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Effects of maxillary protraction for early correction of class III malocclusion

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SUMMARY This prospective study investigated the skeletal, dental, and soft-tissue effects of a mini maxillary protractor appliance in class III subjects with maxillary retrusion and mandibular protrusion and compared these changes with those of untreated, well matched control sample with normal occlusions.

Twenty patients with class III malocclusion (mean age 11.1 ± 0.8 years) and 20 subjects with normal occlusion (mean age 10.9 ± 0.4 years) were included to this study. The class III subjects were treated with the mini maxillary protractor appliance, and the others were used as control subjects. Paired *t*-test and Student's *t*-test were used to determine the within- and between-group differences, respectively.

In the study group, the maxilla moved forward (SNA, 2.0 degrees and A–Y, 2.4 mm) ($P < 0.001$) with a slight rotation of palatal and occlusal planes (SN–PP, –0.8 degree and SN–OP, –0.7 degree) ($P > 0.05$). The mandible displaced backwards and downwards (SNB, –1.1 degrees; SND, –0.9 degree; B–Y, –0.9 mm and Pog–Y, –0.3 mm; $P < 0.001$). These movements in the maxilla and mandible caused a significant improvement in intermaxillary sagittal relationship (ANB, 3.0 degrees; Convexity, 6.3 degrees; Wits, 4.6 mm; $P < 0.001$). The maxillary incisors moved forward (2.2 degrees) while the mandibular ones backward (–1.9 degrees). The improvement in overjet was 5.0 mm, and 66.1 per cent of this change (3.3 mm) was skeletal (A–Y; 2.4 mm and B–Y; –0.9 mm), and the remaining (1.7 mm) dentoalveolar (U1–NA; 0.9 mm and L1-NB; –0.8 mm). The change in Ls–E measurement was more in the study group (2.1 mm), and the difference between the groups was statistically significant ($P < 0.001$).

Introduction

Class III skeletal pattern is one of the most difficult malocclusions to diagnose and treat in orthodontics and is characterized by mandibular prognathism, maxillary retrognathism, retrusive mandibular dentition, protrusive maxillary dentition, and a combination of these components (Sanborn, 1955; Nanda, 1980; Guyer *et al.*, 1986; Pangrazio-Kulbersh *et al.*, 1998; Kilic *et al.*, 2010b). It has been reported that two-thirds of skeletal class III malocclusions are due to either maxillary retrognathism or a combination of maxillary retrognathism and mandibular prognathism (Sanborn, 1955; Nanda, 1980; Guyer *et al.*, 1986). The prevalence of this anomaly was found to be approximately 1–5 per cent in white populations; (Emrich *et al.*, 1965; Thilander and Myrberg, 1973), while this prevalence was as high as 14 per cent for Asian populations (Iwagaki, 1938; Irie and Nakamura, 1975).

Class III skeletal patterns often exhibit a high incidence of deficient transverse maxillary growth (Hata *et al.*, 1987), and maxillary expansion is often the first treatment procedure. According to Proffit and Fields (1993), maxillary expansion should be applied to mobilize the maxillary sutures before maxillary protraction. Furthermore, McNamara (1987) and Turley (1988) have recommended the use of bonded rapid maxillary expansion appliance for several days before beginning the protraction in order to facilitate maxillary movement. Optimal treatment timing is one of the most important factors to be taken in consideration while treating skeletal class III patients with orthopedic forces (Melsen and Melsen, 1982; Proffit, 1992). Orthopedic treatment applied during prepubertal and pubertal periods can shorten the treatment time, and favourable anterior occlusion can be obtained if mandibular growth is properly controlled during and after retention period (Campbell, 1983; Chong *et al.*, 1996). Some researchers (Proffit, 1992; Sung and Baik, 1998; Yavuz *et al.* 2009) reported that greater skeletal changes with the use of maxillary protraction appliances are possible in young patients. Nonetheless, some researchers (Baik, 1995; Sung and Baik, 1998; Yüksel *et al.*, 2001) compared the treatment changes obtained at different ages and found no statistically significant difference.

