0.28	1.58	0.43	2.95	–0.54	2.78	0.72	2.48	—	—
Ptm	1.34	1.79	1.83	4.24	0.60	1.98	0.45	3.55	—	—
Pog	5.30	2.45	2.20	3.23	3.76	4.33	2.85	2.93	—	—
Me	4.96	1.56	2.40	2.48	3.95	2.63	2.24	1.57	***	—
Go	1.75	2.70	3.10	1.61	1.92	2.49	1.91	1.25	—	—
Ar	2.56	5.28	2.02	2.90	1.42	1.74	0.78	2.36	—	—
Max 1	3.15	2.53	1.56	1.85	4.09	4.85	1.88	1.25	*	—
Max E	4.89	2.06	2.36	2.42	3.67	3.44	2.40	2.33	*	—
Mand 1	4.53	2.58	1.34	2.01	2.24	3.02	1.24	1.73	**	—
Mand E	2.94	2.10	3.03	1.44	2.52	2.78	2.72	1.60	—	—
A	1.68	1.95	0.44	3.47	2.33	3.05	2.28	1.51	—	—
B	5.19	1.99	4.04	2.34	3.54	3.33	2.15	2.18	—	*
Gn	5.22	2.18	2.49	2.09	4.10	3.17	2.41	1.11	**	—
ANS	1.78	1.55	–0.01	2.67	1.47	2.04	1.59	1.21	—	—
PNS	2.05	1.29	1.33	1.97	1.76	1.58	1.47	1.04	—	—

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

incisors inclined labially and the mandibular incisors inclined lingually during MPBA use.

A Case Treated with the MPBA

Figs 4 to 6 show one patient who was treated with the MPBA, an 8-year 5-month-old boy with the chief complaint of an anterior crossbite. His skeletal and denture patterns showed typical skeletal Class III malocclusion (Fig 4). A cephalometric analysis also suggested maxillary retrusion (Table XI). The MPBA was used to correct his malocclusion. This appliance consisted of an acrylic face bow, an intraoral component, and 2 elastic bands. The intraoral component consisted of 4 bands that were cemented on the maxillary deciduous molars and permanent first molars, and a palatal button connecting the 4 bands (Fig 5*A*

Table VIII. Student *t* test of annual angular changes

	Treatment group		*Control group*		
Variables (°)	*Mean*	*SD*	*Mean*	*SD*	*t test*
UNA	1.48	1.93	0.05	2.07	*
UNB	–1.37	1.92	0.82	1.72	***
ANB	2.85	2.79	–0.77	1.22	***
Conv	–5.98	5.03	–1.57	2.35	—
FH/UN	0.86	3.64	0.45	2.76	—
NF/UN	–0.88	2.29	–0.52	2.02	—
Max 1/UN	9.10	7.51	2.75	4.99	***
Max 1/FH	8.23	6.37	2.30	5.56	**
RP/UN	2.06	2.42	–0.11	2.71	**
RP/FH	2.92	4.67	0.34	3.55	*
UN/UGn	1.90	2.17	–0.78	1.72	***
Y–axis	2.77	3.47	–0.33	2.32	***
UNP	–1.31	1.77	0.83	1.73	***
MP/UN	1.87	2.98	–0.88	1.97	***
MP/FH	2.74	3.69	–0.43	2.54	**
Gonial angle	–0.18	3.32	–0.77	3.17	—
Mand 1/MP	–4.57	7.10	–1.38	4.29	*
Int Inc A	–6.40	8.48	–0.48	7.60	**
Occ plane	0.05	3.48	–0.66	2.56	—

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

Table IX. Findings of Student *t* test for the annual linear changes between treatment and control groups

	Treatment group		*Control group*		
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*t test*
U–N	0.84	1.08	0.89	1.52	—
Ar–Go	–0.33	5.14	1.10	2.17	—
Go–Me	1.73	2.96	1.00	2.48	—
Ar–Me	1.24	3.50	1.68	2.18	—
Ar–Pog	0.95	3.75	2.08	2.51	—
N–ANS	1.38	1.90	0.94	1.90	—
ANS–Me	4.26	2.72	0.80	1.52	***
N–Me	5.07	2.74	1.92	1.91	***
Me–NF	3.41	2.18	0.96	1.46	***

