Original Article

Corticotomy-assisted maxillary protraction with skeletal anchorage and Class III elastics

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ABSTRACT

Objective: To analyze the treatment effects of corticotomy-assisted maxillary protraction with skeletal anchorage and Class III elastics in patients with Class III malocclusions.

Materials and Methods: The study group consisted of 19 patients with a mean age of 13.12 ± 1.28 years. Initially, patients were monitored for 5 months before treatment to evaluate growth changes. Changes during control, protraction and fixed orthodontic treatment periods were compared with the cephalometric radiographs taken initially, before protraction, after protraction, and after fixed orthodontic treatment. Treatment outcomes also were compared with the growth effects.

Results: Sagittal measurements of maxilla showed significant improvements (3.59 ± 1.32 mm) during the protraction period (3.85 ± 1.12 months) whereas no significant changes were seen during the control period. Upper and lower incisor inclinations were increased, and the upper occlusal plane angle showed significant counterclockwise rotation during protraction. Significant soft-tissue changes also reflected the underlying skeletal changes. Maxillary advancement was stable during fixed orthodontic treatment.

Conclusion: Compared with control period of the patients, this protocol produced significant improvements in skeletal and soft-tissue structures. (*Angle Orthod.* 2015;85:48–57.)

KEY WORDS: Elastics; Maxillary protraction; Skeletal anchorage

INTRODUCTION

Orthopedic protraction of the maxilla is a popular treatment protocol; however, there are some limitations such as problems with patient compliance, limited protraction of the maxilla (2–3 mm in 9–12 months), unwanted dentoalveolar effects, and a chance of relapse due to late mandibular growth.[1–6] Therefore orthodontists are still searching for fast and effective treatment protocols that are also applicable after a growth spurt. We also know that early orthopedic interventions play a significant role in correcting the appearance of the face and thus improving the psychological status of such patients, especially those between the ages of 13 and 19 years, when they develop self-confidence.[7,8]

Recently, osseointegrated implants, titanium screws, onplants, and miniplates have been used as stable anchorage for maxillary protraction.[9–13] However, many of these studies are based on facemask wear except the study of De Clerck et al.,[13] in which the patients were treated by using Class III elastics and bone anchorage. In this study, we designed an intraoral mechanic for the fast and effective treatment of skeletal Class III cases and applied it to a group of patients and evaluated the results cephalometricaly and statistically.

MATERIALS AND METHODS

G*Power (version 3.1.7, Franz Faul, Universitat Kiel, Kiel, Germany) software was used for sample-size calculation. Five patients were required for a power of 80% at the 5% significance level. Thus, the sample

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Figure 1. Customized acrylic cap splint with the hooks in the molar region.

size of this study, 19 patients, presented a power of 99.9%.

The 19 patients (9 girls and 10 boys) in this prospective study had a mean age of 13.12 ± 1.28 years. The average growth stage was stage 4 according to the cervical vertebral maturation method. All subjects had skeletal Class III malocclusion characterized by maxillary retrognathism (ANB $< 0^{\circ}$; $N^{\perp}A < 0$ mm; maxillary depth $< 90^{\circ}$), normal or low-angle vertical pattern (SN-MP $< 35^{\circ}$; $\sum < 396^{\circ}$: FMA $< 25^{\circ}$), permanent dentition, no systemic disease, and temporamandibular joint dysfunction. All subjects and their parents were informed about the treatment protocols and signed a consent form that was previously approved by the ethics committee of Marmara University.

Subjects were monitored for 5 months (mean = 5.36 ± 1.48 months) before treatment to evaluate growth changes. At the end of this period, a customized acrylic splint with hooks in the molar region was constructed and bonded on maxillary dentition (Figure 1). Then surgery was performed on all patients under general anesthesia. In the first step of the surgery, miniplates (Multipurpose Implant, Tasarimmed, Istanbul, Turkey) were placed on the anterior wall of the symphysis on both sides between the canines and the first premolars; the tip was oriented in the level of proximal contacts (Figures 2a and 3). Miniscrews 2 mm in diameter and 7 mm in length were used to fix the miniplates (Mondeal, Tuttlingen, Germany). In the second step of the surgery, an incomplete Le Fort I osteotomy was performed to release the maxilla (Figure 2b). Le Fort I osteotomy included the lateral nasal walls of the maxilla, but the nasal walls and nasal septum were left intact. The pterygoid plates were not involved because there was no conjunction at this young age. Three days after surgery, Class III elastics were applied between the

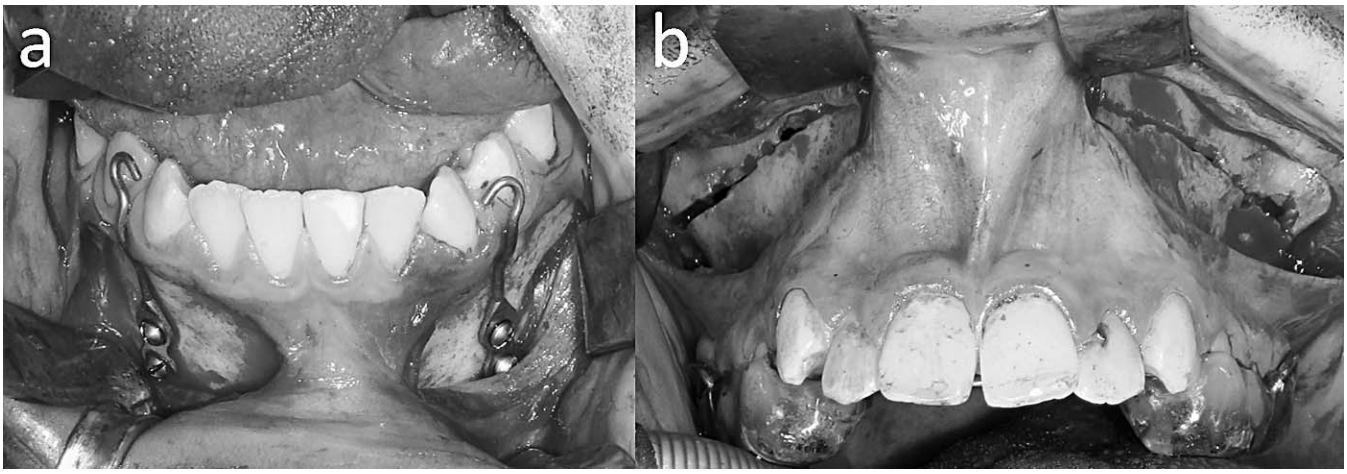

Figure 2. (a) Miniplates on the anterior wall of the symphysis; (b) Incomplete Le Fort I osteotomy.