Protraction of maxilla with a facemask is the most common treatment procedure for class III malocclusions with maxillary retrusion and mandibular protrusion. The effects of maxillary protraction have been investigated by many authors and following changes were reported: acceleration of forward growth of maxilla with a counterclockwise rotation, forward movement of maxillary dentition, retardation of mandibular growth, and backward

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movement of mandible with a clockwise rotation (Irie and Nakamura, 1975; Campbell, 1983; Sung and Baik, 1998; Uçüncü *et al.*, 2000; Kilic *et al.*, 2010a).

A mini maxillary protraction appliance was developed by Altug and Arslan (2005) for correction of class III malocclusions. However, soft tissue effects of this new appliance have not been investigated yet. Thus, the purpose of this prospective clinical study was to investigate skeletal, dental, and soft tissue effects of the mini maxillary protractor in class III subjects with maxillary retrusion and mandibular protrusion, and to compare these changes with those of untreated control sample with normal occlusion.

Subjects and Methods

Ethical approval for the present prospective study was obtained from the Ethical Committee of Ataturk University, Faculty of Dentistry. An informed consent was signed by parents of the subjects included to this study.

Sample size for the groups was calculated based on a significance level of 0.05 and a power of 80 per cent to detect a clinically meaningful difference of 1 mm (±0.98 mm) for the distance from point A to PM Vertical (Y) passing through ethmoid registration point and pterygo-maxillary fissure inferior. Power analysis showed that 16 subjects in each group were required. To compensate for possible dropouts during the trial, we decided to enroll more patients.

The study group was selected according to the following criteria: (1) Skeletal class III malocclusion characterized by maxillary deficiency and/or mandibular protrusion (ANB less than 0 degrees, Wits less than −1 mm, overjet less than 0 mm); (2) Vertically normal growth pattern (SN–GoMe = 32 degrees ± 6); (3) Minimum or moderate crowding (less than 5 mm) in both dental arches; (4) Late mixed or early permanent dentition. Exclusion criteria were craniofacial anomalies, lingual nonocclusion of posterior dentition, and previous orthodontic treatment. The patients and their parents were informed about the mini maxillary protractor appliance and study protocol. Those accepted to enroll the study were included to the study group (10 males and 10 females; mean age 11.1 ± 0.8 years).

Age and gender matched control subjects were chosen from the longitudinal archive of the Department of Orthodontics at Ataturk University (10 males and 10 females; mean age: 10.9 ± 0.4 years). The selection was based on presence of normal growth and development (skeletal class I; 0 degrees<ANB<4 degrees), a balanced facial appearance, class I molar relationship, minimal dental crowding (less than 2 mm), absence of anterior and/or posterior crossbites, and no previous orthodontic treatment.

The patients were treated by one author (MC) by means of the mini maxillary protractor appliance until 2 mm positive overjet was obtained (Figure 1). The appliance consisted of intra- and extra-oral parts. Maxillary part was a full-coverage acrylic splint type maxillary expander with two hooks extended to the vestibular fornix of the canines. Mandibular part composed of an acrylic plate covering all posterior teeth and a chin cup, which were connected each other by a special bow. The bow was bent from 1.2 mm stainless steel round arch wire, and a horizontal bar was soldered on it to apply protraction forces from the hooks on the maxillary expander. Extra-oral part of the appliance was a cervical headgear.

Figure 1 Intraoral and extraoral photographs of mini maxillary protractor used in the study.

Palatal screw on the maxillary part of the appliance was activated twice a day for 5 days (total of 2 mm expansion) even if a posterior crossbite was absent. At the end of the fifth day, the protraction headgear was applied. A protraction force of 450–500 g was applied bilaterally between the hooks and horizontal bar. Direction of the force was adjusted to be approximately 30 degrees downward from occlusal plane. The patients were instructed to wear their appliances for at least 20 hours per day until a 2 mm positive overjet was achieved. Edgewise fixed appliances were used for alignment of the teeth if needed.

Cephalometric radiographs were obtained before (T1) and after (T2) protraction therapy in the study group. The films were taken in a standard position by one operator using the same X-ray machine and cephalostat (Siemens Nanodor 2; Siemens AG, Munich, Germany). Films of the control subjects were obtained from files of the longitudinal archive, which were obtained previously by the same X-ray machine and cephalostat. In order to determine skeletal, dental, and soft tissue changes, 17 linear and 14 angular measurements were used. Landmarks and measurements used in this study are shown in Figures 2–4. All measurements were made by one author (MC).

