Maxillary protraction effects of TTBA (Tandem Traction Bow Appliance) therapy in Korean Class III children

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Objective: The purpose of this study was to investigate the maxillary protraction effects of the Tandem Traction Bow Appliance (TTBA), a new appliance devised several years ago for the treatment of growing skeletal Class III patients. **Methods:** Participants were 88 Korean children (42 boys, 46 girls) with skeletal Class III malocclusion treated with TTBA at the orthodontic clinic of Ewha Womans University Mokdong Hospital. Mean age at the start of treatment was 7.5 years ± 1.5 years. Mean treatment periods were 13 ± 3 months. Pretreatment and posttreatment lateral cephalograms were traced and superimposed by the same investigator and analyzed by modified McNamara analysis and pitchfork analysis. Changes were evaluated with paired *t*-tests at a significance level of $p < 0.05$. **Results:** The maxilla and maxillary dentition moved forward. The mandible moved backward, although not significantly; and the mandibular dentition moved forward. The net dental changes combined with the apical base change resulted in a favorable total molar relationship correction. Net dental movement was 26% and the apical base change 74% of the total molar relationship correction. **Conclusion:** These results suggest that TTBA has a maxillary protraction effect that can be useful in the treatment of growing skeletal Class III malocclusion with maxillary deficiency. **(Korean J Orthod 2007;37(3):231-40)**

Key words: Skeletal Class III malocclusion, TTBA therapy, Modified McNamara analysis, Pitchfork analysis

INTRODUCTION

Skeletal Class III anomaly is one of the most difficult malocclusions to correct in orthodontics, with an incidence of approximately 5% in the white population and as high as 48% in the Japanese population.[1-3] Skeletal Class III malocclusion may result from maxillary retrognathism, mandibular prognathism, or a combination of the two.[4] Although the traditional treatment for a developing skeletal Class III malocclusion has focused on the mandible as the primary etiologic cause,[5] studies[6-10] suggest that 42% to 63% of skeletal Class III malocclusions display maxillary retrusion or hypoplasia, in combination with a normal or mildly prognathic mandible. For these reasons, in conjunction with the directional growth modification of the mandible, orthopedic protraction of underdeveloped or retrognathic maxilla is one of the major objectives in the treatment of certain skeletal Class III malocclusions.

The purpose of this study was to investigate the maxillary protraction effects of short-term treatment with the Tandem Traction Bow Appliance (TTBA), a new appliance devised several years ago for the treatment of growing skeletal Class III patients.[11]

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MATERIAL AND METHODS

Subjects & Protocol

Patients

Participants were 88 Korean children (42 boys, 46 girls) with skeletal Class III malocclusion who were treated with TTBA at the orthodontic clinic of Ewha Womans University Mokdong Hospital. Table 1 shows the chronologic age, Hellmans dental developmental stage, and CVM (cervical vertebrae maturation) stage[12] at the start of treatment. Mean chronologic age was 7.5 years ± 1.5 years, and the majority of the children were in the early mixed dentition stage, and before the pubertal growth spurt. The criteria for patient selection were as follows. (1) Korean ancestry, (2) deciduous or mixed dentition at the start of treatment, (3) skeletal Class III malocclusion identified by a combination of an edge-to-edge incisor relation or anterior crossbite, Angle Class III molar relationship or mesial step, and an ANB measurement of less than 0°, (4) no previous orthodontic treatment, (5) treatment only with TTBA and no other appliances, (6) pretreatment and posttreatment lateral cephalograms made on the same cephalostat and of good quality, (7) no anterior, posterior and lateral functional shift on jaw closing movement, and (8) no other craniofacial anomalies.

Table 1. Chronologic age, dental developmental stage and CVM stage of samples

Classification	Number	%
Chronologic age (years)		
4-6	10	11.4
6-8	43	48.8
8-10	28	31.8
10-12	7	8.0
Hellman's dental developmental stage		
II_A	5	5.7
II_C	15	17.0
III_A	55	62.5
III_B	10	11.4
III_C	3	3.4
CVM stage		
CVM_1	64	72.7
CVM_2	21	23.9
CVM_3	3	3.4
Total	88	100.0

Appliance and treatment sequence

TTBA, a newly devised appliance for the treatment of growing skeletal Class III patients, was introduced several years ago,[11] and it has been used widely and successfully in orthodontics. It consists of an upper splint, a lower splint, and a traction bow. The upper splint contains the buccal hook (placed on the maxillary first deciduous molar or premolar region) and a labial bow. The lower splint has a tube for the traction bow. The design of the TTBA is illustrated in Figure 1.