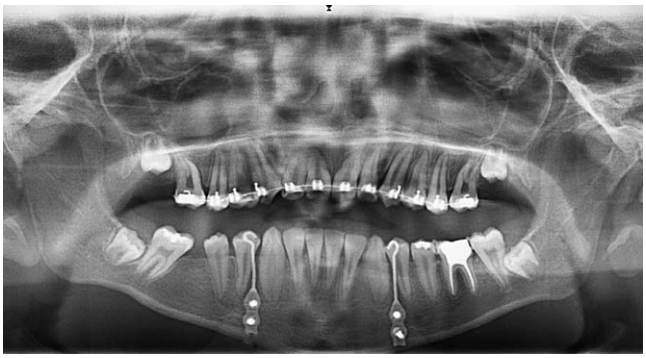

Figure 3. Panoramic radiograph indicating the miniplate insertion in the mandible.

hooks of the maxillary splint and the miniplates at an initial force of 300 g per side, which was increased to 600 g per side at 10 days (Figure 4). Patients were asked to change the elastics twice a day and wear them full time, except during meals, until a Class II dental relationship was achieved, at which time the acrylic splints were debonded. Bite opening was observed during the protraction protocol; thus, the patients were instructed to chew gum for 2 weeks after debonding to achieve self-correction of open bite by taking advantage of occlusal forces. After closure of the openbite, miniplates were removed under local anesthesia and treatment continued with the straight-wire technique. During fixed orthodontic treatment, upper premolars were extracted in five patients to relieve crowding and Class II canine relationships. Class III bianators were also applied in growing patients for nighttime wear.

Cephalometric radiographs were taken before treatment, at the end of control period (just before bonding of the upper splint), after protraction, and after debonding. The treatment progress of one patient from this group is shown in Figures 5 and 6.

Cephalometric Method

Thirty-four parameters were traced and measured on the lateral cephalograms (Figures 7 and 8). To determine the sagittal and vertical changes of certain anatomic points, two reference planes were used. The horizontal reference plane (RP1) was drawn with a 7° angle below the SN plane at point sella, and a perpendicular line was drawn to the first plane through the S point (RP2). Perpendicular lines were drawn to these reference planes from selected anatomical points (Figure 8).

Statistical Analysis

Statistical analysis was conducted using NCSS 2007 and PASS 2008 software programs (NCSS, Kaysville, Utah). The data were evaluated using *t*-tests.

Figure 4. Class III elastic between the hooks of the maxillary splint and the miniplates.

One week after the first measurements, the tracings and measurements were repeated by the same author on 30 randomly selected lateral cephalograms. Intraclass correlation coefficients, which were calculated for each variable to assess the reliability of the measurements, ranged from 0.973 to 1.000. No significant differences were found between the first and second measurements of those randomly selected cephalograms.

RESULTS

Miniplates were stable during the protraction period. Only one miniplate was loose at the end of the protraction period. Miniplates were removed uneventfully with local anesthesia before fixed orthodontic treatment. The control, protraction, and fixed orthodontic treatment periods lasted 5.36 ± 1.48 months, 3.85 ± 1.12 months, and 23.13 ± 7.03 months, respectively.

Descriptive statistics for the cephalometric measurements are reported in Tables 1 and 2. Tables 3 and 4 show the differences at the three periods and the statistical comparisons of those periods. During the control period, no significant changes were found in sagittal skeletal parameters, whereas A point showed 3.59 ± 1.32 mm ($P < .01$) forward movement and B point presented 1.85 ± 1.46 mm ($P < .01$) backward movement during protraction. The skeletal changes in the maxilla and mandible led to significant improvement in ANB (−4.18 ± 1.47°; $P < .01$; Table 3). No significant change was recorded in sagittal skeletal parameters during fixed orthodontic treatment.

Regarding the vertical skeletal parameters, no significant changes were seen during the control period. During protraction, a significant decrease was seen in the SN-UOP angle (8.28 ± 4.41°, $P < .01$),

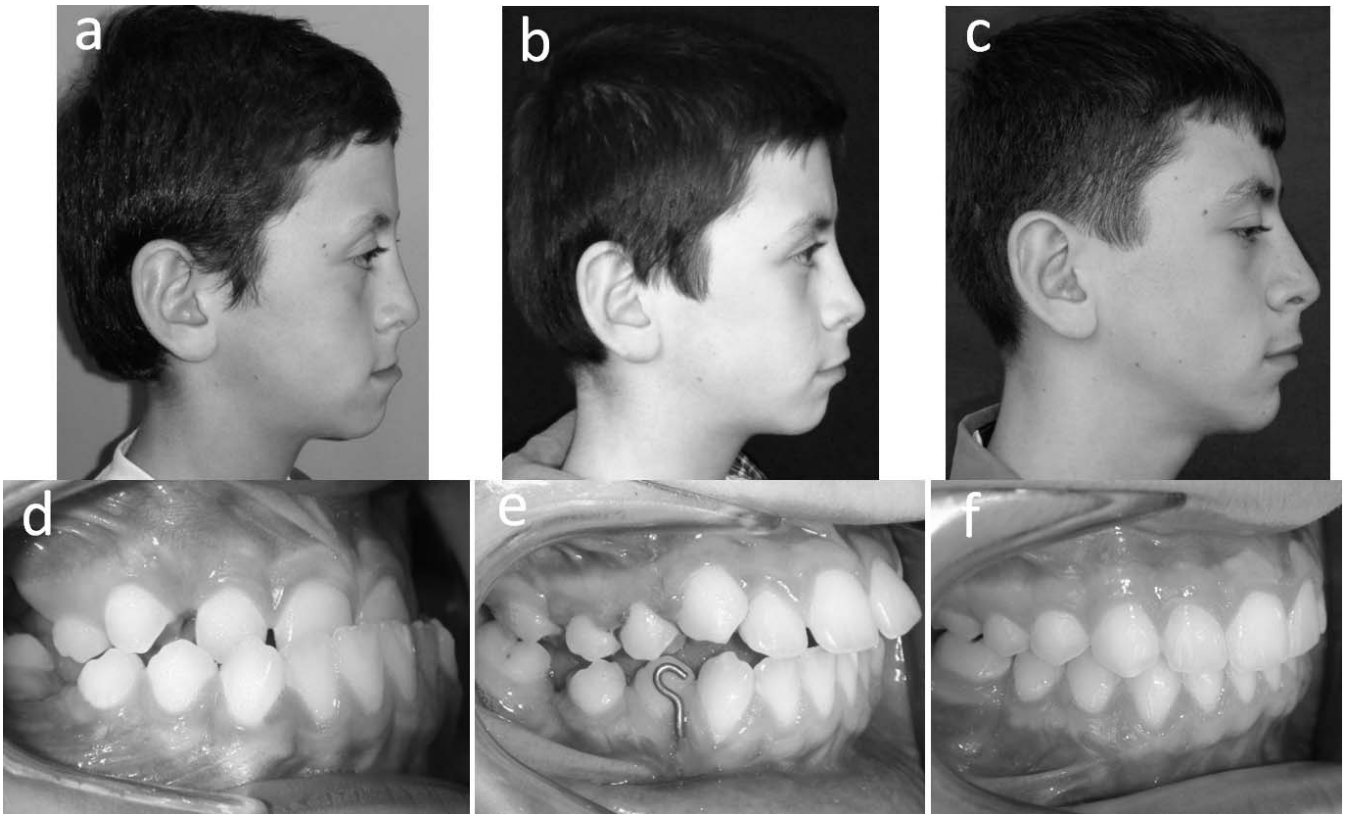

Figure 5. (a,d) Initial photographs of the patient; (b,e) Photographs after protraction; (c,f) Photographs at the end of fixed orthodontic treatment.