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

and *B*). The chin pad was made of acrylic and based on an impression of the patient's chin; it was fixed on an acrylic face bow that is adjusted to the patient's facial profile by heating. The bilateral elastic bands were connected from the hooks on the acrylic face bow to the soldered buccal hooks on the adjusted bands and then the intraoral component was pulled forward by about 400 g of elastic force unilaterally in a 20° to 30° direction downward from the occlusal plane (Fig 5). The MPBA was worn for 10 to 12 hours or more a day for about 10 months until a normal overjet of the anterior teeth could be achieved. He needed no retainer and showed no relapse 1 year

Table X. Student *t* test of annual horizontal (x–axis) and vertical (y–axis) changes between treatment and control groups

	Treatment group		*Control group*		
Variables (mm)	*Mean*	*SD*	*Mean*	*SD*	*t test*
X-axis					
Or	1.78	3.03	0.37	3.20	—
Ptm	0.31	1.80	0.66	2.04	—
Pog	–2.58	4.21	1.82	3.95	***
Me	–2.43	4.71	1.78	3.82	**
Go	2.49	2.16	–0.41	2.65	***
Ar	1.06	1.25	–2.60	1.80	**
Max 1	5.53	4.10	2.46	3.00	**
Max E	1.88	3.74	1.33	3.57	—
Mand 1	–2.29	3.45	1.63	2.80	***
Mand E	–0.59	2.11	2.01	2.98	***
A	1.86	2.39	0.62	2.52	—
B	–2.35	3.72	1.58	3.20	***
Gn	–2.43	4.02	2.49	3.60	***
ANS	2.08	2.77	0.37	2.33	—
PNS	–0.03	2.15	1.00	2.31	—
N	0.84	1.09	0.89	1.52	—
Y–axis					
Or	–0.23	2.40	0.60	2.62	—
Ptm	0.88	1.91	1.00	3.82	—
Pog	4.34	3.75	2.62	3.00	—
Me	4.33	2.31	2.31	1.94	**
Go	1.64	2.55	2.39	1.49	—
Ar	1.85	3.48	1.27	2.60	—
Max 1	3.73	4.09	1.75	1.49	*
Max E	4.14	3.01	2.39	2.31	**
Mand 1	3.11	3.04	1.28	1.80	**
Mand E	2.67	2.51	2.85	1.52	—
A	2.08	2.67	1.54	2.59	—
B	4.16	2.97	2.91	2.39	—
Gn	4.53	2.85	2.44	1.54	**
ANS	1.59	1.85	0.95	2.04	—
PNS	1.87	1.46	1.41	1.45	—

*$P < .05$; **$P < .01$; ***$P < .001$; —, not significant.

after the MPBA therapy (Fig 6). Table XI shows the skeletal and dentoalveolar cephalometric evaluations before and after MPBA treatment.

DISCUSSION

Samples

In most studies on the effects of the maxillary protraction therapy, the treated subjects have been compared with control subjects who had normal occlusion and a normal skeletal relationship.[15-18] To evaluate the net effects of the MPBA, the craniofacial changes of untreated children with Class III malocclusion must be subtracted from the craniofacial growth of subjects treated with the MPBA; the dentoalveolar and skeletal growth trends in subjects with Class III malocclusion may differ from those of nor-

