Case Report

Camouflage treatment of skeletal Class III malocclusion with asymmetry using a bone-borne rapid maxillary expander

Yu-Jin Seo[a]; Kyu-Rhim Chung[b]; Seong-Hun Kim[c]; Gerald Nelson[d]

ABSTRACT

This case report presents the successful use of palatal mini-implants for rapid maxillary expansion and mandibular distalization in a skeletal Class III malocclusion. The patient was a 13-year-old girl with the chief complaint of facial asymmetry and a protruded chin. Camouflage orthodontic treatment was chosen, acknowledging the possibility of need for orthognathic surgery after completion of her growth. A bone-borne rapid expander (BBRME) was used to correct the transverse discrepancy and was then used as indirect anchorage for distalization of the lower dentition with Class III elastics. As a result, a Class I occlusion with favorable inclination of the upper teeth was achieved without any adverse effects. The total treatment period was 25 months. Therefore, BBRME can be considered an alternative treatment in skeletal Class III malocclusion. (*Angle Orthod.* 2015;85:322–334.)

KEY WORDS: Class III malocclusion; Mini-implant; Rapid maxillary expansion; Asymmetry, C-expander; Camouflage

INTRODUCTION

Skeletal Class III malocclusion is characterized by proclination of the upper incisors and retroclination of the lower incisors to compensate for the sagittal skeletal discrepancy.[1] Furthermore, buccal inclination of the upper posterior teeth and lingual version of the lower posterior teeth are often observed owing to the transverse skeletal discrepancy. In patients with severe skeletal discrepancies, orthognathic surgery after decompensation of the dentition is necessary to achieve normal occlusion. However, if the skeletal discrepancy is mild to moderate, the clinician will seek the patient's opinion before deciding on a treatment plan of orthodontic camouflage treatment or of orthodontic treatment combined with orthognathic surgery.

A common strategy of orthodontic camouflage treatment is the use of intermaxillary Class III elastics to correct the sagittal discrepancy.[2–5] Class III elastics result in mesial movement of the upper dentition and distal movement of the lower dentition with proclination of upper and retroclination of the lower dentition.[2,5–8] They also induce extrusion of the upper molars and lower incisors, resulting in counterclockwise rotation of the occlusal plane and an increase in the facial height.[5,8] However, proclined upper incisors and flat smile arcs are unfavorable esthetic outcomes. The position and inclination of the upper incisors and the sagittal cant of the occlusal plane are important components of facial and smile esthetics.[9] To prevent these undesirable changes, several studies have reported mini-implant–assisted distalization of the lower dentition.[8–12]

In the camouflage treatment approach, the clinician will address the sagittal discrepancy and will consider nonsurgical maxillary expansion. Tooth-anchored expanders have been conventionally used, but they have several disadvantages, such as limited skeletal expansion, undesirable buccal tipping of the teeth, and buccal bone dehiscence.[13–16] To avoid these adverse effects, skeletal anchorage for rapid maxillary expansion has been reported.[17–19]

This report presents the case of a patient with skeletal Class III malocclusion, transverse discrepancy, and facial asymmetry. The patient was successfully

[a] Clinical Fellow, Department of Orthodontics, Kyung Hee University School of Dentistry, Seoul, South Korea.

[b] Professor and Chairman, Department of Orthodontics, School of Medicine, Ajou University, Suwon, Korea.

[c] Associate Professor and Chairman, Department of Orthodontics, Kyung Hee University School of Dentistry, Seoul, Korea.

[d] Clinical Professor and Chair, Division of Orthodontics, Department of Orofacial Science, University of California San Francisco, San Francisco, Calif.

Corresponding author: Dr Seong-Hun Kim, Department of Orthodontics, Kyung Hee University School of Dentistry, #1 Hoegi-dong, Dongdaemun-gu, Seoul 130-701, Republic of Korea
(e-mail: bravortho@gmail.com)

Accepted: May 2014. Submitted: March 2014.
Published Online: July 17, 2014

Figure 1. Pretreatment facial and intraoral photographs.

treated with a bone-borne rapid maxillary expander (BBRME), which was also used as indirect anchorage for Class III elastics. The purpose of this report is to suggest BBRME as an alternative camouflage treatment for Class III malocclusions.

Diagnosis and Etiology

A 13-year-old girl complained of facial asymmetry, a protruded chin, and difficulty in occluding her teeth. Clinical examination showed that she had a prognathic profile, a relatively long lower face, and facial asymmetry with the chin deviating to the left (Figure 1). Intraoral examination revealed a bilateral Class III molar relationship with a unilateral Class III canine relationship on the right (Figures 1 and 2). Anterior edge-to-edge bite and deficient posterior buccal overjet were associated with anteroposterior positional discrepancy and a protruded mandible but no CO-CR

Figure 2. Pretreatment cast models.

Figure 3. Pretreatment radiographs: lateral and posteroanterior cephalograms, panoramic radiograph, and hand-wrist radiograph.

discrepancy. The lower posterior teeth were tipped lingually and the upper posterior teeth buccally, indicating compensation of the transverse discrepancy. Minor crowding was present in the upper and lower dentition, with arch length discrepancy of −1.5 mm and −2.5 mm, respectively.

