Changes following the use of protraction headgear for early correction of Class III malocclusion

Yea-Hwe Chong, BDS, MSc, MDS, MSD; John C. Ive, DDS, MSD; Jon Årtun, DDS, Dr. Odont

Animal experiments have shown that the application of retractive forces to the growing mandible results in a temporary reduction in growth activity at the condyles,[1,2] and that growth behavior resumes once the forces are removed.[3] Clinical studies also indicate a limited ability to achieve a permanent reduction in the amount of mandibular growth.[4-7] Conversely, it is well established that sutural growth can be stimulated.[8-11] For these reasons, and because relative mandibular prognathism is more often due to maxillary deficiency than mandibular excess,[12-16] maxillary protraction may be the treatment of choice for the majority of the cases with Class III malocclusion.

Maxillary protraction is accomplished using an elastic force from a facemask to the dentition.[17-20] In most clinical situations elastics are attached to orthodontic appliances, which may explain the typical finding of a combined skeletal and dental treatment effect.[19-26] Such treatment is most often performed in the late mixed or early permanent dentition to take maximum advantage of growth.[21,23,26] However, there are indications that the relative skeletal response may increase if treatment is initiated earlier.[27-30] A possible disadvantage of early intervention is the potential for extended total treatment time. To avoid that, a predictable and significant improvement should be achieved within a defined time frame.

Abstract

The purpose of this study was to evaluate treatment effects and posttreatment changes following the application of elastic forces from a facemask to the dentition for the early correction of Class III malocclusion. Cephalograms made before and after treatment and at a minimum of 1 year follow-up (mean 3.57 years, S.D. 2.07) of 16 patients were compared with those of 13 untreated matched controls. Pretreatment age ranged from 4.58 to 8.25 years (mean 6.80 years, S.D. 1.13), and mean active treatment time was 0.61 years (S.D. 0.15). Available study models at the three time periods were also analyzed. Treatment resulted in a significant improvement in the maxillomandibular relationship and overjet ($P < 0.001$). The major treatment effect was a downward and backward movement of the mandible and retroclination of the mandibular incisors. However, any skeletal and dentoalveolar advancement of the maxilla contributed to the clinically significant improvement. No differences were observed between the patients and the controls during the posttreatment follow-up. Despite some relapse, the patients demonstrated a net improvement in maxillomandibular relationship and overjet at the end of follow-up relative to the controls. Overcorrection of the overjet during treatment may be important for maintaining a successful correction.

Key Words

Treatment changes • Posttreatment changes • Protraction headgear • Early correction • Class III malocclusion

Submitted: May 1995 **Revised and accepted:** August 1995 Angle Orthod 1996;66(5):351-362.

Table 1
Ages of pre- (T1), and post- (T2) treatment and a minimum of 1 year follow-up (T3) cephalograms of Class III cases treated with protraction headgear, and ages at time of available cephalograms of untreated Class III controls

	Treated (n=16) Mean	S.D.	Control (n=13) Mean	S.D.
Age at T1 (years)	6.80	1.13	6.36	0.54
Age at T2 (years)	7.95	1.33	8.02	0.76
Age at T3 (years)	11.52	1.92	11.74	0.50
Treatment Time (years)	0.61	0.15		

Several studies have evaluated treatment effects of maxillary protraction headgear, either alone[22,24,25] or in combination with chin cup therapy.[21,23,26] However, rarely have the patients included in the different samples been treated according to a standardized protocol. In some studies, treatment time has been variable[24] or very long.[23] In addition, the few available studies on maxillary protraction in young Class III patients either lack satisfactory follow-up evaluation[24,25] or used controls with normal overjet and maxillomandibular relationship.[22,26] Attempts at establishing predictors for posttreatment stability are virtually nonexistent. The aim of our study was to evaluate treatment effects and posttreatment changes following a short intervention with maxillary protraction headgear for early correction of Angle Class III malocclusion, and to determine possible factors associated with the outcome.