which presented a significant increase after fixed treatment (-4.51 ± 19.75 mm; $P < .01$). In addition, SN-MP ($P < .01$), FMA ($P < .01$), Σ ($P < .05$), and N-Me ($P < .01$) demonstrated increases during the protraction period, all of which remained during the fixed treatment except SN-MP. A significant increase was seen in S-Go (-2.34 ± 2.16 mm; $P < .01$) during fixed treatment, although no changes were seen during the control and protraction periods (Table 3).

No significant changes were found in dental parameters during the control period. However, during the protraction period, the upper and lower incisors were proclined $9.66^\circ \pm 5.26^\circ$ and $3.63^\circ \pm 3.16^\circ$, respectively. The upper incisors were uprighted $6.26^\circ \pm$

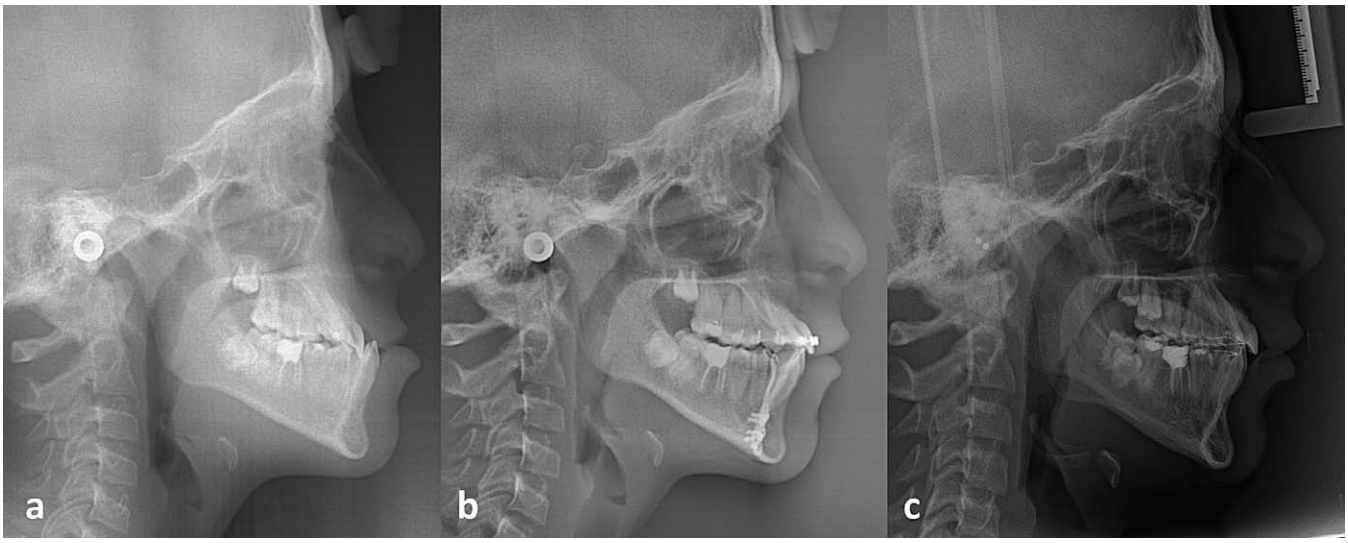

Figure 6. Cephalometric radiographs of the patient: (a) Initial; (b) After protraction; and (c) At the end of fixed orthodontic treatment.

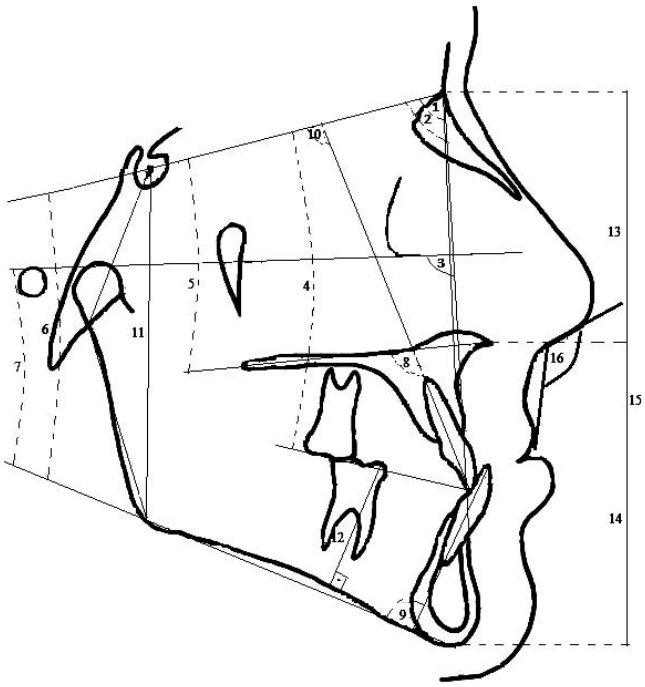

Figure 7. Skeletal, dental, and soft-tissue measurements: 1 indicates SNA (°); 2, SNB (°); 3, maxillary depth (°); 4, SN-UOP (°); 5, Sn-PP (°); 6, SN-MP (°); 7, FMA (°); 8, U1-PP (°); 9, IMPA (°); 10, U1-SN (°); 11, S-Go (mm); 12, L6⊥MP (mm); 13, N-ANS (mm); 14, ANS-Me (mm); 15, N-Me (mm); 16, nasolabial angle (°).