At the first visit (T1), a lateral cephalogram, impression, and construction bite for the appliance are taken. TTBA is delivered and patients are instructed to wear the appliance for 12-14 hours per day. Approximately 300-500 g/side of force is delivered through elastics from the traction bow of the lower splint to the buccal hooks of the upper splint, at an angle of 20° below the occlusal plane to minimize the counterclockwise rotation tendency (Figs 1 and 2).[13] After correction of the crossbite and mesial step or Class III molar relationship (T2), records including lateral cephalogram are taken, and upper and lower splints are fused into the monoblock and used as a retainer. At the end of treatment, the mean chronologic age was 8.7 years ± 1.6 years, and the majority of children were in the early mixed dentition stage (Hellmans dental developmental stage IIIA; the mesial shift of the first molars had not occurred in most cases). Mean treatment periods (T2-T1) were 13 ± 3 months.

Analysis

Cephalometric analysis

Modified McNamara analysis

T1 and T2 lateral cephalograms were traced by the

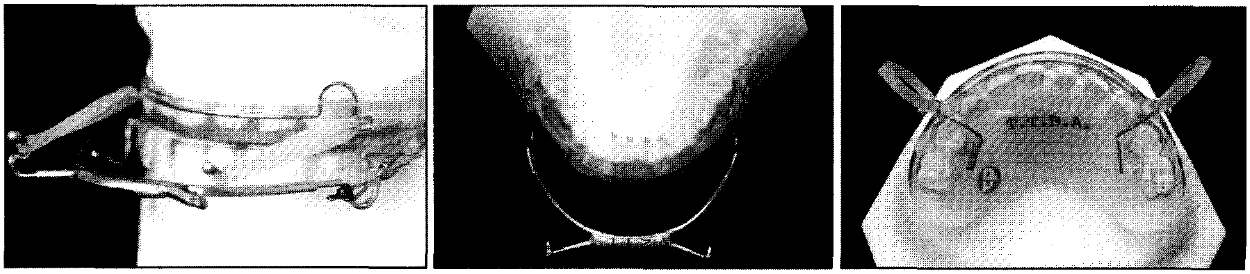

Fig 1. Tandem Traction Bow Appliance (TTBA).