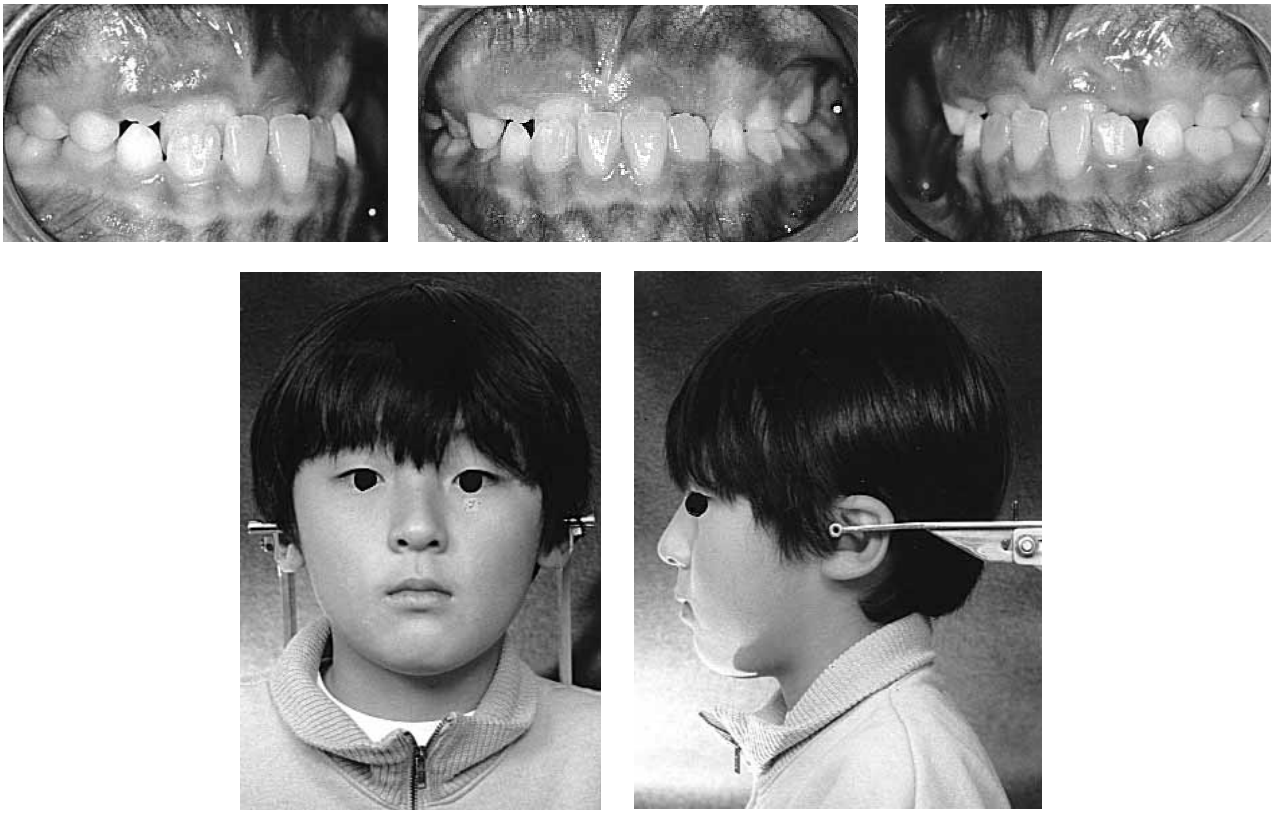

Fig 4. Intraoral and facial photographs before treatment.

mal subjects. Therefore, an adequately matched control sample (skeletal pattern, dental development) was established in this study.

An ANOVA of the cephalometric measurements at the TT1 and CT1 stages showed no significant effect of gender on any measurement except for the angle of convexity. The ratio of boys to girls in the treatment group did not differ from that in the control group. Therefore, the following evaluation of the effects of the MPBA was performed in the pooled subjects of boys and girls (Table I).

Evaluation of Skeletal Changes

The point A advancement of the maxilla,[18] an increase in maxillary length,[15,19] and a downward increase in point A[20] have all been reported in recently published clinical studies on maxillary protractors.

In our study, the UNA angle increased by 1.48° in the treatment group, whereas it increased by only 0.05° in the control group (Table VI). The angular change of point A in the treatment group was 3 times that in the control group, and the difference was statistically significant ($P < .05$). Moreover, the MPBA therapy for about 10 months resulted in an average 1.8 mm advancement of point A, even in cases in the mixed dentition. In contrast to the treatment group, the control group showed no significant forward growth of the maxilla. In addition, X-Ptm hardly increased, and the horizontal distance between Ptm and point A did not increase. These findings suggest that a large forward displacement of the anterior maxilla was achieved by the biomechanical force of MPBA in the treatment group.

The protracting force has been reported to produce a forward displacement.[21-23] In addition, in animal studies,[24-27] a significant forward displacement of the maxilla was also proven by histologic changes and sutural modifications in the maxillary sutures accompanied by maxillary protraction therapy. As a result, the exfoliation of the maxilla from the pterygoid process was considered to be induced on the skulls as orthopedic effects by MPBA force in the treatment group.