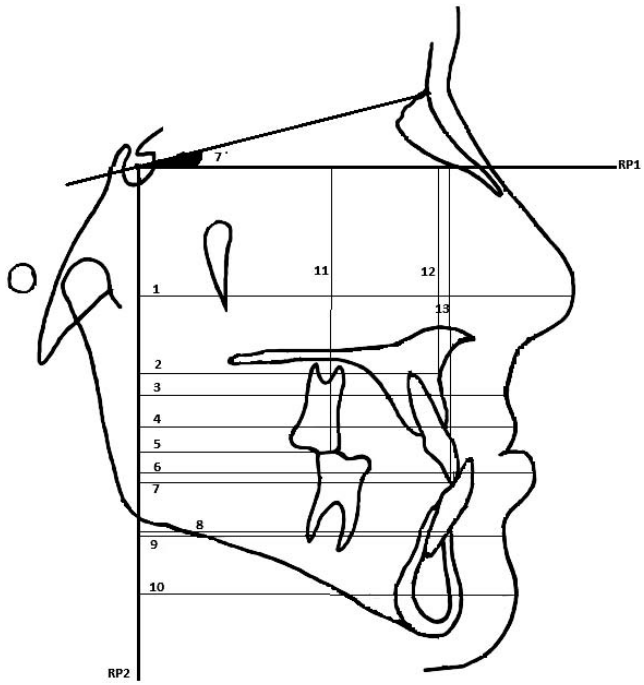

Figure 8. Linear measurements according to reference planes: 1 indicates RP2⊥Pn; 2, RP2⊥A; 3, RP2⊥A′; 4, RP2⊥L_s; 5, RP2⊥U6; 6, RP2⊥L_i; 7, RP2⊥U1; 8, RP2⊥B′; 9, RP2⊥B; 10, RP2⊥Pog′; 11, RP1⊥U6; 12, RP1⊥A; 13, RP1⊥U1.

4.76°, whereas lower incisor inclinations remained constant during fixed treatment. The upper molars were positioned anteriorly (-5.59 ± 2.94 mm; $P < .01$) and inferiorly (-2.97 ± 2.11 mm; $P < .01$) during protraction and remained constant during fixed treatment (Table 4).

The only soft-tissue parameter that revealed a significant increase during the control period was the nasal projection (-0.73 ± 0.21 mm; $P < .05$). However, during protraction, the upper lip moved forward (RP2⊥A′; RP2⊥L_s; $P < .01$), the pogonion moved backward (1.71 ± 1.84 mm; $P < .01$), and nasal projection increased (-2.56 ± 1.20 mm; $P < .01$); all of these changes were maintained throughout fixed treatment (Table 4).

DISCUSSION

The use of skeletal anchorage or corticotomy assistance in the maxilla for Class III treatment has been reported previously.[9–16] These methods are usually applied with a facemask, which may lead to inadequate treatment outcomes because of problems with patient compliance. Therefore, in this study we aimed to design an intraoral mechanism that is more patient friendly and combined it with corticotomy to accelerate the protraction to motivate the patients.

In order to differentiate real treatment outcomes from those that occurred with growth, we monitored patients with no treatment for 5 months before maxillary protraction (mean = 5.36 ± 1.48 months), which was the estimated time for maxillary protraction in similar studies.[16–18]

Miniplates were maintained successfully throughout the treatment in all patients except one, which was loosened after completion of the protraction period. Bone formation was observed around almost all the miniplates when they were removed. Miniplates are reported to be quite stable even under high forces; they are biocompatible, are pliable, and do not require time for osseointegration because they are fixed with monocortical miniscrews.[19–21]

Patients with permanent dentition were selected to avoid damage to the tooth germs during incomplete Le Fort I osteotomy and placement of miniplates. Thus, the earliest age for this protocol is around 13 years, which is too late for orthopedic protraction but too early for orthognathic surgery. If not treated, these patients should wait for 5–7 years for surgery, which may lead to psychological disturbances at this age period because perceptions of facial esthetics are known to influence psychological development from early childhood to adulthood. Studies report that laypeople evaluate prognathic profiles more negatively than retrognathic profiles.[22,23]

Table 1. Mean Values of Sagittal and Vertical Skeletal Parameters at Each Stage[a]

	Control	Preprotraction	Postprotraction	Final	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
	Median (Minimum/Maximum)	Median (Minimum/Maximum)	Median (Minimum/Maximum)	Median (Minimum/Maximum)	*P*
Sagittal skeletal parameters					
SNA	78.05 ± 3.59	78.11 ± 3.45	80.87 ± 3.74	81.26 ± 3.5	**
	78.50 (71.5/86.0)	78.0 (72.0/86.0)	82.0 (73.5/89.0)	82.0 (74.0/88.5)	
RP2$^{\perp}$A	67.38 ± 5.58	67.20 ± 5.40	70.8 ± 5.68	70.99 ± 5.51	**
	67.7 (56.8/76.8)	67.5 (58.0/76.8)	70.0 (62.5/80.0)	70.50 (62.0/80.8)	
Maxillary depth	87.13 ± 2.64	87.11 ± 2.62	90.47 ± 3.06	90.53 ± 2.84	**
	87.50 (82.0/92.0)	88.0 (82.0/92.0)	90.0 (86.0/96.0)	90.0 (86.5/97.5)	
SNB	81.74 ± 3.67	82.03 ± 3.61	80.58 ± 3.62	81.03 ± 3.71	**
	82.0 (73.5/87.0)	82.0 (74.0/88.0)	80.5 (72.5/86.5)	81.50 (72.0/86.5)	
RP2$^{\perp}$B	69.94 ± 8.13	70.50 ± 7.74	68.65 ± 7.39	70.44 ± 7.51	**
	69.6 (54.0/85.7)	70.0 (55.5/85.7)	68.5 (53.0/81.0)	70.0 (52.0/84.2)	
$^{+}$ANB	−3.71 ± 2.26	−3.92 ± 2.43	0.26 ± 2.77	0.24 ± 2.49	**
	−3.50 (−8.0/−0.5)	−3.0 (−9.0/−0.5)	0.0 (−5.5/5.0)	0.0 (−5.5/4.5)	
Corpus	81.93 ± 4.21	82.16 ± 4.73	82.75 ± 4.37	83.59 ± 4.62	**
	81.10 (76.1/90.1)	80.70 (75.1/91.0)	81.0 (76.0/92.0)	83.0 (78.3/94.0)	
Vertical skeletal parameters					
RP1$^{\perp}$A	52.92 ± 4.16	52.85 ± 4.04	52.82 ± 4.48	54.25 ± 4.52	*
	52.0 (47.4/62.3)	52.8 (46.0/61.3)	52.5 (44.0/62.9)	54.0 (45.5/63.0)	
N-ANS	57.13 ± 3.78	57.2 ± 3.49	57.13 ± 4.05	57.74 ± 3.98	NS
	57.0 (51.5/65.6)	56.8 (51.0/65.6)	57.0 (49.0/67.7)	57.8 (50.0/67.0)	
SN-PP	9.74 ± 3.83	9.79 ± 3.16	8.89 ± 3.75	9.11 ± 3.68	NS
	8.5 (4.0/17.0)	9.0 (5.0/16.0)	8.5 (3.0/15.0)	9.0 (3.5/16.0)	
SN-UOP	18.42 ± 5.42	18.21 ± 5.95	9.93 ± 6.57	14.45 ± 5.14	**
	17.5 (8.0/31.0)	18.5 (8.5/31.0)	10.0 (−4.0/21.0)	14.0 (4.0/24.0)	
ANS-Me	67.68 ± 5.69	68.42 ± 5.78	70.92 ± 5.83	71.27 ± 7.53	**
	68.1 (55.3/76.4)	69.0 (57.0/78.0)	72.0 (60.0/80.5)	72.0 (57.5/84.0)	
SN-MP	34.34 ± 6.77	34.34 ± 6.64	35.68 ± 6.53	34.5 ± 7.32	**
	35.0 (20.5/45.5)	35.0 (21.0/47.0)	37.0 (22.0/48.0)	35.0 (16.5/48.5)	
FMA	25.34 ± 6.32	24.97 ± 6.28	26.37 ± 6.4	25.55 ± 7.04	*
	26.5 (12.5/34.5)	26.0 (12.0/32.5)	27.5 (13.5/36.0)	27.0 (9.5/35.0)	
$\sum$	395.68 ± 6.74	395.55 ± 6.84	396.5 ± 6.5	395.92 ± 7.68	*
	398.0 (382.5 /407.0)	396.0 (382.5/ 408.5)	396.0 (383.5/ 408.5)	395.5 (378.0/ 411.5)	
N-Me	124.83 ± 8.31	125.46 ± 8.44	128.05 ± 8.98	128.49 ± 10.27	**
	124.2 (108.9 /141.0)	126.0 (108.0/ 140.0)	129.0 (109.0/ 145.4)	129.0 (111.0/ 147.0)	
S-Go	79.91 ± 7.91	80.57 ± 7.94	81.14 ± 8.59	83.48 ± 8.08	**
	77.6 (70.5/96.8)	80.0 (71.0/98.5)	79.0 (72.0/99.5)	82.6 (72.5/102.2)	