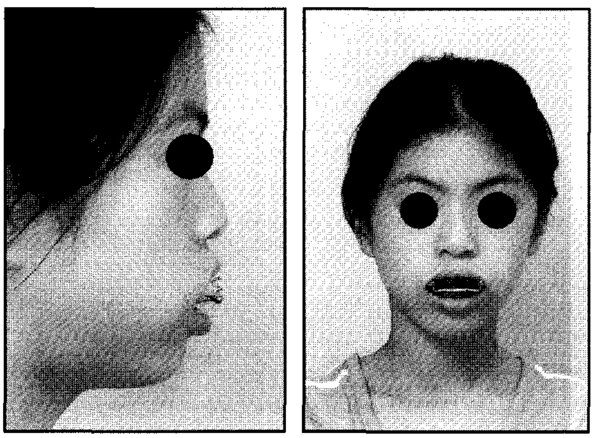

Fig 2. TTBA *in situ.*

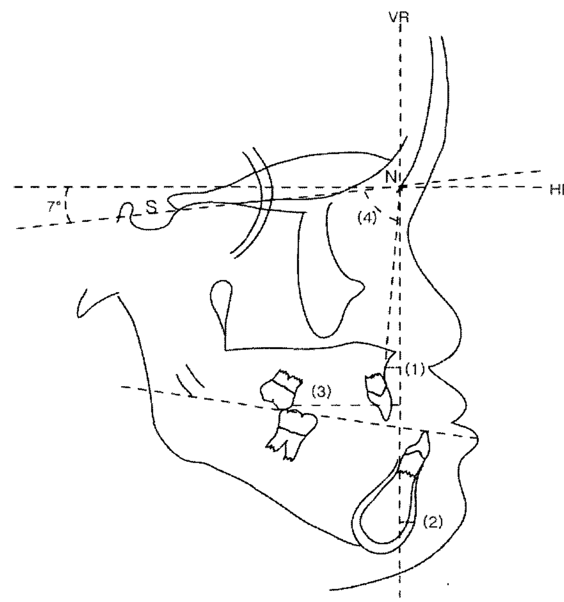

Fig 3. The reference planes and four measurements. *HR*, horizontal reference plane; *VR*, vertical reference plane; *(1)*, N ⊥ A-point (mm), horizontal distance from A-point to VR; *(2)*, N ⊥ Pog (mm), horizontal distance from pogonion to VR; *(3)*, N ⊥ Mx6 (mm), horizontal distance from the maxillary first molar to VR; *(4)*, SNA (°), angle between SN line and NA line.

same investigator. It has been reported that the plane constructed by reducing 7° from the sella-nasion line (SN-7 degree plane) is approximately parallel with, but more reproducible than, the Frankfort horizontal plane. For this reason, the SN-7 degree plane on the T1 lateral cephalogram was used as the horizontal reference plane. The vertical reference plane was defined as a line perpendicular to the horizontal reference plane which passes through Nasion. After construction of reference planes on the T1 lateral cephalogram, the T2 lateral cephalogram was superimposed on the T1 lateral cephalogram using Björk's method.[14,15] The reference planes on the T1 lateral cephalogram were then duplicated onto the T2 lateral cephalogram. The constructed reference planes, 3 linear and 1 angular measurements are shown in Figure 3. Signs of the values were defined as follows: they were positive if the values were on the right side of the vertical reference plane; they were negative if the values were on the left side. All measurements were made up to 0.5 mm accuracy. The values were measured twice and averaged to reduce measurement errors. The changes (from T1 to T2) of the four measurements were calculated.

Pitchfork analysis

The pitchfork analysis (Figs 4-6)[16] has been used to distinguish the skeletal and dental treatment effects

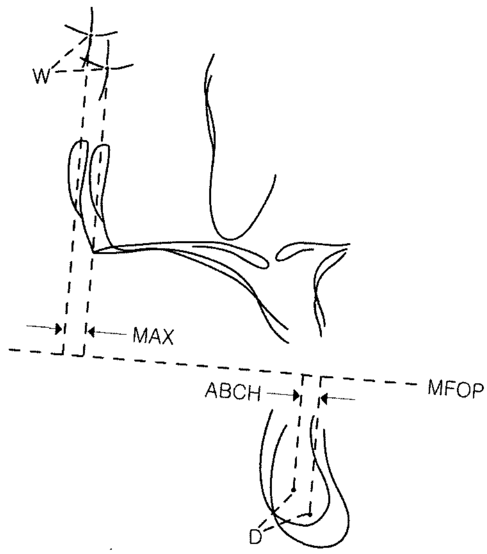

Fig 4. Measurements of MAX and ABCH with maxillary regional superimposition. *W*, Point on the outline of the greater wings which crosses jugum; *D*, center of the symphysis body (by inspection); *MAX*, maxillary advancement relative to the cranial base; *ABCH*, mandibular displacement relative to the maxilla; *MAND*, mandibular displacement relative to the cranial base. (MAND =ABCH - MAX)

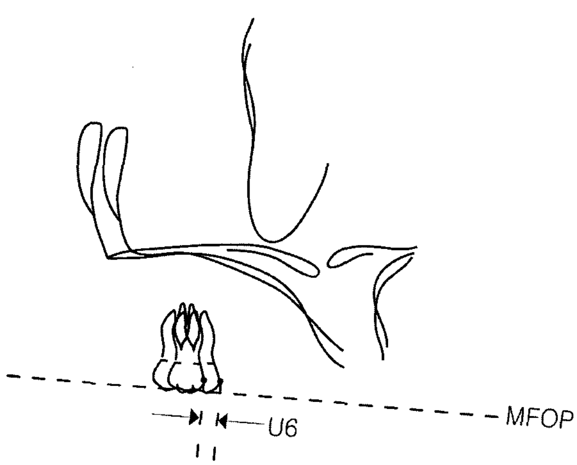

Fig 5. Maxillary tooth movement with maxillary regional superimposition. *U6*, Maxillary first molar movement relative to the maxilla.