The initial lateral cephalometric analysis showed a skeletal Class III relationship (ANB, 0.9°) with excessive mandibular growth (Mn body to anterior cranial base, 1.2°) and a vertical growth pattern (FMA, 32.3°; Figure 3; Table 1). Dental compensation was noted with proclined upper incisors (U1 to FH, 126.2°) and lingual version lower incisors (IMPA, 84.9°). The posteroanterior cephalogram showed deviation of the mandible to the left, with shorter ramus length on the left side and the cant of the occlusal plane (Figure 3). The upper dental midline was coincident with the facial midline, whereas the lower dental midline was deviated by 2 mm to the left (Figures 1 and 3). There were no other significant findings from the panoramic radiograph,

Table 1. Lateral Cephalometric Analysis

Variable	Mean	SD	Pretreatment	Posttreatment	Difference
Sagittal					
ANB (°)	3.45	1.87	0.9	2.8	1.9
SNA (°)	81.08	3.73	76.0	76.5	0.4
SNB (°)	78.01	3.81	75.1	73.7	−1.4
A point to N-Perp, mm	0.4	2.3	0.5	1.0	0.5
Pog to N-Perp, mm	−1.8	4.5	−0.5	−3.1	−2.5
Wit's appraisal, mm	−2.74	0.3	−4.5	−3.8	0.7
Mn body to anterior cranial base	1.08	0.03	1.2	1.3	0.1
Vertical					
Sum, °	397.16	6.63	406.7	408.8	2.1
Saddle angle, °	125.45	5.32	128.3	128.8	0.4
Articular angle, °	147.68	5.25	149.4	151.6	2.2
Gonial angle, °	124.31	5.36	129.0	128.4	−0.6
SN-FH, °			14.5	14.5	0.0
FH-Palatal plane angle, °	1.2	4.72	−4.9	−4.9	0.1
FH to Occl plane angle, °	29.63	5.66	7.5	10.3	2.8
FH to mandibular plane angle, °	29.63	5.66	32.3	34.4	2.1
Facial height ratio (posterior/anterior)	65.3	8.75	59.0	58.0	−1.0
ANS-Me/Nasion-Me	0.55	0.02	0.6	0.6	0.0
Dental					
U1-FH, °	113.8	6.37	126.2	115.6	−10.6
U1 to SN, °	105.28	6.64	111.8	101.2	−10.6
IMPA, °	91.62	5.23	84.9	76.6	−8.3
Overbite, mm	2.5	1	−0.5	2.0	2.5
Overjet, mm	2.5	1	1.5	4.1	2.6
U6 to palatal plane, °	–	–	106.0	106.0	0.0
L6 to mandibular plane, °	–	–	103.0	109.5	6.5
Soft tissue					
Upper lip to E-line, mm	0.86	2.36	−0.1	−0.1	−0.1
Lower lip to E-line, mm	5.87	2.93	0.9	0.9	0.0

except for the developing third molars. Residual growth was expected to some extent, because the hand-wrist radiograph demonstrated MP3-G or SMI 7-8 (Figure 3) and the patient's menarche had begun a year ago. The patient was diagnosed with skeletal Class III malocclusion, with transverse discrepancy and facial asymmetry.

Treatment Objectives

The treatment objectives were to (1) establish a proper occlusion, (2) resolve the transverse discrepancy, (3) improve inclination of the compensated teeth, (4) correct the midline discrepancy, (5) maintain periodontal health, and (6) establish an esthetic profile. Furthermore, the jaw growth needed to be monitored constantly.

Treatment Alternatives

Orthognathic surgery after growth completion can be the first treatment option because of the anteroposterior jaw relationship and facial asymmetry. In this approach, vertical facial height can also be improved with impaction of the maxilla and reduction genioplasty. When positioning the casts to a Class I molar relationship and assuming an upright position of the compensated posterior teeth, the transverse discrepancy disappeared, indicating a normal transverse relationship.

Camouflage treatment was an alternative, considering the mild anteroposterior discrepancy, the extent of malocclusion, and the patient's facial profile. The sagittal and midline discrepancies can be improved by orthodontic treatment, assuming non-extraction and asymmetric distalization of the lower dentition. However, expansion of the maxilla is necessary not only to correct the transverse discrepancy but also to increase the arch perimeter, thus allowing reduction of the crowding. If the maxillary suture is patent, expansion can be achieved by a variety of methods in adolescent patients. The characteristics and design of the expander need to be considered carefully. In this case, the design should be such that the expander does not hinder tooth movement, since camouflage treatment with a full fixed orthodontic appliance is planned, aside from the maxillary expansion. Furthermore, growth observation is essential, because residual growth is expected to some extent.

After considering all the alternatives, the patient's family chose camouflage orthodontic treatment, as

Figure 4. C-expander for maxillary expansion and its utilization for indirect skeletal anchorage for tooth movement. (A) Maxillary expansion was successfully achieved. Note the spaces in the anterior region. (B) While holding the expander for stability of expansion, leveling and alignment can also be achieved. (C) The upper first molars were connected to the expander for indirect absolute anchorage against Class III elastics. Mesh pads were bonded on the upper first molars, and the wires soldered to mesh pad were connected to C-expander using acrylic resin. (D) Multiloop edgewise archwire with tip-back bend in the lower dentition.

they did not want orthognathic surgery. They were informed that orthognathic surgery could be recommended after growth completion.

Treatment Progress

Initial treatment was started with maxillary expansion. The C-expander, which is a BBRME appliance, consists of three parts: four mini-implants (1.8-mm diameter, 8.5-mm length; C-implant Co., Seoul, Korea), an expansion screw, and an acrylic body. Four mini-implants were placed on the palatal slope 8 mm apical to the alveolar ridge: two between the canines and first premolars and the other two between the second premolars and first molars. An acrylic resin body with an expansion screw was fabricated on the cast model, along the curvature of the hard palate. After installation of the mini-implants, the fabricated acrylic body was connected to the mini-implants by adding acrylic resin. The expansion screw (Forestadent Co, Pforzheim, Germany) was turned once a day (0.25 mm/d), and the process was terminated at 6 weeks. Separation of the midpalatal suture was assessed clinically by the development of the median diastema (Figure 4) and also through cone-beam computed tomograms and radiographs (Figures 5 and 6; Table 2).