[a] Analysis of variance: * $P < .05$; ** $P < .01$; NS indicates not significant.

The literature contains few cases in which growing patients underwent surgery, and the long-term consequences of such interventions are not known. Some findings suggest that orthognathic Class III surgery at early ages will result in recurrence of the Class III skeletal relationship as the mandible continues to grow normally.[24] Other disadvantages of the surgical protocol include the need for bone grafts, lifetime miniplates, miniscrews for fixation, blood transfusion, and complicated fixed orthodontic treatment before surgery.[25] Therefore, we wanted to treat patients with Class III malocclusion as early as possible with a protocol that does not affect future maxillomandibular growth. Considering that no down fracture and no rigid fixation were done in our protocol, we expected the maxilla to grow anteroposteriorly in response to possible mandibular growth after surgery. On the other hand, the protocol did not include osteotomy of the nasal septum and lateral nasal walls. According to Wolford et al.,[24] anteroposterior maxillary growth may be expected with such a surgical protocol, thereby keeping the nasal septum attached to the palate.

Comparison of the cephalometric data between control and protraction periods showed highly significant maxillary advancement with this new treatment protocol in a considerably short time (approximately 3.6 mm in 3.8 months). Kircelli and Pektas[12] reported 4.8 mm maxillary advancement in 10.8 months, whereas Sar et al.[26] reported 2.3 mm advancement in 6.78 months by using facemask through miniplates

Table 2. Mean Values of Dental and Soft-Tissue Parameters at Each Stage[a]

	Control	Preprotraction	Postprotraction	Final	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
	Median (Minimum/Maximum)	Median (Minimum/Maximum)	Median (Minimum/Maximum)	Median (Minimum/Maximum)	*P*
Dental parameters					
U1-SN	105.84 ± 6.59 106 (95/120)	105.84 ± 6.2 105 (96/118)	115.5 ± 7.44 115 (103/131)	109.24 ± 4.68 110 (96/116)	**
U1-PP	115.39 ± 5.39 115 (107/128)	115.47 ± 5.32 114 (108/125.5)	124.05 ± 6.36 125 (113/138)	118.24 ± 4.24 119 (107/123)	**
RP2⊥U1	71.09 ± 6.74 71.2 (58.7/84.6)	71.68 ± 6.68 71.8 (60/84)	77.42 ± 6.86 77 (64.5/91)	75.24 ± 7.71 76 (61.5/90.4)	**
RP1⊥U1	75.98 ± 5.37 76 (64.4/86.9)	76.14 ± 5.26 76.1 (64.5/86.5)	74.61 ± 6.08 74.5 (60.5/86.7)	76.9 ± 6.33 77 (63/89.5)	**
RP2⊥U6	40.54 ± 6.15 40.2 (25.8/49)	41.09 ± 6.21 40.2 (30/52.5)	47.58 ± 6.72 46 (34.5/59.4)	46.69 ± 7.52 45.5 (32/59)	**
RP1⊥U6	70.09 ± 4.78 69.3 (62.6/79.3)	70.05 ± 5.12 69 (62.5/78.8)	73.02 ± 5.35 72 (65/84.6)	73.44 ± 5.31 73.9 (64/84)	**
IMPA	83.16 ± 5.96 83.5 (72/94)	82.47 ± 5.99 80 (72/93)	86.11 ± 6.72 85 (76/104)	84.24 ± 6.01 83 (77/104)	**
L6⊥MP	31.21 ± 2.76 32 (23.9/34.5)	31.62 ± 3.11 32.3 (24.5/35.6)	31.73 ± 3.59 31.5 (24/36.5)	33.31 ± 3.56 33.6 (25/38)	**
+Overjet	−2.79 ± 1.94 −3 (−5.8/1.1)	−2.66 ± 2.02 −2.6 (−6.1/1.1)	3.67 ± 1.58 3.2 (1.5/7.7)	2.87 ± 0.67 3 (1.5/4.1)	**
+Overbite	3.58 ± 2.75 3 (0/8.5)	3.6 ± 2.66 3.5 (0/7.5)	−0.13 ± 1.75 0 (−3.5/2)	2.61 ± 0.56 2.5 (1.4/3.9)	**
Soft-tissue parameters					
Nasolabial angle	103.26 ± 11.34 102 (89/124)	103.26 ± 9.98 104 (88/123)	102.82 ± 10.73 102 (83/121)	105.32 ± 9 103 (85/120)	NS
RP2-Pn	102.25 ± 6.28 102.5 (90.3/113.5)	102.98 ± 6.6 102 (92/115.7)	105.54 ± 6.99 104.9 (95/117.5)	106.56 ± 6.46 107 (93.7/117.3)	**
RP2-A′	86.16 ± 6.85 84.9 (75.6/101.3)	86.15 ± 7.28 85.5 (73/101.3)	89.74 ± 7.29 88.7 (80/104)	89.66 ± 6.72 88 (78/103.3)	**
RP2-Ls	89.01 ± 6.76 88.9 (78.2/102.4)	89.28 ± 7.11 87.9 (78.5/104)	92.61 ± 7.7 92.3 (82/107)	92.34 ± 7.04 91 (78.5/105.3)	**
RP2-Li	89.94 ± 8.08 89.1 (76.4/106.8)	90.08 ± 8.49 88.4 (74.5/109)	90 ± 8.16 90 (75.5/106)	90.35 ± 7.86 90 (74/106.4)	NS
RP2-B′	82.88 ± 8.19 82 (68.7/102.4)	83.3 ± 8.12 82.7 (67.5/101.3)	81.21 ± 8.2 80.5 (66/97.5)	81.76 ± 8.36 82 (66.5/101.2)	**
RP2-Pog′	84.68 ± 9.8 84.8 (68.1/106.8)	85.26 ± 9.99 85 (67/108.5)	83.55 ± 9.73 83.5 (66/104)	85.38 ± 9.71 85 (64/107.4)	*