The angle of nasal floor to UN (NF/UN) decreased slightly in both groups, but the decreased angle of NF/UN in the treatment group did not show any statistically significant difference from that in the control group. Namely, in both groups, the maxilla showed little counterclockwise rotation to the anterior cranial base. Some investigators[28,29] have reported that the

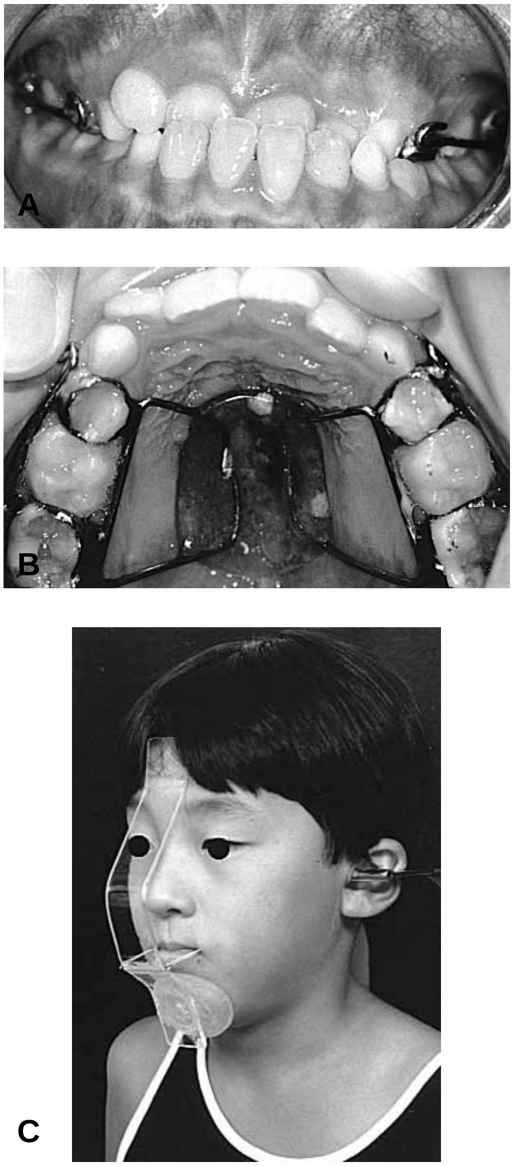

Fig 5. Intraoral and facial photographs at beginning of traction.

force generated parallel to the occlusal plane produced the counterclockwise rotation of the nasal floor at any age. In addition, Tanne et al[22] found the center of resistance to the protraction forces in the maxillary protraction therapy. The MPBA was designed to protract the maxilla forward and downward in the direction of the force through the center of resistance. That is to say, this counterclockwise rotation of the nasal floor in the treatment group may not be the result of the reported counterclockwise rotation of the maxilla as an outcome of protraction forces. In this study, no patient exhibited an anterior open bite after using the MPBA. The force vector seemed to enable the maxilla to protract downward. When patients are suspected of developing an anterior open bite, the anteroposterior position of intraoral hooks and the direction of protracting force should be selected after carefully considering the vertical dimensions of their faces.

In the control group, the UNB angle and horizontal changes of point B increased significantly, and the linear measurements (Ar-Go, Ar-Me, Ar-Pog) also tended to increase (Table VII). These findings suggest that the mandible grew longer, both in a forward and downward direction, in the control group. On the other hand, in the treatment group, the angle of UNB showed a significant decrease and 5 angles (MP/UN, MP/FH, RP/UN, RP/FH, Y-axis) significantly increased (Table VII). Point B also showed a significant backward and downward change (Table IX). However, 4 lengths (Ar-Go, Go-Me, Ar-Me, and Ar-Pog) in the mandible did not show any significant differences between both groups. These findings suggest that the size of the mandible was greater in the control group, whereas the mandible in the treatment group did not develop but instead made a clockwise rotation. Accordingly, lower facial height (ANS-Me) and total facial height (N-Me) increased significantly in the treatment group. These findings, which included an especially significant increase in anterior facial height, have been reported in previous studies.[11,12,30-32] In these reports, the inherited prognathic characteristics of the skeletal Class III profiles were not altered in mature individuals, and some investigators[29,33,34] reported an increase in the lower facial height with a mandibular clockwise rotation as an unfavorable phenomenon for occlusal stability.

But even in our study of early mixed dentition patients, the orthopedic force of the MPBA was unable to inhibit and alter the normal forward growth of the mandible; therefore, such mandibular clockwise rotation is considered to be necessary and unavoidable for correcting an anterior crossbite. In other words, the backward and downward rotation of the mandible appeared to be a contributory factor in the successful treatment in mixed dentition.