After a 6-week consolidation period, the upper and lower fixed appliances were bonded while holding the C-expander for stability of expansion. After leveling and aligning, the lower third molars were extracted. A 0.019 × 0.025-inch stainless-steel archwire was engaged in the upper dentition, and a 0.016 × 0.022-inch stainless-steel multiloop edgewise archwire with tip-back bend was engaged in the lower dentition. Class III elastics (5/16-inch, 4 oz) were used for distalization of the lower dentition for 5 months bilaterally and another 6 months unilaterally on the right side. The upper molars were reinforced by connecting the upper first molars to the C-expander to prevent the mesial movement of the upper dentition or extrusion of the molars by the Class III elastics. This indirect anchorage acted as an absolute anchor via the mini-implants within the C-expander. Other elastics were applied with different vectors and forces on each side, to achieve midline correction and interdigitation. The C-expander and the mini-implants were removed at completion of treatment, after debonding. For retention, lingual fixed retainers were bonded on the upper and lower incisors, and circumferential removable retainers were used in both arches. The patient was advised to practice a tongue posture to contact the palatal surface.

TREATMENT RESULTS

The total duration of treatment was 25 months. A Class I occlusion with proper interdigitation, overbite, and overjet was achieved (Figures 7 and 8). The upper and lower dental midline coincided with the facial

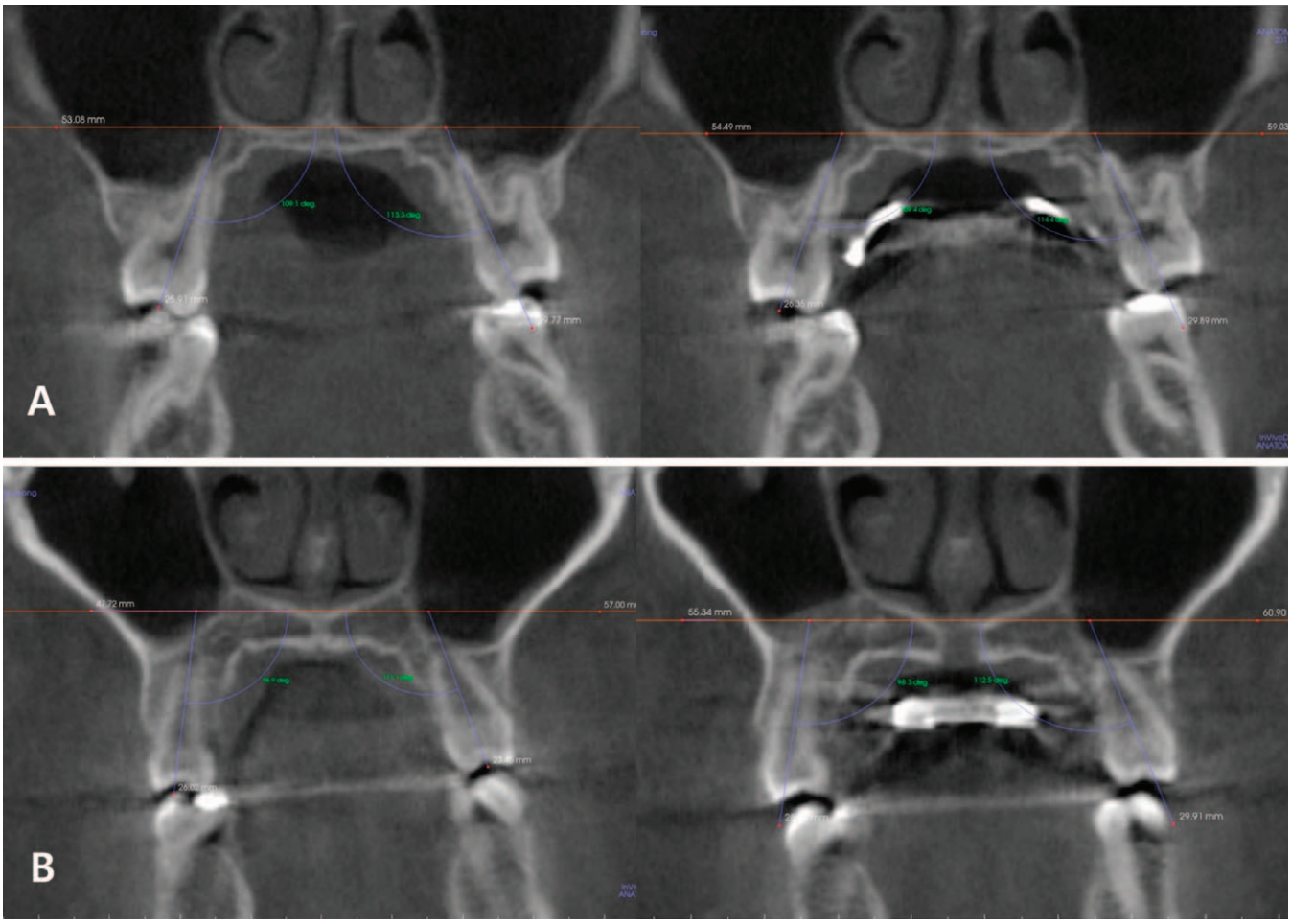

Figure 5. Images of cone-beam computed tomograms taken before and after the bone-borne maxillary expansion. Palatal suture was separated and expanded with minimal tipping of the teeth and the alveolar bone. The added lines were used for measuring the inclination of the teeth (nasal floor and axis of the palatal root). (A) At the upper first molar. (B) At the upper second premolar (left, before expansion; right, after expansion).

midline. The patient developed a straight profile, and the facial asymmetry improved (Figures 7 and 9). Although the lower facial height remained elongated, the patient and her parents were satisfied with the facial profile and occlusion that was achieved without orthognathic surgery.