[a] Analysis of variance: * $P < .05$; ** $P < .01$; NS indicates not significant.

on the lateral nasal wall of maxilla. These values are similar to our results, but the speed of protraction in our study is dramatically faster (3.8 months), which motivates patients to wear the elastics. On the other hand, in studies of corticotomy-assisted facemask therapy, Molina et al.[14] reported 4–12 mm changes of A point in 3–4 weeks, whereas Rachmiel et al.[15] and Kucukkeles et al.[16] reported 6.8 mm over 3 weeks and 4 mm over 2 months, respectively. These protraction rates were faster than ours but demanded patient compliance with full-time facemask wear. In the study of De Clerck et al.,[13] the maxilla was protracted through Class III elastics between miniplates, called the bone-anchored maxillary protraction (BAMP) protocol. They reported that A point moved 4 mm forward in 12 months, which was a longer protraction period than ours.

There were no significant changes in sagittal skeletal parameters related to the mandible during the control period; during the protraction period, the mandible presented backward rotation, thereby decreasing the projection of the chin, which contributes to correction of the Class III profile. This finding was similar to the findings of previous facemask studies.[16,26] A possible explanation of this rotation might be significant counterclockwise rotation of the occlusal plane, which is unavoidable when maxillary protraction is made through a force vector below the center of resistance of maxilla as in many facemask studies. Sagittal changes achieved during the protraction

Table 3. Difference Values of Skeletal Parameters Between Periods with the Significance of Changes in Each Period and Comparison of Changes in the Periods[a]

	Control Preprotraction (A) (n = 19) Mean ± SD Median (Minimum/Maximum)	P	Preprotraction Postprotraction (B) (n = 19) Mean ± SD Median (Minimum/Maximum)	P	Postprotraction Final (C) (n = 19) Mean ± SD Median (Minimum/Maximum)	P	Post Hoc Measurements A–B	Post Hoc Measurements B–C
Sagittal skeletal parameters								
SNA	−0.05 ± 0.04 0.00 (−1.00/0.50)	NS	−2.76 ± 1.15 −2.50 (−4.50/−0.50)	**	−0.39 ± 0.74 −0.50 (−2.00/1.00)	NS	**	**
RP2⊥A	0.18 ± 0.83 0.00 (−0.16/2.54)	NS	−3.59 ± 1.32 −3.23 (−6.88/−1.50)	**	−0.20 ± 0.93 −0.41 (−2.49/1.37)	NS	**	**
Maxillary Depth	0.026 ± 0.61 0.00 (−1.00/1.00)	NS	−3.36 ± 1.66 −3.50 (−7.00/−1.00)	**	−0.05 ± 1.15 0.00 (−1.50/3.00)	NS	**	**
SNB	−0.29 ± 0.48 0.00 (−1.00/0.50)	NS	1.45 ± 0.93 1.50 −0.50/3.00)	**	−0.45 ± 1.05 0.00 (−2.50/1.50)	NS	**	**
RP2⊥B	−0.57 ± 1.16 −0.50 (−2.91/1.87)	NS	1.85 ± 1.46 2.00 (−0.69/4.68)	**	−1.79 ± 2.78 −1.00 (−9.17/1.77)	NS	**	**
+ANB	0.21 ± 0.48 0.50 (−0.50/1.00)	NS	−4.18 ± 1.47 −4.50 (−6.50/−2.00)	**	0.03 ± 0.94 0.00 (−1.50/2.00)	NS	**	**
Corpus	−0.24 ± 1.10 −0.25 (−2.11/1.66)	NS	−0.59 ± 0.93 −0.29 (−2.89/1.52)	NS	−0.84 ± 1.32 −0.52 (−4.22/1.43)	NS	NS	NS
Vertical skeletal parameters								
RP1⊥A	0.07 ± 1.05 0.00 (−2.12/1.75)	NS	0.02 ± 1.30 0.00 (−2.00/2.50)	NS	−1.42 ± 2.12 −2 (−4.38/2)	NS	NS	NS
N-ANS	−0.07 ± 1.08 0.00 (−2.11/2.60)	NS	0.07 ± 1.11 0.00 (−2.11/2.00)	NS	−0.62 ± 1.69 −0.50 (−5.14/2.63)	NS	NS	NS
SN-PP	−0.05 ± 1.85 −0.50 (−3.00/4.00)	NS	0.90 ± 1.60 1.00 (−2.50/3.00)	NS	−0.21 ± 1.70 −0.50 (−3.00/3.00)	NS	NS	NS
SN-UOP	0.21 ± 2.36 0.00 (−2.50/7.50)	NS	8.28 ± 4.41 8.00 (−1.50/16.00)	**	−4.51 ± 19.75 −4.00 (−13.00/3.00)	**	**	**
ANS-Me	−0.75 ± 1.27 −0.66 (−2.68/2.09)	NS	−2.50 ± 1.81 −2.78 (−6.50/1.40)	**	−0.35 ± 5.55 −1.00 (−9.75/19.04)	NS	*	NS
SN-MP	0.00 ± 0.04 0.00 (−2.00/2.00)	NS	−1.34 ± 0.80 −1.50 (−2.50/0.50)	**	1.18 ± 1.73 1.00 (−1.00/5.50)	*	**	**
FMA	0.37 ± 1.13 0.50 (−1.50/3.00)	NS	−1.39 ± 1.59 −1.50 (−4.50/3.50)	**	0.82 ± 1.64 0.50 (−2.00/4.00)	NS	**	**
∑	0.13 ± .00 0.00 (−2.00/2.00)	NS	−0.94 ± 1.33 −1.00 (−3.00/2.00)	*	0.58 ± 2.30 0 (−3.50/5.50)	NS	*	NS
N-Me	−0.63 ± 1.40 −0.51 (−3.12/2.28)	NS	−2.59 ± 1.86 −2.60 (−6.34/1.81)	**	−0.45 ± 5.30 −1.50 (−6.93/17.63)	NS	*	NS
S-Go	−0.65 ± 1.28 −0.51 (−2.93/1.90)	NS	−0.57 ± 1.17 −0.50 (−4.23/1.00)	NS	−2.34 ± 2.16 −2.73 (−6.72/1.89)	**	NS	*

[a] Bonferroni test + Wilcoxon signed-rank test: * $P < .05$; ** $P < .01$; NS indicates not significant.

period were stable during fixed orthodontic treatment, which is promising for the long term (Table 3).