Statistical analysis

To determine the errors associated with the radiographic measurements, 15 radiographs were selected randomly.

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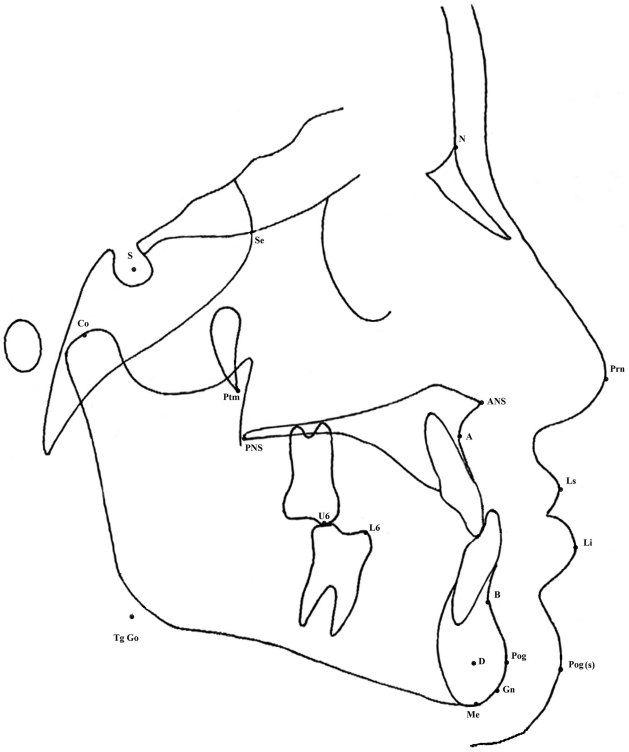

Figure 2 Landmarks used in the study: S, sella; N, nasion; Or, orbitale; Ls, labiale superior; Li, labiale inferior; Pog(s), soft tissue pogonion; A, Point A; B, Point B; D, Point D; Pog, pogonion; Gn, Gnathion; Co, Condylon; ANS, Spina nasalis anterior; PNS, Spina nasalis posterior; Me, menton; Tg Go, Tangent gonion; Se, intersection of the greater wing of sphenoid bone with the floor of anterior cranial fossa; ptm, the most inferior and posterior point on the anterior outline of pterygomaxillary fissure; Prn, pronasale.

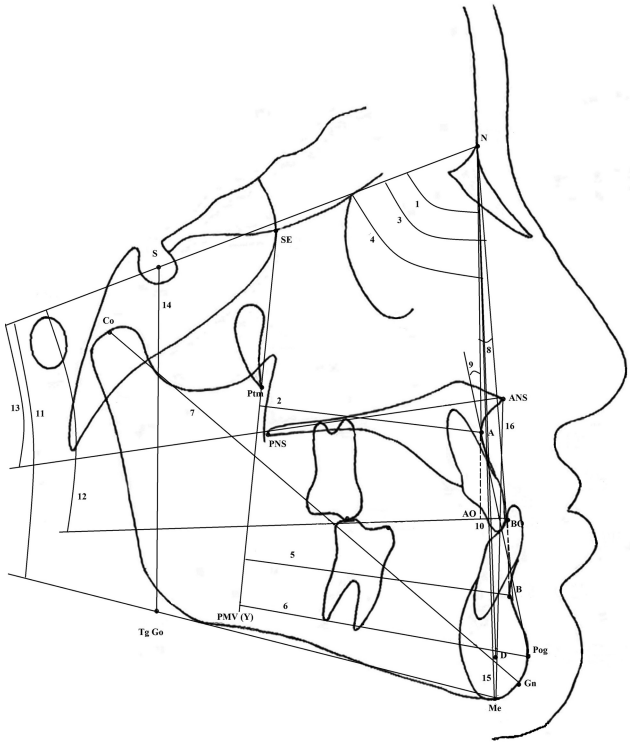

Figure 3 Skeletal measurements used in the study: (1) SNA; (2) A–PMV (Y line); (3) SNB; (4) SND; (5) B–Y; (6) Pog–Y; (7) Co-Gn; (8) ANB; (9) Convexity angle; (10) Wits; (11) SN–GoMe; (12) SN–OP; (13) SN–PP; (14) S–Go; (15) N–Me; (16) ANS–Me.