Superimposition of the lateral cephalometric tracings before and after treatment showed that the mandible rotated clockwise (FH to mandibular plane angle, from 32.3° to 34.4°) owing to vertical growth, and the ANB angle increased from 0.9° to 2.8° (Figures 9 and 10; Table 1) with retrusion of the chin, resulting in a straight profile. The upper incisors were retroclined into normal inclination (U1 to FH, from 126.2° to 115.6°). The lower incisors were retracted and retroclined along with the extrusion (IMPA, from 84.9° to 76.6°), and the lower molars were tipped backward with mandibular distalization, thus establishing a positive overbite and overjet. With respect to the vertical growth of both jaws, as shown in Figure 10, extrusion of the upper and lower molars might have resulted from the compensatory alveolar growth. Soft tissue changes accompanied the skeletal and dental changes.

Sufficient maxillary expansion with minimal tipping of the segment was achieved through the C-expander, resulting in an average 5.08-mm increase in transverse width, with only 0.98° buccal tilting of the posterior teeth and 1.98° buccal tilting of the alveolar bone (Figure 5; Table 2). The inclination of the upper dentition was corrected, and it remained within the normal range at completion of treatment (Figures 7 and 8). The maxillary arch width, before and after treatment, showed minimal changes at the level of the cusp tip but greatly changed at the level of the dental cervical margin (Figures 2, 8, and 11; Table 3). This implies that the uprighting of the upper canines and posterior teeth was achieved through skeletal expansion and the subsequent recovering lingual inclination.

During treatment, the patient did not complain of discomfort. There were no complications, such as

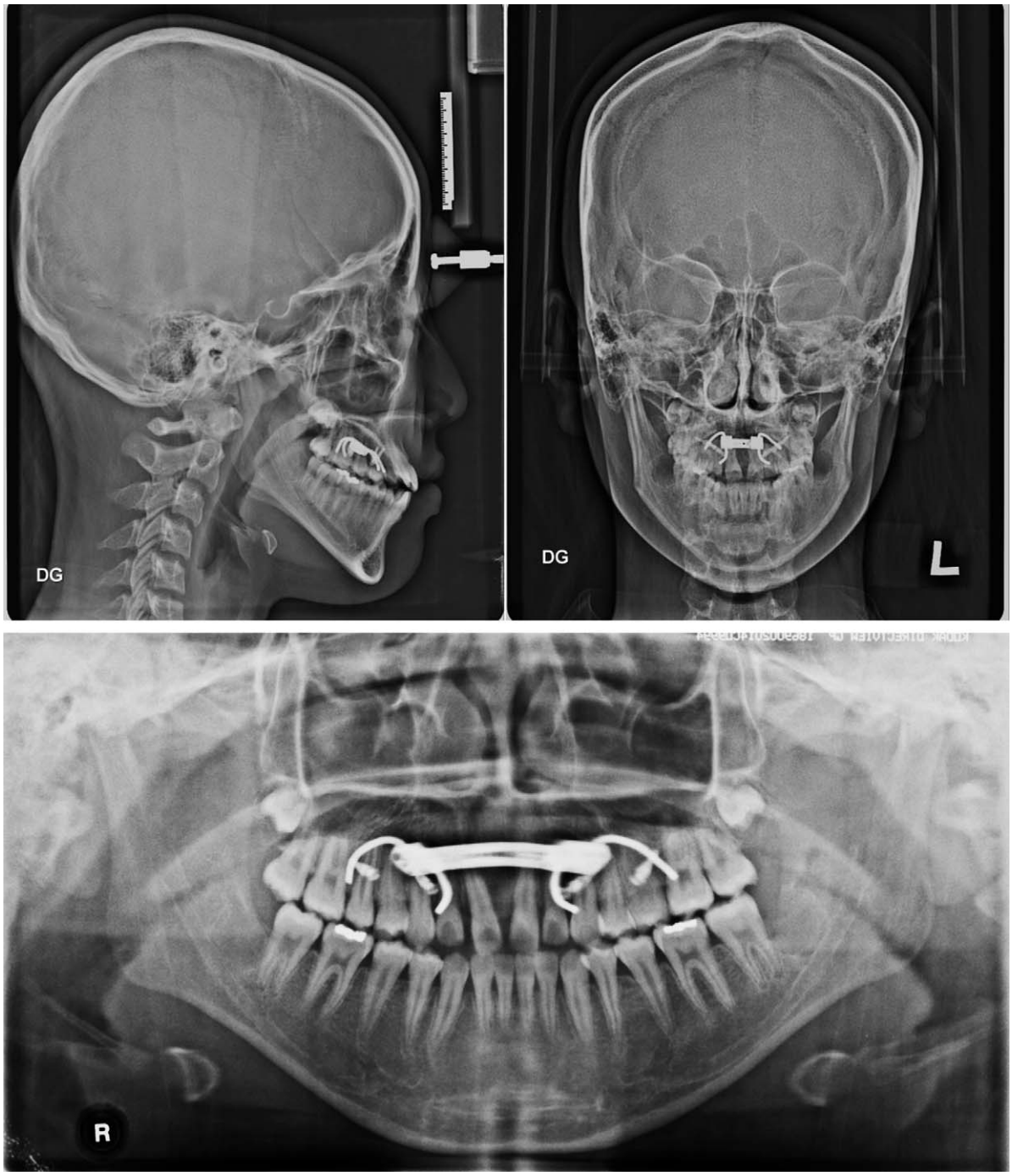

Figure 6. Midtreatment radiographs after maxillary expansion: lateral and posteroanterior cephalograms, panoramic radiograph.