Counterclockwise rotation of the upper occlusal plane resulted in a temporary anterior openbite clinically that was spontaneously corrected by occlusal forces after removal of the appliance, as we observed in the first few patients. This led us to instruct the rest of the patients to chew gum three times daily for 30 minutes after meals to speed up bite correction. During fixed orthodontic treatment the upper occlusal plane presented clockwise rotation and anterior rotation of the mandible. This latter finding probably occurred because of continued growth in posterior facial height ($P < .01$) and concomitant extrusion of the lower molars during fixed treatment. Anterior facial dimensions increased slightly during protraction and remained stable during fixed treatment but the values were small to be clinically important.

Regarding dental changes on the maxilla and mandible during the control period, there were no significant changes as with the other parameters. However, during protraction, upper incisor inclinations increased due to the counterclockwise rotation of the upper occlusal plane and the toothborne device, as

Table 4. Difference Values of Dental and Soft-Tissue Parameters Between Periods with the Significance of Changes in Each Period and Comparison of Changes in the Periods[a]

	Control Preprotraction (A) (n = 19) Mean ± SD / Median (Minimum/Maximum)	*P*	Preprotraction Postprotraction (B) (n = 19) Mean ± SD / Median (Minimum/Maximum)	*P*	Postprotraction Final (C) (n = 19) Mean ± SD / Median (Minimum/Maximum)	*P*	Post Hoc Measurements A–B	Post Hoc Measurements B–C
Evaluation of dental parameters								
U1-SN	0.01 ± 2.32 −0.50 (−5.50/4.00)	NS	−9.66 ± 5.26 −9.00 (−19.50/−1.00)	**	6.26 ± 4.76 6.00 (−1.00/15.00)	**	**	**
U1-PP	−0.08 ± 2.51 −0.50 (−4.00/5.00)	NS	−8.58 ± 4.86 −8.00 (−18.00/−2.00)	**	5.82 ± 4.16 5.00 (0.00/16.00)	**	**	**
RP2⊥U1	−0.59 ± 1.11 −0.52 (−2.95 /1.52)	NS	−5.74 ± 2.91 −4.95 (−13.04/−2.00)	**	2.18 ± 5.66 1.00 (−2.82/23.34)	NS	**	**
RP1⊥U1	−0.17 ± 1.39 −0.09 (−3.34/3.17)	NS	1.54 ± 1.63 1.50 (−1.44/4.50)	**	−2.30 ± 2.05 −3.00 (−5.02/2.00)	**	*	**
RP2⊥U6	−0.55 ± 2.07 −0.53 (−5.52/2.72)	NS	−5.59 ± 2.94 −5.80 (−13.78/−1.12)	**	−0.89 ± 2.09 −1.41 (−4.53/4.09)	NS	**	**
RP1⊥U6	0.04 ± 0.87 0.00 (−2.00/2.07)	NS	−2.97 ± 2.11 −2.50 (−10.20/1.00)	**	−0.43 ± 2.22 0.00 (−4.86/2.89)	NS	**	**
IMPA	0.68 ± 1.17 0.50 (−1.00/3.50)	NS	−3.63 ± 3.16 −3.00 (−12.00/0.00)	**	1.87 ± 4.81 3.00 (−9.00/9.00)	NS	**	**
L6⊥MP	−0.40 ± 1.08 −0.50 (−2.60/1.21)	NS	−0.12 ± 1.36 −0.50 (−2.00/3.06)	NS	−1.58 ± 1.46 −1.50 (−4.16/1.50)	**	NS	*
[+]Overjet	−0.12 ± 0.49 0.00 (−1.06/1.11)	NS	−6.33 ± 0.36 −6.00 (−9.69/−1.80)	**	0.80 ± 1.57 0.49 (−1.38/4.65)	*	**	**
[+]Overbite	−0.02 ± 0.79 0.00 (−1.12/1.90)	NS	3.72 ± 1.92 3.50 (−1.00/7.50)	**	−2.74 ± 1.53 −2.44 (−6.00/0.00)	**	**	**
Evaluation of soft-tissue parameters								
Nasolabial Angle	0.01 ± 4.43 0.00 (−11.00/ 8.00)	NS	0.45 ± 8.63 0.00 (−14.00/21.00)	NS	−2.50 ± 4.91 −3.00 (−12.00/8.00)	*	NS	NS
RP2⊥Pn	−0.73 ± 0.92 −1.00 (−2.23/0.71)	*	−2.56 ± 1.20 −2.50 (−5.81/−0.50)	**	−1.02 ± 2.11 −1.00 (−4.78/2.69)	NS	**	*
RP2⊥A′	0.01 ± 1.53 0.00 (−2.12/5.11)	NS	−3.59 ± 1.97 −4.00 (−7.00/0.50)	**	0.08 ± 2.36 −0.23 (−4.54/4.70)	NS	**	**
RP2⊥Ls	−0.27 ± 1.46 0.00 (−4.23/2.55)	NS	−3.33 ± 2.08 −3.50 (−7.10/0.50)	**	0.27 ± 2.58 0.39 (−4.49/4.84)	NS	**	**
RP2⊥Li	−0.14 ± 1.94 0.00 (−2.64/5.27)	NS	0.08 ± 1.63 0.00 (−3.06/3.04)	NS	−0.35 ± 2.60 −0.18 (−5.50/3.66)	NS	NS	NS
RP2⊥B′	−0.42 ± 1.53 −0.50 (−2.90/1.94)	NS	2.09 ± 2.36 1.63 (−2.50/9.42)	**	−0.55 ± 4.66 −0.59 (−4.69/16.37)	NS	**	*
RP2⊥Pog′	−0.58 ± 1.70 −1.50 (−3.11/2.64)	NS	1.71 ± 1.84 1.60 (−2.00/5.00)	**	−1.83 ± 2.84 −2.13 (−6.00/3.10)	NS	**	**

[a] Bonferroni test + Wilcoxon signed-rank test: * $P < .05$; ** $P < .01$; NS indicates not significant.

was found in previous facemask studies.[26–28] Interestingly, the lower incisors also proclined, which was also reported in the study of De Clerck et al.[13] using a similar force vector. The explanation of the proclination of the lower incisors must be the new posture of the tongue acting on the lower incisors after correction of anterior crossbite, which was also reported in the BAMP protocol.[13] During fixed orthodontic treatment, this increase in lower incisor inclination remained, whereas the upper incisors uprighted. Upper molars and incisors moved mesially during protraction; 64.2% of this movement was skeletal and 35.8% was dental.