Landmark identification, tracing, and measurements were repeated after a period of 1 month by the same author (MC). Intra-class correlation coefficients were performed to assess the reliability of measurements as described by Houston (1983). The coefficients of reliability for all measurements were above 0.92, confirming the measurement reliability.

Descriptive statistics of all variables were computed for T1 and T2 periods in each group. Shapiro–Wilks normality test showed a normal distribution, and thus parametric tests were used in statistical evaluations. Since there was no gender difference in both groups, the data for males and females were pooled. The initial measurements and treatment/control changes were compared between the groups by means of Student's *t*-test. All statistical analyses were performed by the Statistical Package for Social Sciences (Windows 7, version 15.0, SPSS Inc., Chicago, IL, USA).

Results

Mean ages of the study and control groups were 11.1 ± 0.8 and 10.9 ± 0.4 years, respectively (P = 0.891). Mean treatment and observation periods were 8.10 ± 2.53 and 11.95 ± 0.22 months in the study and control groups, respectively ($P < 0.001$).

Table 1 shows the results of Student's *t*-test comparing the initial measurements of both groups. SNA, ANB, convexity, SN/OP, IMPA, and L1-NB angles and Wits appraisal, A–Y distance, overjet, overbite, and Ls–E measurements were significantly smaller in the study group, whereas SNB, U1–SN, and U1–NA angles and Co–Gn, B–Y, Pog–Y, U1–NA, and Pog (s)–Y measurements were significantly larger in the study group as compared with the control group.

Table 2 shows the comparison of the changes in the study and control groups. Notable changes were observed in most of the variables in the study group. Maxilla moved forward (SNA, 2.0 degrees and A–Y, 2.4 mm) ($P < 0.001$) in combination with an insignificant rotations of palatal and occlusal planes (SN–PP, −0.8 degrees and SN–OP, −0.7 degrees) ($P > 0.05$). The mandible was displaced backward and downward (SNB, −1.1 degrees; SND, −0.9 degrees; B–Y, −0.9 mm and Pog–Y, −0.3 mm) ($P < 0.001$). Mandibular length (Co–Gn) increased 2.5 mm in the control group and 1.6 mm in the study group ($P < 0.01$). Combined movements of maxilla and mandible caused a significant improvement in intermaxillary sagittal relationship (ANB, 3.0 degrees; Convexity, 6.3 degrees; Wits, 4.6 mm)

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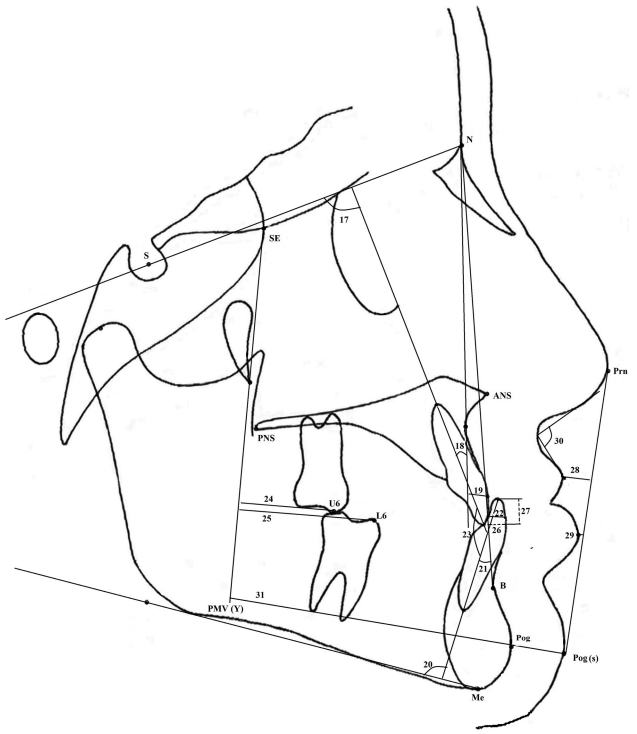

Figure 4 Dental and soft tissue measurements used in the study: (17) U1–SN (18) U1–NA degree; (19) U1–NA mm; (20) IMPA; (21) L1–NB degree; (22) L1–NB mm; (23) U1–L1; (24) U6–Y; (25) L6–Y; (26) Overjet; (27) Overbite; (28) Ls–E; (29) Li–E; (30) Nasolabial angle; (31) Pog (s)–Y.