inflammation of the palatal soft tissue, that were induced by the appliance. Although local gingival swelling was observed on the buccal side of the posterior teeth during debonding, this was related to poor oral hygiene around the brackets and not to the expander itself. At the 9-month posttreatment follow-up, the gingival swelling had resolved, and stable occlusion had been maintained (Figure 12).

DISCUSSION

The conventional method of Class III camouflage treatment usually includes Class III elastics.[2,5–8] However, Class III elastics aggravate the already proclined upper incisors and extrude the upper molars, resulting in an unesthetic smile and unintended clockwise rotation of the mandible.[9] To avoid this, several studies have reported mini-implant–assisted distalization of

Table 2. Changes Before and After Bone-Borne Maxillary Expansion in the Coronal View[a]

		Inclination of the Alveolar Bone, °			Inclination of the Teeth, °			Transverse Width, mm: At the Level of Center of Pulp Chamber			Transverse Width, mm: At the Level of Root Apex		
		Before Expansion	After Expansion	Difference	Before Expansion	After Expansion	Difference	Before Expansion	After Expansion	Difference	Before Expansion	After Expansion	Difference
Upper second molar	Right	101.60	103.10	1.50	118.00	118.50	0.50	48.80	53.24	4.44	39.27	43.03	3.76
	Left	101.70	102.50	0.80	117.90	118.10	0.20						
Upper first molar	Right	102.40	105.50	3.10	109.10	109.40	0.30	45.70	50.60	4.90	34.40	39.03	4.63
	Left	112.30	114.00	1.70	113.30	114.40	1.10						
Upper second premolar	Right	110.40	113.20	2.80	96.90	98.30	1.40	41.50	46.55	5.05	35.98	41.45	5.47
	Left	119.90	125.00	5.10	111.10	112.50	1.40						
Upper first premolar	Right	88.30	88.70	0.40	85.70	89.60	3.90	34.98	40.91	5.93	31.60	37.34	5.74
	Left	114.80	115.20	0.40	106.40	105.40	−1.00						
Mean				1.98			0.98			5.08			4.90

[a] The reference line was tangent to the nasal floor at its most inferior level, as seen in Figure 6. Inclination of the alveolar bone was measured by the angle between the reference line and the tangent of the palatal slope, and inclination of the teeth, by the angle between the reference line and the axis of the palatal root.

the lower dentition.[8–12] The advantage of this method is its ability to tip the lower molars distally with intrusion and the lower incisors lingually with extrusion, while avoiding any movement of the upper dentition.[8–12] Mini-implants can be installed in the posterior area of the maxilla or the mandible, with a goal to cancel or avoid the vertical force vector of the Class III elastics. In the case of maxillary mini-implants, Class III elastics are applied from this skeletal anchorage instead of the upper molars.[8,10,12] As for mini-implants in the mandible, Class I elastics (elastic chain or Ni-Ti coil spring) are applied.[9,11,12]

Transverse maxillary deficiency can be treated with nonsurgical expansion such as tooth-borne or tooth-and-tissue-borne expansion in adolescent and young adult patients.[20–22] However, the expanding force applied through the teeth has been reported to contribute to adverse effects such as limited skeletal effect, undesirable tooth tipping, bony dehiscence, gingival recession, root resorption, and relapse.[13–16,23] To overcome these adverse effects, BBRME with skeletal anchorage has been reported.[17–19] The major advantage of BBRME is that it provides maximum skeletal and minimum dental effects, since the expansion forces can be directly applied to the basal bone and not to the teeth.[18,19] However, a previous study using finite element analysis reported that the treatment effects differed, depending on the type of expander and position of the mini-implants.[19] Therefore, the design of the appliance is critical to the achievement of the desired effect.

In this case, it was reasonable to use maxillary skeletal anchors for the Class III elastics instead of mandibular mini-implants, since the treatment plan called for both bone-borne rapid maxillary expansion and distalization of the lower dentition. Considering these factors, the C-expander with palatal mini-implants was selected for BBRME. Mini-implants were first used for maxillary expansion and then used as an indirect anchorage for the distalization of the lower dentition, without additional installation of mandibular mini-implants. As a result of the maxillary expansion, the transverse discrepancy was corrected and the upper dentition was aligned without further proclination of the teeth. The lower dentition was distalized by Class III elastics without further proclination of the upper incisors.

The C-expander, as observed in this case as well as other previous studies, has several advantages in orthodontic treatment:

- Mini-implants on the palatal slopes demonstrate the least stress concentration around the anchorage and a relatively parallel alveolar expansion, compared with other BBRME.[19]

Figure 7. Posttreatment facial and intraoral photographs.

Figure 8. Posttreatment cast models.