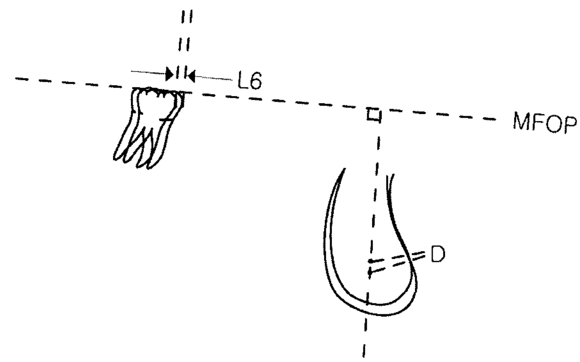

Fig 6. Mandibular tooth movement with D-point-perpendicular registration. *L6*, Mandibular first molar movement relative to the mandible.

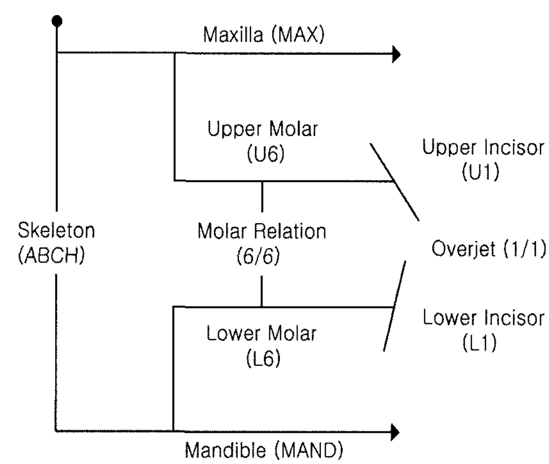

Fig 7. Pitchfork diagram. *MAX*, Maxillary advancement relative to the cranial base; *ABCH*, mandibular displacement relative to the maxilla; *MAND*, mandibular displacement relative to the cranial base. (MAND = ABCH - MAX); *U6*, maxillary first molar movement relative to the maxilla; *L6*, mandibular first molar movement relative to the mandible; *6/6*, total molar relationship correction (6/6 = ABCH + U6 + L6).

along the mean functional occlusal plane (MFOP = averaged T1 and T2 functional occlusal planes). Cephalometric tracings were superimposed on the maxilla by orienting on the palatal plane (ANS-PNS), the lingual palatal curvature, and the lower anterior border of the zygomatic process (key ridge), registering at the inferior border.[17,18] All sagittal measurements were measured parallel to MFOP. Signs of the values were defined as follows: they were positive if the tendency was to correct a Class II molar relationship or to reduce the overjet; they were negative if there was

Table 2. Changes of cephalometric measurements after TTBA therapy

Variables	T_1	T_2	$T_2 - T_1$	
	Mean ± S.D	Mean ± S.D	Mean ± S.D	*p* value
N ⊥ A-point (mm)	-2.42 ± 2.73	-0.82 ± 2.89	-1.60 ± 1.34	0.000*
N ⊥ Pog (mm)	-5.33 ± 5.20	-5.42 ± 5.93	-0.09 ± 3.65	0.821
N ⊥ Mx6 (mm)	-26.44 ± 2.84	-24.97 ± 2.56	-1.47 ± 2.10	0.000*
SNA (°)	-79.33 ± 3.47	-81.03 ± 3.78	-1.71 ± 2.02	0.000*

*$p < 0.001$; N ⊥ A-point (mm), horizontal distance from A-point to VR; N ⊥ Pog (mm), horizontal distance from pogonion to VR; N ⊥ Mx6 (mm), horizontal distance from maxillary first molar to VR; SNA (°), angle between SN line and NA line.

Table 3. Descriptive statistics for pitchfork analysis (mm)

Variables	Mean ± SD	Contribution (%)	Implication
Skeletal changes			
MAX	-1.08 ± 0.90	-30	FWD
MAND	-1.63 ± 2.47	-44	BWD
ABCH	-2.71 ± 2.36	-74	FC
Dental changes			
U6	-1.83 ± 1.38	-50	FWD
L6	-0.87 ± 1.78	-24	FWD
Net dental changes	-0.96 ± 2.42	-26	FC
Total molar relationship correction			
6/6	-3.67 ± 2.28	100	FC

MAX, Maxillary advancement relative to the cranial base; MAND, mandibular displacement relative to the cranial base. ABCH, mandibular displacement relative to the maxilla; U6, maxillary first molar movement relative to the maxilla; L6, mandibular first molar movement relative to the mandible; 6/6, total molar relationship correction; FWD, forward displacement; BWD, backward displacement; FC, favorable change in treatment of Class III.

an increase in overjet or the molar relationship moved toward Class II. The so-called "pitchfork diagram" (Fig. 7) provides a convenient and logical means of organizing and summarizing the various components of changes that come together at the occlusal plane.