($P < 0.001$). In addition, significant increases were observed in SN–GoMe angle (1.5 degrees; $P < 0.001$) and lower face height (Study Group, 2.6 mm and Control Group, 1.5 mm) ($P < 0.05$).

At least 2 mm positive overjet was obtained in all of the subjects with class III malocclusion. Mean overjet change was 5.0 mm in the study group and 0.1 mm in the control group ($P < 0.001$). Class III molar occlusion was overcorrected to class I or class II molar relationship by the aid of sagittal movements of maxillary (4.1 mm) and mandibular (−1.4 mm) first molars. The changes in maxillary and mandibular first molar positions were statistically significant when compared with those of control group ($P < 0.05$ and $P < 0.001$, respectively). Overbite increased 0.1 mm in the study group and 0.7 mm in the control, and the difference between the groups was not statistically significant ($P > 0.05$).

In the study group, maxillary incisors proclined (2.2 degrees, $P < 0.001$) and mandibular incisors retroclined (−1.9°, $P < 0.01$) significantly. The change in Ls–E measurement was more in the study group (2.1 mm), and the difference between the groups was statistically significant ($P < 0.001$). Pog (s)–Y distance decreased (−0.6 mm) in the study group, whereas it increased (2.5 mm) in the control group with growth ($P < 0.001$).

Table 1 The results of Student's *t*-test comparing the initial measurements of the study and control groups.

Measurements	Study group	Control group	*P*
	Mean and SD	Mean and SD	
Skeletal measurements			
SNA (°)	76.8±2.0	80.3±3.1	***
A-Y (mm)	47.8±2.6	50.6±1.4	***
SNB (°)	79.2±2.3	77.0±2.8	*
SND (°)	76.6±2.3	74.5±2.6	NS
B–Y (mm)	52.7±3.0	50.7±3.3	*
Pog–Y (mm)	56.5±3.9	52.8±6.0	*
Co–Gn (mm)	117.4±5.4	113.4±4.7	*
ANB (°)	−2.4±1.0	3.3±1.2	***
Convexity (°)	−7.0±2.6	5.1±3.7	***
Wits (mm)	−6.4±2.3	−0.2±1.9	***
SN/GoMe (°)	32.7±3.6	32.3±3.8	NS
SN/OP (°)	17.3±3.6	19.5±3.0	**
SN/PP (°)	11.5±3.6	9.5±3.6	NS
S–Go (mm)	72.8±4.6	74.7±4.8	NS
N–Me (mm)	112.5±6.6	112.7±6.0	NS
ANS–Me (mm)	52.1±3.5	50.9±3.1	NS
Dental measurements			
U1–SN (°)	104.9±5.5	100.3±4.5	*
U1–NA (°)	26.4±4.3	20.4±4.9	**
U1–NA (mm)	5.0±1.5	3.7±1.2	**
IMPA (°)	87.1±4.6	94.4±4.6	***
L1–NB (°)	20.2±4.5	24.0±4.1	**
L1–NB (mm)	4.1±1.6	4.6±1.4	NS
U1–L1 (°)	136.1±8.2	132.9±5.8	NS
U6–Y (mm)	25.8±3.5	25.8±3.0	NS
L6–Y (mm)	28.8±2.8	27.2±3.5	NS
Overjet (mm)	−1.8±1.1	2.9±0.8	***
Overbite (mm)	1.3±1.7	3.0±1.3	**
Soft tissue measurements			
Ls–E (mm)	−5.7±1.8	−2.0±2.4	***
Li–E (mm)	−2.0±1.3	−0.8±2.6	NS
Nasolabial (°)	110.2±7.9	108.3±8.3	NS
Pog (s)–Y (mm)	67.7±4.5	63.2±7.3	*