Materials and methods

Sample

The sample comprised 16 consecutive cases (8 boys, 8 girls) treated by two orthodontists for Class III malocclusion. Standardized lateral cephalometric radiographs were made before (T1), at the end of or shortly after active treatment (T2), and after a minimum observation period of 1 year (T3). Available study models at the three time periods were also used. Subjects were included if they presented with a negative overjet and/or a mesial step in the postlactal plane. Clinical examinations were carried out to ensure that the negative overjet was not due to the presence of a pseudo-Class III malocclusion, as characterized by a significant anterior centric relation to centric occlusion (CR-CO) shift. The age at the start of treatment ranged from 4.58 to 8.25 years. All patients were treated with protraction headgear and none had undergone any prior orthodontic treatment.

Similar records of 13 children (8 boys, 5 girls) with untreated Class III malocclusions were obtained from the Burlington Growth Center at the University of Toronto in Toronto, Canada, and the Bolton-Brush Growth Center at Case Western Reserve University in Cleveland, Ohio. The ages at each time period were similar to those of the treated group (Table 1).

Appliance and treatment procedures

Maxillary protraction was instituted using forward and downward traction directed approximately 30 to 40 degrees to the maxillary occlusal plane. Intraoral anchorage was provided via molar bands cemented to the deciduous second molars or first permanent molars, which were linked together by 0.036 inch lingual and labial stainless steel wires soldered to the bands. Protraction forces of 8 to 10 oz (230 to 285 g) on each side were delivered by elastics attached to hooks situated on either side of the intraoral appliance, between the maxillary lateral incisors and canines. A Delaire facemask[17] was used to provide the extraoral anchorage. Patients were asked to wear the facemask for periods ranging from 12 to 16 hours a day. In three cases where posterior crossbites were present, a bonded palatal expander was used in conjunction with the maxillary protraction. Protraction therapy was discontinued when a positive overjet and/or a flush postlactal plane was achieved. Only one phase of active treatment was performed, and maximum treatment time was 12 months. No retention appliances were used.

Cephalometric analysis

Cephalograms were traced and superimposed by hand by the principal investigator. Cephalometric landmarks were identified as shown in Figure 1. A total of 9 linear and 11 angular measurements were recorded on each cephalometric tracing, (Tables 2, 3, 5 and 7) and an additional 13 linear measurements on the superimpositions (Tables 4 and 6).

Overall superimposition was performed using the "best fit" on the ethmoid triad, which consists of the sphenoethmoidal plane, the greater wings of the sphenoid bone, and details of surrounding anatomical structures.[31] The "average occlusal plane" for the three time periods, or the average of the inclination of the occlusal plane relative to the anterior cranial base at T1, T2, and T3, was transferred to the T2 tracing (Figure 2).