Statistical analysis

The changes (from T1 to T2) were evaluated with paired *t*-tests, at a level of significance of $p < 0.05$.

RESULTS

Modified McNamara analysis

The descriptive statistics and comparisons of paired samples (T1, T2) are shown in Table 2.

Skeletal and dental changes

After TTBA therapy (T2-T1), A point (N ⊥ A point, 1.60 mm; SNA, 1.71°) and the maxillary first

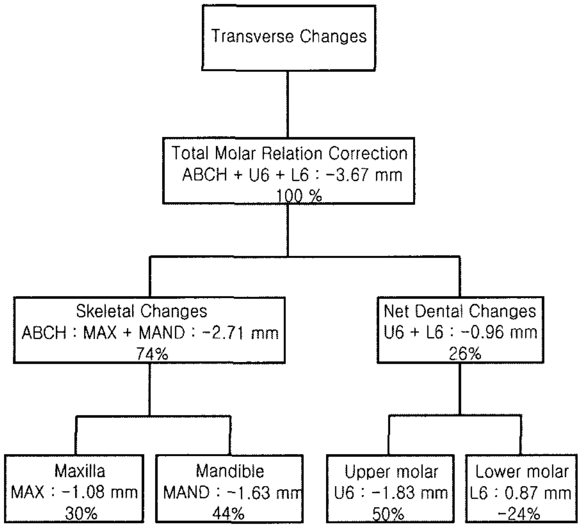

Fig 8. Total molar relationship correction after TTBA therapy. *MAX*, Maxillary advancement relative to the cranial base; *ABCH*, mandibular displacement relative to the maxilla; *MAND*, mandibular displacement relative to the cranial base (MAND = ABCH - MAX); *U6*, maxillary first molar movement relative to the maxilla; *L6*, mandibular first molar movement relative to the mandible; *6/6*, total molar relationship correction (6/6 = ABCH + U6 + L6).

molar (N ⊥ Mx6, 1.47 mm) moved forward significantly ($p < 0.001$). Pogonion (N ⊥ Pog, -0.09 mm) was displaced backward, but the displacement was not statistically significant.

Pitchfork analysis

Descriptive statistics and a schematic diagram of the pitchfork analysis are shown in Table 3 and Figure 8.

Skeletal changes

The maxilla was translated in an anterior direction (MAX, -1.08 mm), and the mandible was displaced in a posterior direction (MAND, -1.63 mm), resulting in a favorable apical base change (ABCH = MAX + MAND = -2.71 mm) in this treatment of Class III malocclusion.

Dental changes

The upper and lower molars moved forward (U6, -1.83 mm, L6, 0.87 mm), resulting in a favorable net dental movement (U6 + L6 = -0.96 mm) in this treatment of Class III malocclusion.

Total molar relationship correction

The net dental changes (U6 + L6 = -0.96 mm) combined with the apical base change (ABCH = MAX + MAND = -2.71 mm) resulted in a favorable total molar relationship correction (6/6 = ABCH + U6 + L6 = -3.67 mm) in this treatment of Class III malocclusion. The net dental movement (U6 + L6) was 26% (U6, 50%; L6, -24%) and the apical base change (ABCH) was 74% (MAX, 30%; MAND, 44%) of the total molar relationship correction.

DISCUSSION

Many factors affect maxillary protraction, including treatment timing, appliance type, expansion of maxilla, treatment protocol, force magnitude, direction and sites of application, patient compliance, favorable growth potential, and an appropriate biologic response, but most of these factors are still the subject of controversy.[19] Maxillary expansion/face-mask therapy has been used successfully in protracting the maxilla for many years. However, it is worn extraorally and is not as comfortable or esthetic as an intraoral appliance; thus, the intraoral appliance used here (TTBA) was devised several years ago and has since been used widely and efficiently.[11]