NS: Not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Discussion

In the present study, treatment effects of the maxillary protractor appliance were evaluated by means of untreated and age and gender matched control group. Since ethical considerations did not allow postponing the treatment of class III subjects for scientific purposes, the control group was formed by the subjects with dental and skeletal class I relationship. Similarly, many authors (Battagel, 1993; Takada *et al.*, 1993; Kapust *et al.*, 1998; Sung and Baik, 1998; Kiliçoglu and Kirliç, 1998; Mouakeh, 2001; Arman *et al.*, 2004; Altug and Arslan, 2006; Kilic *et al.*, 2010a; Kilic *et al.*, 2010b) have used class I untreated subjects as control like in this study. Comparison of the first records showed that the study group had a retrusive maxilla and upper lip, protrusive mandible and lower lip, proclined maxillary incisors, retroclined mandibular incisors, and reduced overjet and overbite, which were the main characteristics of a class III malocclusion.

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Table 2 The results of Student's *t*-test comparing the changes in the study and control groups.

Measurements	Study Group	Control Group	
	Mean and SD	Mean and SD	*P*
Skeletal measurements			
SNA (°)	2.0±0.8	0.3±0.7	***
A–Y (mm)	2.4±1.0	1.2±0.7	***
SNB (°)	−1.1±0.8	0.5±0.6	***
SND (°)	−0.9±0.8	0.5±0.6	***
B–Y (mm)	−0.9±1.7	1.8±1.0	***
Pog–Y (mm)	−0.3±2.1	2.2±1.4	***
Co–Gn (mm)	1.6±2.7	2.5±2.0	**
ANB (°)	3.0±1.2	−0.2±0.5	***
Convexity (°)	6.3±2.9	−0.1±1.1	***
Wits (mm)	4.6±1.9	0.2±1.4	***
SN/GoMe (°)	1.4±0.7	−0.3±1.1	***
SN/OP (°)	−0.7±2.6	0.1±1.3	NS
SN/PP (°)	−0.6±1.6	−0.1±1.2	NS
S–Go (mm)	0.6±0.9	1.9±1.0	NS
N–Me (mm)	4.1±1.9	2.4±1.5	NS
ANS–Me (mm)	2.6±1.3	1.5±1.1	*
Dental measurements			
U1–SN (°)	2.2±2.3	−1.1±2.3	***
U1–NA (°)	0.1±4.2	−1.3±3.1	NS
U1–NA (mm)	0.9±1.5	0.2±0.9	**
IMPA (°)	−1.9±2.6	1.3±3.1	**
L1–NB (°)	−2.5±3.3	0.9±3.9	**
L1–NB (mm)	−0.8±0.7	0.1±0.8	***
U1–L1 (°)	−0.1±5.7	0.1±4.5	NS
U6–Y (mm)	4.1±2.1	2.7±2.4	*
L6–Y (mm)	−1.4±2.2	1.6±0.9	***
Overjet (mm)	5.0±1.7	−0.1±0.7	***
Overbite (mm)	0.1±2.1	0.7±1.5	NS
Soft tissue measurements			
Ls–E (mm)	2.1±1.6	−0.3±0.9	***
Li–E (mm)	−0.6±1.8	−0.4±1.0	NS
Nasolabial (°)	−1.7±7.9	−1.1±6.4	NS
Pog(s)–Y (mm)	−0.6±1.7	2.5±1.2	***