Evaluation of Dental Changes

The maxillary incisors (increase in angles Max 1/FH and Max 1/UN) in the treatment group inclined significantly more labially, and displacement of the incisal tip of the maxillary incisor was more forward than in the control group. The mandibular incisors inclined more lingually (decrease in angle Mand 1 to MP) and displacement of the incisal edge of the mandibular incisor was more backward than in the control group. The interincisor angle of these teeth showed a significant

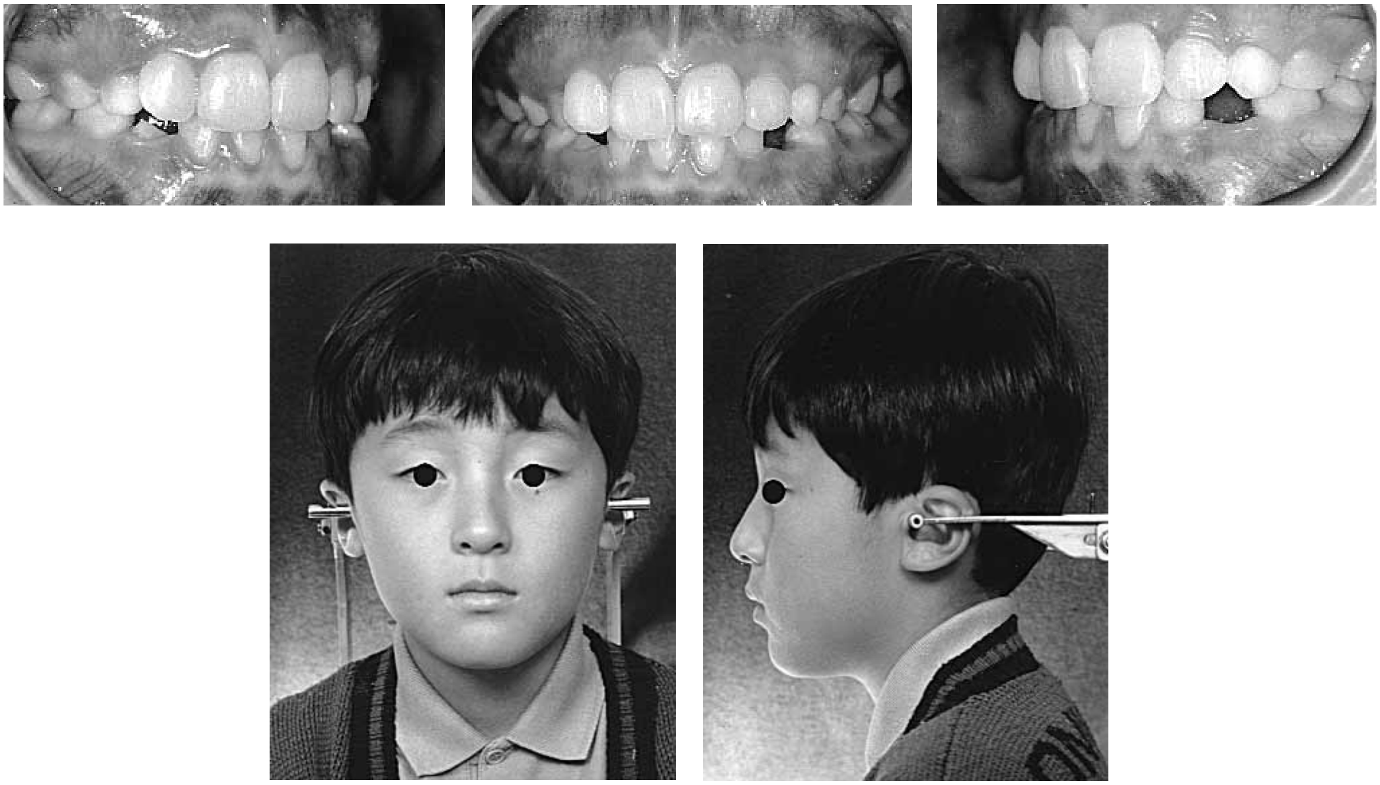

Fig 6. Intraoral and facial photographs after MPBA treatment.

decrease in the treatment group. Labial tipping and the forward movement of the maxillary incisors and lingual tipping and backward movement of the mandibular incisors corrected the anterior crossbite. The biomechanical protraction force may have affected the maxillary incisors in the maxillary alveolus and thus resulted in their forward displacement. Lingual tipping of the mandibular incisors may be the result of a restrained effect with a chin pad of the MPBA. Labial tipping of maxillary incisors and lingual tipping of mandibular incisors may also be side effects of the attempt to obtain a normal overbite, spacing for the maxillary incisors, and crowding for the mandibular incisors.