Recommendations for reducing cephalometric errors include the use of high-quality radiographs and replication and averaging of all measurements.[20,21] In this study, the values were measured twice two weeks apart by the same investigator and averaged to reduce measurement errors. The reliability coefficient was found to be high (> 0.8) in both analyses. Two cephalometric analyses were used for different purposes in this study. Use of McNamara analysis (based on Björk's superimposition technique[14,15]) allowed for the evaluation of posttreatment changes (from T1 to T2). Björks superimposition technique is generally acknowledged to achieve the highest degree of accuracy among various superimposition methods.[22,23] On the other hand, with the pitchfork analysis, the skeletal and dental contributions to correction in Class III

Table 4. Changes of occlusal plane and mandibular plane

Variables	T_1	T_2	$T_2 - T_1$	
	Mean ± SD	Mean ± SD	Mean ± SD	*p* value
OP to SN (°)	16.06 ± 20.21	15.67 ± 05.65	-0.39 ± 20.27	0.859
SNMP (°)	31.91 ± 03.44	32.15 ± 03.52	0.24 ± 01.81	0.226

OP to SN (°), angle between the occlusal plane and SN line; SNMP (°), angle between SN line and mandibular plane.

malocclusion can be distinguished. In the pitchfork analysis, regional maxillary superimposition and occlusal reference plane play a key role. Depending on treatment modalities, various degrees of rotational effects may occur on the structures of the facial cranium, and the reproducibility of the pitchfork analysis may not be high, as indicated by two investigations.[24,25] In this study, however, changes in the occlusal plane (OP to SN, -0.39°; $p < 0.05$) were not statistically significant (Table 4).

The greatest shortcoming of this study was the absence of control samples; using a Class I control group to compare with a Class III treatment group may lead to underestimation of the treatment effects and overestimation of posttreatment changes.[26] However, until now there have been no major longitudinal studies of untreated Class III subjects. Given the absence of true longitudinal data, Miyajima et al.[27] attempted to estimate the growth of untreated Class III subjects at distinct developing stages (a cross-sectional study). In spite of the virtue of having an untreated Class III control sample, the most valuable control samples are the patients themselves, and the common way to manage this is to have a pretreatment observation period.[7,28]

The results of this study demonstrated a significant skeletal and dental response to TTBA therapy, and skeletal change was primarily a result of anterior movement of the maxilla (Table 2). When compared as an annual growth rate of untreated Class III controls in a study of similar design,[29] the result confirmed a true maxillary orthopedic effect after TTBA therapy (N ⊥ A point, 1.73 mm; SNA, 1.85°). However, no significant changes occurred in the horizontal (N ⊥ Pog point, -0.09 mm; $p < 0.05$) and vertical (SNMP, 0.24°; $p < 0.05$) positions of the mandible (Tables 2 and 4), an outcome consistent with results found by Mermigos et al.,[10] who reported that the mandibular plane remained unchanged. Changes in the anterior-posterior position of the mandible occur because of many factors, including rotation of the palatal/occlusal plane, extrusion of teeth and subsequent mandibular rotation, mandibular rotation directly induced by the appliance (distalizing or retraction force on the chin), and the growth pattern of the mandible. In this study, however, there was no significant rotation of the occlusal plane, similar to findings of some other studies,[6,9,10,29-31] but in contrast with those of other investigators.[2,3,7,8,26,32-36]

Many factors may affect the rotation of the palatal/occlusal plane, including site of force application, direction of elastic traction, the presence of a biteblock that places an intrusive force on the molar area, and the original facial pattern of the patients. Tanne et al.[37] and Hata et al.[38] demonstrated that palatal plane rotation occurs where the PNS drops more than the ANS because the line of force is directed below the center of resistance of the maxilla, creating a moment for rotation. All patients in this study were treated with elastic traction attached in the premolar area, with an angle of about 20° below the occlusal plane to minimize the counterclockwise rotation tendency.[13] Teeth extrusion and subsequent mandibular rotation can also influence the anterior-posterior position of the mandible. TTBA has no maxillary expansion system, and a non- expansive mechanism is less extrusive to upper molars than the maxillary expansion system. This outcome is consistent with the findings of Mermigos et al.,[10] who used maxillary protraction without maxillary expansion. Additionally, TTBA has a biteblock 3-4 mm thick in the posterior area, which may serve as an intrusion block for the posterior teeth. Consequently, it is suggested that preservation of the palatal/occlusal plane angle, the non-expansive mechanism of the appliance, and the presence of a posterior biteblock reduced the backward rotation of the mandible and affected the anterior-posterior position of the mandible. In most cases of Class III malocclusion treatment, the mandible is displaced downward and backward. In this study, however, the position of the mandible was maintained by virtue of these factors (unchanged occlusal plane, non-expansive mechanism, the presence of a biteblock), not by the mandibular body remodeling process that compensate the downward and backward rotation of the mandible. The mean treatment period (13 months) was apparently too short to remodel the mandibular border.