NS: Not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

The decision to start early orthopedic treatment or to wait until growth is completed is not easy. The advantages of early treatment include minimizing dental compensation and overclosure of mandible, which can lead to a better facial esthetics and self-esteem during this important growth period. Many researchers (Takada *et al.*, 1993; Chong *et al.*, 1996; Kapust *et al.* 1998; Baccetti *et al.*, 2000) recommended early orthopedic treatment in order to obtain more skeletal effect and they showed that late treatment, alternatively, resulted in more mandibular rotation and dentoalveolar changes. Maxillary protraction has been applied during late-mixed and/or early permanent dentition stages in order to obtain maximum growth advantage (Irie and Nakamura, 1975; Ishii *et al.*, 1987; Takada *et al.*, 1993). On the other hand, it has been known that these patients might still need some surgical approaches after early orthopedic and orthodontic treatment and that treatment time with mandibular surgery alone would be shorter (Cha *et al.*, 2011). Facial growth pattern and pretreatment overbite measurement are the factors to be considered for treatment prognosis and also for prevention of relapse (Battagel, 1993; Uner *et al.*, 1995). The patients included to the present study had normal vertical growth patterns (SN–GoMe: 32.7±3.6) and nearly normal overbite relationships (1.3±1.7), and they were in late mixed and/or early permanent dentition stages.

Different types of maxillary protraction appliances have been used successfully for treatment of class III malocclusions (Haas, 1965; Dellinger, 1973; Nanda, 1980; Turley, 1988; Tanne and Sakuda, 1991; Ngan *et al.*, 1992; Takada *et al.*, 1993; Alcan *et al.*, 2000, Altug and Arslan, 2006) and orthopedic maxillary expansion, which was reported to facilitate the maxillary protraction (Haas 1965; Turley, 1988; Ngan *et al.*, 1992; Altug and Arslan, 2006). Turley (1988) suggested that maxillary expansion 'disarticulates' the maxilla and initiates cellular response in the circummaxillary sutures, allowing a more positive reaction to protraction forces. Baik (1995) treated 60 patients with protraction facemask, 47 patients with maxillary expansion and 13 patients without expansion, and found significantly greater forward movement of maxilla in the maxillary expansion group. In the present study, maxillary expansion was applied for disarticulating of maxillary sutures rather than correction of posterior crossbite, since the improvement of maxillomandibular relationship into a class I occlusion was sufficient to eliminate the posterior crossbite.

The treatment changes showed maxillary anterior displacement. SNA angle increased 2.0 degrees and the distance from point A to Y axes increased 2.4 mm. The same increases were 0.3 and 1.8 mm in the control group, respectively. The difference between the groups regarding these parameters was statistically significant ($P < 0.001$). Forward displacement of maxilla with maxillary protraction has been demonstrated both clinically and experimentally (Dellinger, 1973; Kambara, 1977; Jackson *et al.*, 1979; Tanne and Sakuda, 1991; Baik, 1995; Sung and Baik, 1998; Alcan *et al.*, 2000; Yüksel *et al.*, 2001; Cha *et al.*, 2011). Sung and Baik (1998) found 1.7 mm anterior movement of point A in 12-year-old age group treated with facemask and expansion. In a study accomplished by Cha *et al.* (2011), anterior movement of point A was 1.0 mm in an older age group (mean age, 13.07 years) treated with similar treatment protocol. In the present study, mean age of the study group was approximately 11 years, and we are in agreement with the literature that showed greater skeletal changes at younger ages.

The present study also showed that positional changes of mandible contributed to class III correction. Downward and backward rotation of mandible (SNB, −1.1 degrees; SND, −0.9 degrees; B–Y, −0.9 mm; and Pog–Y, −0.3 mm) improved the maxillomandibular skeletal relationship and facial convexity but resulted in an increase in lower anterior face height (2.6 mm) and mandibular plane angle (1.4 degrees). These findings were consistent with the results of

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many authors applying maxillary protraction with expansion (Turley, 1988; Baik, 1995; Sung and Baik, 1998; Baccetti *et al.*, 2000; Altug and Arslan, 2006).

The increases in ANB (3.0 degrees) and Convexity (6.3 degrees) angles and Wits appraisal (4.6 mm) were statistically significant (P <0.001). The increase of SNA angle was approximately twice more than the decrease of SNB angle. In agreement with our finding, Yavuz *et al.* (2009) and Kapust *et al.* (1998) found that SNA angle showed an increase more than the decrease in SNB angle.