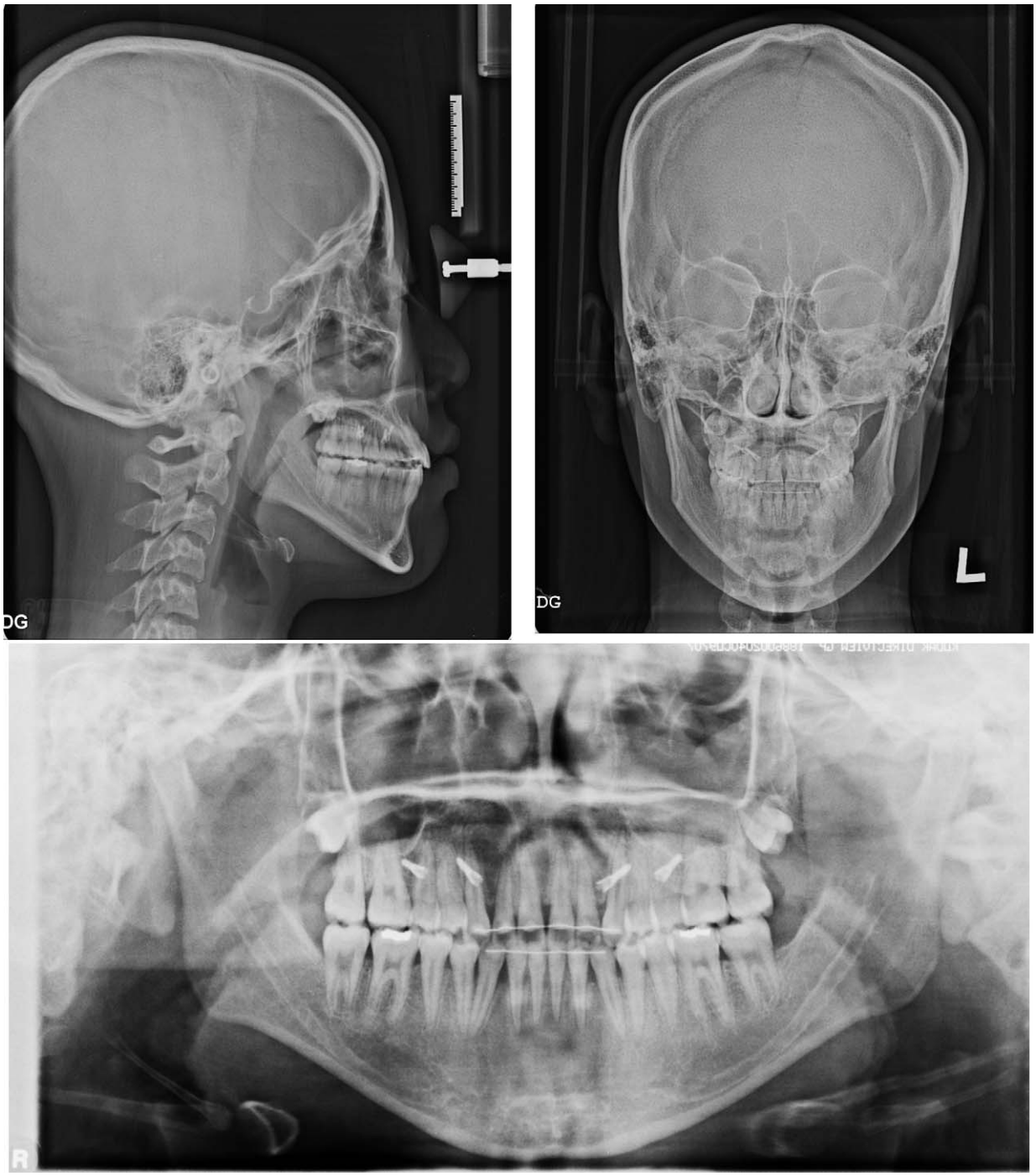

Figure 9. Posttreatment radiographs after maxillary expansion: lateral and posteroanterior cephalograms, panoramic radiograph.

- The expander itself can be used for retention after completing expansion, without necessitating the transpalatal arch or removable appliances that conventional protocol demands.
- The teeth can be aligned and leveled simultaneously using the fixed appliance because this expander does not contact any teeth.[18]
- Indirect absolute anchorage can be provided by connecting the desired anchor tooth to the C-expander appliance that is supported by mini-implants.
- Oral hygiene is better since they permit brushing and flossing of all teeth as opposed to tooth-borne expanders.[18]

This combined method of BBRME with modified Class III elastics using indirect anchorage achieved a Class I relationship and a favorable facial profile