The results of the pitchfork analysis showed that the net dental changes (U6 + L6 = -0.96 mm) combined with the apical base change (ABCH = MAX + MAND = -2.71 mm) resulted in a favorable total molar relationship correction (6/6 = ABCH + U6 + L6 = -3.67 mm) in this treatment of Class III malocclusion.

The net dental changes (U6 + L6) made up 26% (U6, 50%; L6, -24%) and the apical base change (ABCH) covered 74% (MAX, 30%; MAND, 44%) of the total molar relationship correction. Another study using a protraction facial mask with RME[35] reported an overall ratio of 3:2 of skeletal displacement versus incisor tipping. In a study involving MPBA therapy,[34] the correction was approximately 70% skeletal displacement and 30% incisor tipping. Furthermore, Merwin et al.,[28] who used 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 comparison with other studies, the overall ratio of skeletal versus dental contribution in this study was higher.

Macdonald et al.[26] found that after protraction of the maxilla with face-mask/expansion therapy, the maxilla continued to grow anteriorly in an amount equal to untreated Class III patients but less than untreated Class I patients; therefore, overcorrection of the Class III malocclusion or part-time wear of the face mask to counteract the post-protraction growth deficiency of the maxilla is recommended. This recommendation would be adapted to TTBA also.

CONCLUSIONS

This study investigated maxillary protraction effects after TTBA therapy with the following results.

1. The maxilla and maxillary dentition moved forward.
2. The mandible moved backward, although not significantly, while the mandibular dentition moved forward.
3. The net dental changes combined with the apical base change resulted in a favorable total molar relationship correction.
4. The net dental movement was 26% and the apical base change 74% (MAX, 30%; MAND, 44%) of the total molar relationship correction, and the skeletal contribution to correction of this Class III malocclusion was higher than in other studies.

These results suggest that TTBA has a maxillary protraction effect that is useful in the treatment of a growing skeletal Class III malocclusion with maxillary deficiency.

- 국문초록 -

한국인 성장기 III급 부정교합의 TTBA 치료 후 상악골 견인 효과

김 혜 진 · 전 윤 식 · 임 원 희

이 논문의 목적은 성장기 골격성 III급 부정교합의 치료를 위하여 새로이 고안된 Tandem Traction Bow Appliance (TTBA)의 상악골 견인 효과를 평가하는 것이다. 이화여자대학교 목동병원 치과 교정과에 내원한 성장기 골격성 III급 부정교합 환자 중 TTBA로 치료받은 88명(소년 42명, 소녀 46명)을 대상으로 하였다. 치료 시작 시 연령은 7세 6개월 ± 1년 6개월이었으며, 평균 치료 기간은 13개월 ± 3개월이었다. 치료 전과 후의 측모두부방사선사진계측이 동일 조사자에 의해 투사 및 중첩되었으며, modified McNamara analysis과 pitchfork analysis로 분석하였다. 치료 전후의 변화를 알아보기 위하여 paired sample *t*-test를 실시하였으며 다음과

같은 결론을 얻었다. 상악과 상악치열은 전방으로 이동하였다. 하악은 후방으로 이동하였으나, 그 양은 통계학적으로 유의하지 않았다. 하악치열은 전방으로 이동하였다. Net dental changes와 apical base change가 복합되어 나타난 결과, III 급 부정교합 치료에 유리한 방향으로 total molar relationship correction이 일어났다. Total molar relationship correction에 대한 기여 정도는 net dental movement 26%, apical base change 74%였다. 이상의 결과는 TTBA 치료가 상악골 결핍을 가진 성장기 골격성 III 급 부정교합에서 유의한 상악골 견인 효과를 가진다는 것을 의미한다.

주요 단어: 골격성 III급 부정교합, TTBA 치료, Modified McNamara analysis, Pitchfork analysis

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