No significant changes were seen in soft-tissue parameters during the control period except for nasal projection. Nasal projection also presented a significant increase during the protraction period. This result was similar to that typically observed after maxillary advancement surgery. Nguyen et al.[29] reported 3.82 mm forward movement of the nose tip as a result of the BAMP protocol. The upper lip and lip sulcus also moved forward, and the soft tissue B point and pogonion moved backward during the protraction period, which showed that improvements in the soft-tissue profile followed the underlying skeletal components during the protraction period.[13,26–28] All of these

changes achieved during the protraction period were maintained during fixed orthodontic treatment.

CONCLUSIONS

- The treatment protocol described in this study was very fast and effective for correcting Class III malocclusion characterized by maxillary retrognathism with a normal or low-angle vertical model.
- The achieved protraction was stable throughout the orthodontic treatment, which is promising.
- The long-term results should be evaluated considering the late mandibular growth.

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REFERENCES

1. Baik HS. Clinical results of the maxillary protraction in Korean children. *Am J Orthod Dentofacial Orthop*. 1995;108: 583–592.
2. Bacetti T, McGill JS, Franchi L, McNamara JA Jr, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face-mask therapy. *Am J Orthod Dentofacial Orthop*. 1998;113:333–343.
3. Turley PK. Managing the developing Class III malocclusion with palatal expansion and facemask therapy. *Am J Orthod Dentofacial Orthop*. 2002;122:349–352.
4. Cha KS. Skeletal changes of maxillary protraction in patients exhibiting skeletal Class III malocclusion: a comparison of three skeletal maturation groups. *Angle Orthod*. 2003;73: 26–35.
5. Kim JH, Viana MA, Graber TM, Omerza FF, BeGole EA. The effectiveness of protraction facemask therapy: a meta-analysis. *Am J Orthod Dentofacial Orthop*. 1999;115: 675–685.
6. Baccetti T, Franchi L, McNamara JA Jr. Cephalometric variables predicting the long- term success or failure of combined rapid maxillary expansion and facial mask therapy. A*m J Orthod Dentofacial Orthop*. 2004;126:16–22.
7. Graber LW. *The Psychological Implications of Malocclusion* [thesis]. Ann Arbor: Center for Human Growth and Development, University of Michigan; 1980.
8. Kenealy P, Frude N, Shaw W. An evaluation of the psychological and social effects of malocclusion: some implications for dental policy making. *Soc Sci Med*. 1989;28: 583–591.
9. Singer SL, Henry PJ, Rosenberg I. Osseointegrated implants as an adjunct to facemask therapy: a case report. *Angle Orthod*. 2000;70:253–262.
10. Enacar A, Giray B, Pehlivanoglu M, Iplikcioglu H. Facemask therapy with rigid anchorage in a patient with maxillary hypoplasia and severe oligodontia. *Am J Orthod Dentofacial Orthop*. 2003;123:571–577.
11. Hong H, Ngan P, Han G, Qi LG, Wei SH. Use of onplants as stable anchorage for facemask treatment: a case report. *Angle Orthod*. 2005;75:453–460.
12. Kircelli BH, Pektas ZO. Midfacial protraction with skeletally anchored face mask therapy: a novel approach and preliminary results. *Am J Orthod Dentofacial Orthop*. 2008; 133:440–449.
13. De Clerck H, Cevidanes L, Baccetti T. Dentofacial effects of bone-anchored maxillary protraction: a controlled study of consecutively treated Class III patients. *Am J Orthod Dentofacial Orthop*. 2010;138:577–581.
14. Molina F, Ortiz Monasterio F, de la Paz Aguilar M, Barrera J. Maxillary distraction: aesthetic and functional benefits in cleft lip-palate and prognathic patients during mixed dentition. *Plast Reconstr Surg*. 1998;101:951–963.
15. Rachmiel A, Aizenbud D, Ardekian L, Peled M, Laufer D. Surgically-assisted orthopedic protraction of the maxilla in cleft lip and palate patients. *Int J Oral Maxillofac Surg*. 1999; 28:9–14.
16. Kucukkeles N, Nevzatoglu S, Koldas T. Rapid maxillary expansion compared to surgery for assistance in maxillary face mask protraction. *Angle Orthod*. 2011;81:42–49.
17. Ngan P, Hägg U, Yiu C, Merwin D, Wei SH. Treatment response to maxillary expansion and protraction. *Eur J Orthod*. 1996;18:151–168.
18. Ngan P, Hägg U, Yiu C, Merwin D, Wei SH. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. *Am J Orthod Dentofacial Orthop*. 1996;109:38–49.
19. Cornelis MA, Scheffler NR, De Clerck HJ, Tulloch JF, Behets CN. Systematic review of the experimental use of temporary skeletal anchorage devices in orthodontics. *Am J Orthod Dentofacial Orthop*. 2007;131(4 suppl):S52–S58.
20. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofacial Orthop*. 2003;124:373–378.
21. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. *Am J Orthod Dentofacial Orthop*. 2006;130:18–25.
22. Demellweek C, Humphris GM, Hare M, Brown J. Children's perception of, and attitude towards, unfamiliar peers with facial port-wine stains. *J Pediatr Psychol*. 1997;22:471–485.
23. Shaw WC, Meek SC, Jones DS. Nicknames, teasing, harassment and the salience of dental features among school children. *Br J Orthod*. 1980;7:75–80.
24. Wolford LM, Karras SC, Mehra P. Considerations for orthognathic surgery during growth, part 2: maxillary deformities. *Am J Orthod Dentofacial Orthop*. 2001;119: 102–105.
25. Cheung LK, Chua HD. A meta-analysis of cleft maxillary osteotomy and distraction osteogenesis. *Int J Oral Maxillofac Surg*. 2006;35:14–24.
26. Sar C, Arman-Özcırpıcı A, Uckan S, Yazıcı AC. Comparative evaluation of maxillary protraction with or without skeletal anchorage. *Am J Orthod Dentofacial Orthop*. 2011;139:636–649.
27. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. *Am J Orthod Dentofacial Orthop*. 1998;113:204–212.
28. Ngan P. Treatment of Class III malocclusion in the primary and mixed dentitions. In: Bishara SE, ed: *Textbook of Orthodontics*. Philadelphia, PA: WB Saunders; 2001:375–411.
29. Nguyen T, Cevidanes L, Cornelis MA, Heymann G, de Paula LK, De Clerck H. Three-dimensional assessment of maxillary changes associated with bone anchored maxillary protraction. *Am J Orthod Dentofacial Orthop*. 2011;140: 790–798.