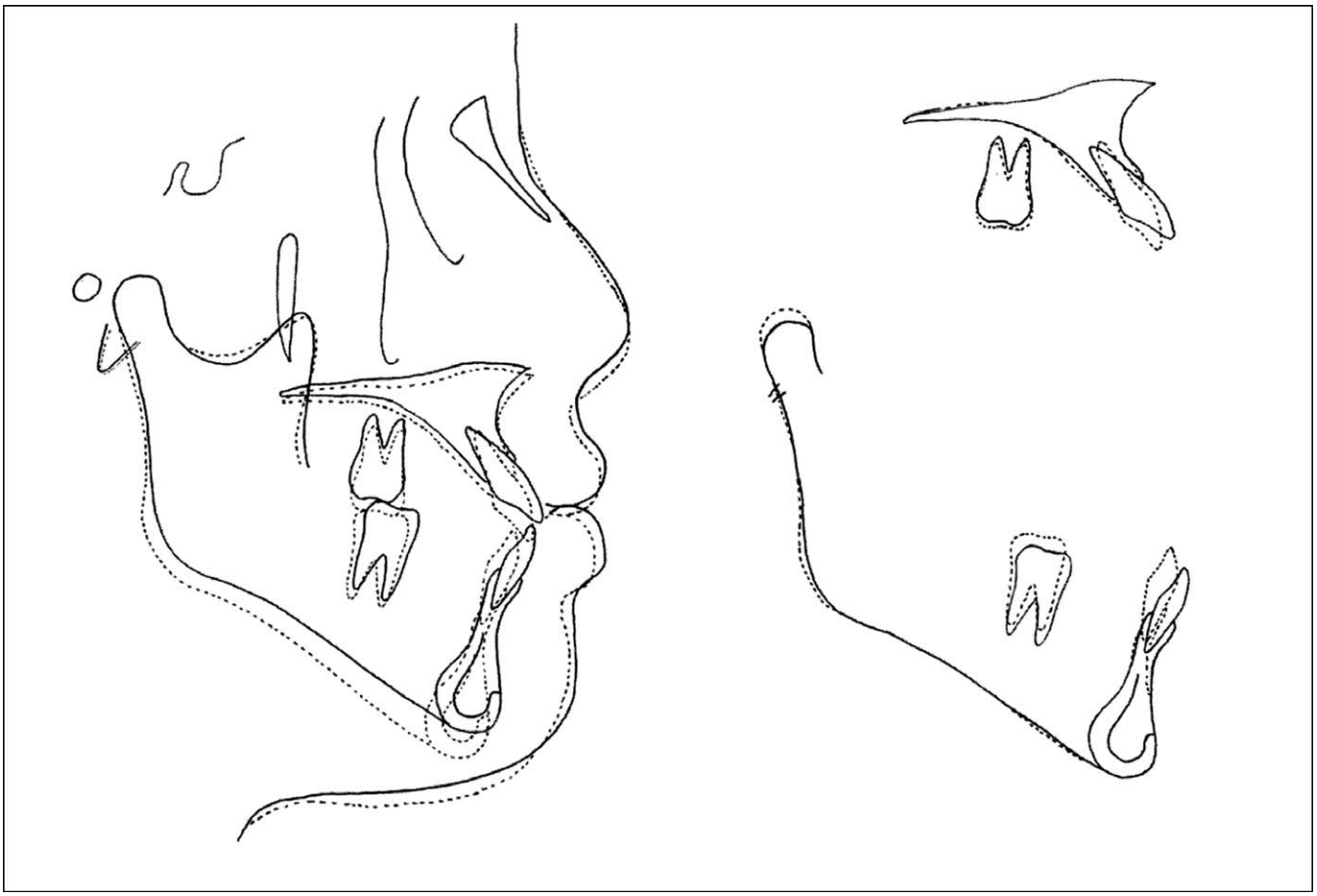

Figure 10. Superimpositions of lateral cephalograms (solid line: pretreatment; dotted line: posttreatment).

without orthognathic surgery, just as the patient and her parents had desired. Furthermore, the acceptable amount and direction of growth in this patient might have contributed to the successful result of the orthodontic camouflage treatment. Nevertheless, while treating adolescent patients with the camouflage method, residual growth should be constantly monitored, considering the possibility of worsening of the mandibular prognathism or facial asymmetry. Regular follow-up is also needed for long-term stability.

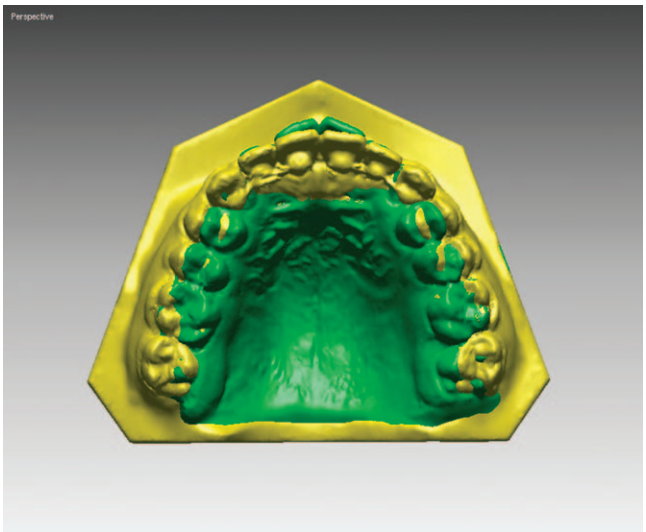

Figure 11. Superimpositions of computed tomography surface scan image (dark gray color: pretreatment; light gray color: posttreatment).

CONCLUSIONS

- This case report demonstrates that BBRME and distalization of the lower dentition using palatal miniimplants can be effective in the treatment method of a moderate skeletal Class III malocclusion.
- BBRME can provide expansion with more skeletal effect and minimal dental tipping, thus improving the inclination of the posterior teeth.
- The use of Class III elastics against indirect anchorage resulted in distalization of the lower dentition, while avoiding unfavorable mesialization of the upper dentition or molar extrusion. Therefore, BBRME can be considered an alternative in the camouflage treatment of Class III malocclusion.

Table 3. Changes in the Maxillary Arch Width (mm) of Cast Models Before and After Treatment[a]

Width	At the Level of Cusp Tip			At the Level of Cervical Point		
	Pretreatment	Posttreatment	Difference	Pretreatment	Posttreatment	Difference
Upper canine	33.92	35.45	1.53	24.30	28.16	3.86
Upper first premolar	44.26	44.33	0.07	27.06	31.73	4.67
Upper second premolar	48.81	50.83	2.02	33.08	36.11	3.03
Upper first molar	55.87	55.72	−0.15	38.46	38.85	0.39
Upper second molar	61.08	61.09	0.01	44.80	45.32	0.52

[a] The reference point was the cusp tip for the upper canine, the buccal cusp tip for the premolar, and the mesiobuccal cusp tip for the upper molar. The reference point for the cervical point was the most bulging cervical point on the palatal surface of the tooth.