Maxillary superimposition was performed on

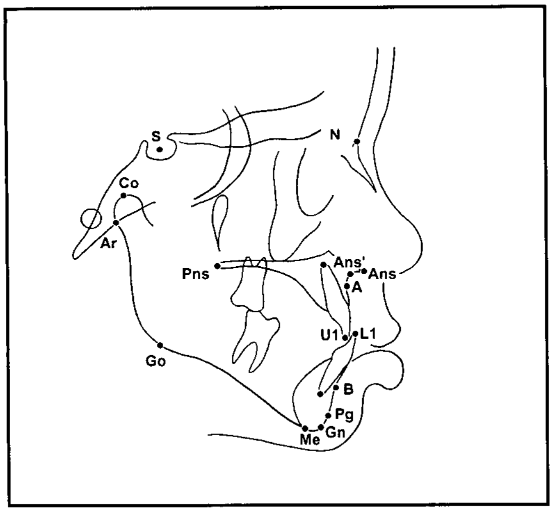

Figure 1

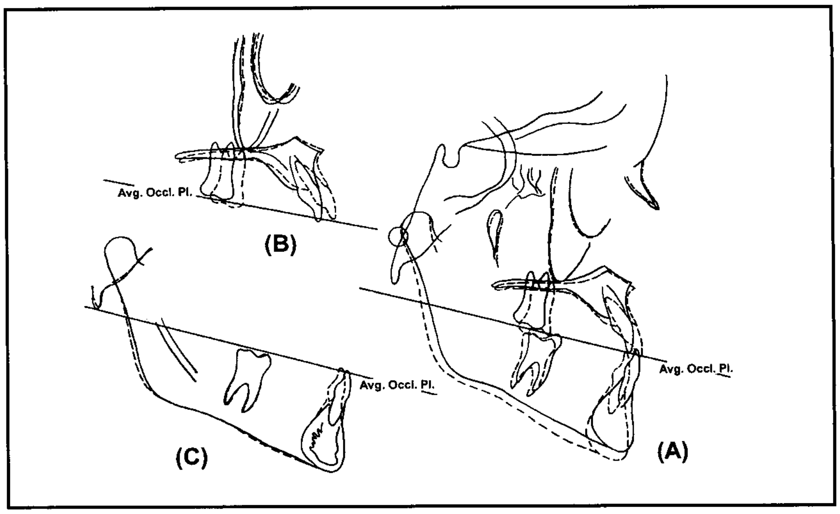

Figure 2

Figure 1
Cephalometric tracing showing landmarks used for determining seven angular (SNA, SNB, ANB, SN-Pg, mx incisor-SN, mn incisor-mn plane, interincisal angle) and five linear (Co-Ans', Co-Gn, Ar-SN perpendicular, Wits, overjet) measurements to describe anteroposterior relationships, and four angular (occlusal plane-SN, palatal plane-SN, mandibular plane-SN, gonial angle) and four linear (Ar-SN, overbite, anterior facial height, posterior facial height) measurements to describe vertical relationships.

Figure 2
Overall (A), maxillary (B) and mandibular (C) superimpositions of cephalometric tracings from pretreatment (——) to posttreatment (- - -) of a patient treated for Class III malocclusion with protraction headgear. Amount of treatment change was measured along the average occlusal plane. Note skeletal (A) and dentoalveolar (B) effects in the maxilla, downward and backward repositioning of the mandible (A), and retroclination of the mandibular incisors (C).

the anterior and posterior borders of the zygomatic process, allowing the floor of the orbit to rise in a ratio of 1.5:1 mm in relation to the lowering of the palatal plane.[32] Mandibular superimposition was made using the "best fit" on the internal anatomy of the symphysis, mandibular canal, and if present, the unerupted third molars.[33]

For each subject, differences in linear and angular measurements from T1 to T2, T2 to T3, and T1 to T3 were calculated. An increase in a variable was recorded as positive while a decrease was recorded as negative. Also, any differences in anteroposterior position of the landmarks were measured along the average occlusal plane on the overall, maxillary, and mandibular superimpositions from T1 to T2 and from T2 to T3. A forward change was recorded as positive, while a backward change was recorded as negative. Linear measurements were made to the nearest 0.01 mm using a Fowler Ultra-Cal III digital caliper (Fred V. Fowler Co, Inc, Newton, Mass) . Angular measurements were made to the nearest 0.5 degree using a protractor.

Treated subjects were divided into two groups according to the clinical result at T3. Successful cases (n = 11) maintained a positive overjet of 2 mm or more at T3 (Figure 3), while failures (n = 5) had an overjet of less than 2 mm at T3 (Figure 4).

Model analysis

Available sets of study models were analyzed by the principal investigator. The distances between the mesiobuccal cusp tips of the maxillary and mandibular deciduous second molars were measured. Also, any difference from flush of the postlactal plane was measured along the occlusal plane. A positive reading indicated a distal step, and a negative reading a mesial step. Measurements were performed using a digital caliper as above to the nearest 0.01 mm.

Method error

The reproducibility of the measurements was assessed by statistically analyzing the difference between double measurements made at least 1 week apart on all cephalograms (N=30), superimpositions (N=20), and available study models (N=23) of 10 randomly selected cases. All cephalograms were retraced and resuperimposed prior to the second measurement. The method error was calculated from the equation:

$$Sx = \sqrt{\frac{\sum d^2}{2n}}$$

where D is the difference between duplicated measurements and N is the number of double measurements.[34] The errors for angular and linear measurements on the cephalograms did not exceed 0.65 degree and 0.36 mm. The maximum