Counterclockwise rotation of palatal plane found by Takada *et al.* (1993), Kapust *et al.* (1998), and Yavuz *et al.* (2009) was not observed in the present study (−0.8 degrees). Westwood *et al.* (2003) and Altug and Arslan (2006) reported an insignificant increase in the palatal plane angle. Possible causes of palatal rotation may be the variations in the application point and/or direction of protraction force and facial pattern of patient. To minimize the rotation of palatal plane, in the present study, protraction force was applied from the hooks near maxillary canines on each side, and its direction was adjusted to be downward 30 degrees from the occlusal plane.

Upper incisors protruded and lower incisors retruded at a statistically significant level, resulting in an increase in overjet measurement. The change in overbite was found to be insignificant. Similar dentoalveolar changes have been reported in the previous studies (Arman *et al.* 2004; Altug and Arslan, 2006; Yavuz *et al.*, 2009; Kilic *et al.* 2010a). Possible explanations of these dentoalveolar changes may be mesial drifting of maxillary dentition (U6–Y, 4.1 mm) resulting from the protraction forces and retrusive effect of chin cup component of the appliance on lower incisors. Merwin *et al.* (1997) reported that skeletal and dental contributions to overjet correction were 63 and 37 per cent, respectively. According to Cha *et al.* (2011), skeletal contribution to overjet correction was 63.1 per cent. In the present study, overjet correction (5.0 mm) was achieved by 66.1 per cent skeletal (A–Y; 2.4 mm and B–Y; −0.9 mm, a total of 3.3 mm) and 33.9 per cent dental (U1–NA; 0.9 mm and L1–NB; −0.8 mm, a total of 1.7 mm) changes. In addition, maxillary skeletal contribution (A–Y; 2.4 mm; 74.2 per cent) to overjet correction was higher than mandibular skeletal contribution (B–Y; −0.9 mm; 25.8 per cent) (Figure 5).

Soft tissue changes contributed to improve class III profiles of the subjects. Upper lip showed significant forward movement (2.1 mm), while the retrusion in lower lip was not significant (−0.6 mm). This movement of upper lip in conjunction with the downward and backward movement of soft tissue chin (−0.6 mm) caused the facial profile to become more convex. These findings regarding soft tissue profile are consistent with the literature (Arman *et al.* 2004; Kilic *et al.* 2010a).

The results from the present study are limited to a short-term observation period of maxillary protraction.

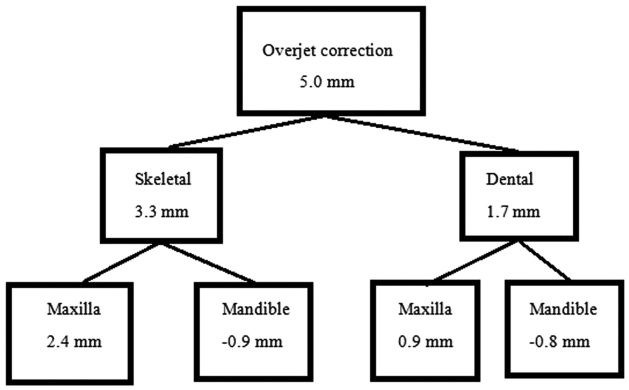

Figure 5 Maxillary and mandibular skeletal and dentoalveolar changes (mm) contributing to overjet correction in class III subjects.

Long-term studies are needed to evaluate the stability of the results of mini maxillary protractor appliance and to compare its effects with those of similar appliances and treatment protocols. Another limitation of the present study is that observation periods of the subjects in the control group were 12.0 ± 0.2 months, while it was 8.1 ± 2.5 months for the patients in the study group. This longer observation period of the control subjects might have masked some effects of mini maxillary protractor appliance. On the other hand, this new appliance is smaller than the conventional face mask, and thus it is more esthetic and acceptable. An additional advantage is also that it is cheap. Since mini maxillary protractor appliance is as effective as the conventional face masks in class III malocclusion treatment, it might be used in class III subjects who do not wish to use conventional face mask due to its appearance.

Conclusions

1. The maxillary protraction appliance caused significant changes in skeletal, dental, and soft tissue structures.
2. The skeletal contribution (66.1 per cent) to overjet correction of 5.0 mm was more than the dentoalveolar contribution (33.9 per cent).
3. The maxillary skeletal contribution (74.2 per cent) to overjet correction was more than the mandibular skeletal contribution (25.8 per cent).

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