Effects of MPBA Therapy

Table XII shows the horizontal changes of 4 major components in correcting the anterior crossbite with the MPBA. The anterior crossbite in Class III malocclusion can thus be corrected not only by forward displacement of the maxilla and labial inclination of maxillary incisors but also by backward movement of the mandible and lingual inclination of the mandibular incisors. In this study, 10 months of MPBA therapy resulted in a point A advancement of 1.2 mm and a point B retrusion of 3.9 mm horizontally, namely the mean mandibular retrusion was 3 times greater than the maxillary advancement. Obviously, mandibular changes affected the correction with MPBA therapy more than the maxillary changes did. The correction was achieved by approximately 70% (19.1% + 52.4%) skeletal displacements and by 30% (28.3% + 0.2%) incisor tipping.

Merwin et al,[35] who treated with a combination of Tubinger reverse-pull headgear with maxillary expansion, reported that overjet correction was achieved by 63% skeletal movement and 37% incisor tipping in patients 8 years of age and older. In addition, they also stated that a rapid palatal expansion induced a loosening of the maxillary sutures, and this loosening made accelerating the maxillary protraction possible. Our results without rapid palatal expansion were similar to their findings. The purpose of the MPBA therapy is not to achieve dentoalveolar changes but to correct the skeletal disharmony. When the MPBA is applied to younger children in the deciduous dentition, the ratio of skeletal movement to incisor movement may be changed in order to correct the skeletal Class III malocclusion. It is therefore important to diagnose anteroposterior skeletal discrepancies in Class III patients and to improve them as early as possible. Fortunately, no relapses have been observed in our treatment group. However, we need to

Table XI. Cephalometric measurements in boy treated with MPBA

Variables (°)	*Before treatment*	*After treatment*	*Changes*
Age	8y 5m	9y 3m	l0m
UNA	78.03	78.39	0.36
UNB	78.20	77.84	–0.36
ANB	–0.17	0.55	0.72
Conv	181.28	179.27	–2.01
FH/UN	9.09	7.54	–1.55
NF/UN	10.20	11.68	1.48
Max 1/UN	86.79	98.77	11.98
Max 1/FH	95.87	106.30	10.43
RP/UN	99.04	99.36	0.32
RP/FH	89.95	91.82	1.87
UN/UGn	70.16	71.08	0.92
Y axis	61.08	63.54	2.46
UNP	78.60	78.74	0.14
MP/UN	33.32	34.83	1.51
MP/FH	24.24	27.29	3.05
Gonial angle	114.28	115.48	1.20
Mand 1/MP	87.65	81.96	–5.69
Int Inc A	152.24	144.44	–7.80
Occ plane	11.24	12.22	0.98

Table XII. Horizontal changes of 4 major factors in correcting anterior crossbite with MPBA therapy

	Maxillary		*Mandibular*	
	Point A	*Max 1*	*Point B*	*Mand 1*
Treatment group (mm)	1.86 (23.4%)	3.67 (46.2%)	–2.35 (29.6%)	0.06 (0.8%)
Control group (mm)	0.62 (15.2%)	1.84 (45.0%)	1.58 (–38.6%)	0.05 (1.2%)
Differences of both groups (mm)	1.24 (19.1%)	1.83 (28.3%)	–3.93 (52.4%)	0.01 (0.2%)

observe the long-term stability of these patients and critically evaluate the effects of the MPBA.

CONCLUSIONS

The authors evaluated the treatment effects induced by the MPBA in patients in the early mixed dentition. The cephalometric measurements of 29 Class III children diagnosed with a retruded maxilla were compared with those of 25 untreated matched subjects. The major findings were as follows:

1. MPBA therapy for Class III malocclusion with maxillary retrusion in the early mixed dentition induced favorable changes in the craniofacial skeleton and alveolus compared with the changes that occurred in matched untreated Class III controls.
2. MPBA therapy in the mixed dentition resulted in a significant forward displacement of the maxilla and clockwise rotation of the mandible. The maxillary incisors tipped labially while the mandibular incisors tipped lingually.
3. The combination of these skeletal and dentoalveolar changes resulted in the successful correction of the skeletal Class III malocclusion.
4. Seventy percent of the horizontal correction of the anterior crossbite was achieved by skeletal movement, and 30% by incisor movement in MPBA-treated children in the early mixed dentition.

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