Figure 12. Follow-up facial and intraoral photographs, 9 months after debonding.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF), funded by the Korean government (MEST; No. 2012R1A5A2051388).

REFERENCES

1. Jacobson A, Evans WG, Preston CB, Sadowsky PL. Mandibular prognathism. *Am J Orthod*. 1974;66:140–171.
2. Lin J, Gu Y. Preliminary investigation of nonsurgical treatment of severe skeletal Class III malocclusion in the permanent dentition. *Angle Orthod*. 2003;73:401–410.
3. Janson G, de Souza JE, Alves Fde A, et al. Extreme dentoalveolar compensation in the treatment of Class III malocclusion. *Am J Orthod Dentofacial Orthop*. 2005;128:787–794.
4. Moullas AT, Palomo JM, Gass JR, Amberman BD, White J, Gustovich D. Nonsurgical treatment of a patient with a Class III malocclusion. *Am J Orthod Dentofacial Orthop*. 2006;129:S111–S118.
5. Hu H, Chen J, Guo J, et al. Distalization of the mandibular dentition of an adult with a skeletal Class III malocclusion. *Am J Orthod Dentofacial Orthop*. 2012;142:854–862.
6. Troy BA, Shanker S, Fields HW, Vig K, Johnston W. Comparison of incisor inclination in patients with Class III malocclusion treated with orthognathic surgery or orthodontic camouflage. *Am J Orthod Dentofacial Orthop*. 2009;135:146.e1–9.
7. Burns NR, Musich DR, Martin C, Razmus T, Gunel E, Ngan P. Class III camouflage treatment: what are the limits? *Am J Orthod Dentofacial Orthop*. 2010;137:9.e1–13.
8. He S, Gao J, Wamalwa P, Wang Y, Zou S, Chen S. Camouflage treatment of skeletal Class III malocclusion with multiloop edgewise arch wire and modified Class III elastics by maxillary mini-implant anchorage. *Angle Orthod*. 2013;83:630–640.
9. Jing Y, Han X, Guo Y, Li J, Bai D. Nonsurgical correction of a Class III malocclusion in an adult by miniscrew-assisted mandibular dentition distalization. *Am J Orthod Dentofacial Orthop*. 2013;143:877–887.
10. Chung K, Kim SH, Kook Y. C-orthodontic microimplant for distalization of mandibular dentition in Class III correction. *Angle Orthod*. 2005;75:119–128.
11. Chung KR, Kim SH, Choo H, Kook YA, Cope JB. Distalization of the mandibular dentition with mini-implants to correct a Class III malocclusion with a midline deviation. *Am J Orthod Dentofacial Orthop*. 2010;137:135–146.

12. Baek SH, Yang IH, Kim KW, Ahn HW. Treatment of Class III malocclusion using miniplate and mini-implant anchorage. *Semin Orthod*. 2011;17:98–107.
13. Smalley WM, Shapiro PA, Hohl TH, Kokich VG, Branemark PI. Osseointegrated titanium implants for maxillofacial protraction in monkeys. *Am J Orthod Dentofacial Orthop*. 1988;94:285–295.
14. Garib DG, Henriques JF, Janson G, de Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. *Am J Orthod Dentofacial Orthop*. 2006;129:749–758.
15. Brunetto M, Andriani Jda S, Ribeiro GL, Locks A, Correa M, Correa LR. Three-dimensional assessment of buccal alveolar bone after rapid and slow maxillary expansion: a clinical trial study. *Am J Orthod Dentofacial Orthop*. 2013; 143:633–644.
16. Pangrazio-Kulbersh V, Jezdimir B, de Deus Haughey M, Kulbersh R, Wine P, Kaczynski R. CBCT assessment of alveolar buccal bone level after RME. *Angle Orthod*. 2013; 83:110–116.
17. Lagravère MO, Carey J, Heo G, Toogood RW, Major PW. Transverse, vertical, and anteroposterior changes from bone-anchored maxillary expansion vs traditional rapid maxillary expansion: a randomized clinical trial. *Am J Orthod Dentofacial Orthop*. 2010;137:304.e1–12.
18. Lee KJ, Park YC, Park JY, Hwang WS. Miniscrew-assisted nonsurgical maxillary expansion before orthognathic surgery for a patient with severe mandibular prognathism. *Am J Orthod Dentofacial Orthop*. 2010;137:830–839.
19. Lee HK, Bayome M, Ahn CS, et al. Stress distribution and displacement by different bone-borne palatal expanders with micro-implants: a three-dimensional finite-element analysis [published online November 11, 2012]. *Eur J Orthod*. doi:10.1093/ejo/cjs063.
20. Handelman CS, Wang L, BeGole EA, Haas AJ. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. *Angle Orthod*. 2000;70:129–144.
21. Stuart DA, Wiltshire WA. Rapid palatal expansion in the young adult: time for a paradigm shift? *J Can Dent Assoc*. 2003;69:374–377.
22. Baysal A, Uysal T, Veli I, Ozer T, Karadede I, Hekimoglu S. Evaluation of alveolar bone loss following rapid maxillary expansion using cone-beam computed tomography. *Korean J Orthod*. 2013;43:83–95.
23. Lione R, Franchi L, Cozza P. Does rapid maxillary expansion induce adverse effects in growing subjects? *Angle Orthod*. 2013;83:172–182.