Figure 3A

Figure 3B

Figure 3C

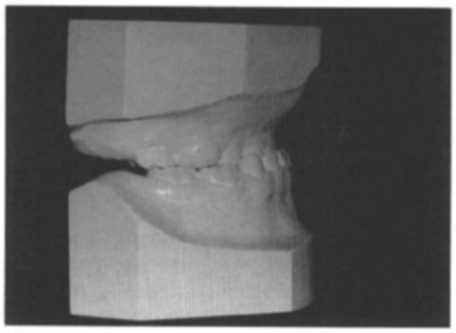

Figure 3D

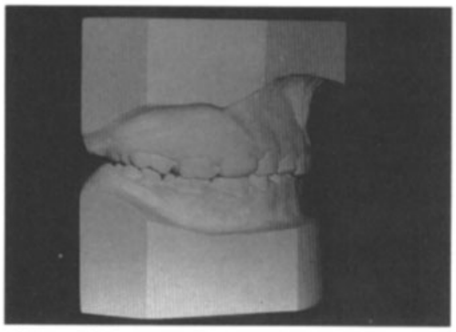

Figure 3E

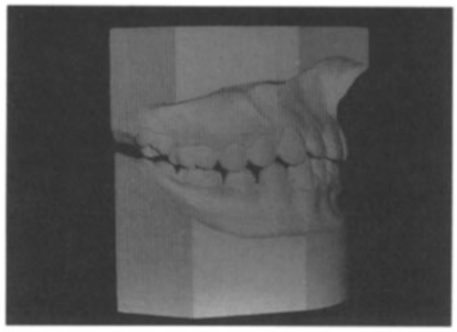

Figure 3F

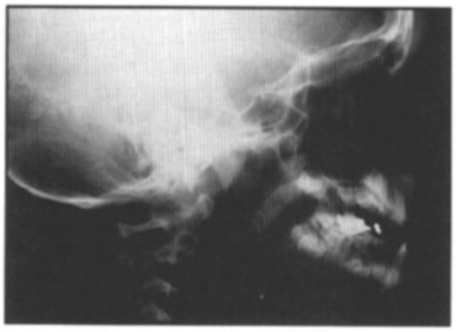

Figure 4A

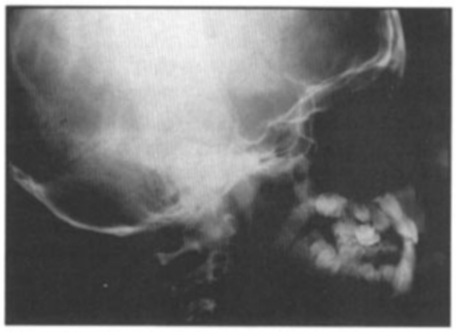

Figure 4B

Figure 4C

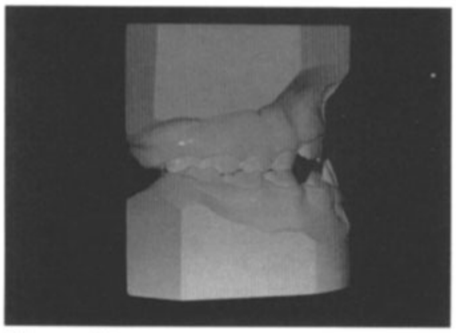

Figure 4D

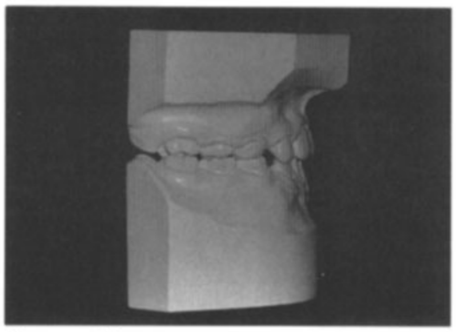

Figure 4E

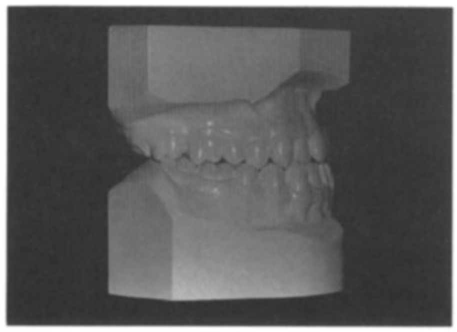

Figure 4F

Figure 3A-F
Cephalograms and study models of a patient treated for Class III malocclusion with protraction headgear. A and D: Pretreatment, age 5 years 1 month. B and E: Posttreatment, age 6 years 2 months. C and F: At time of follow-up, age 12 years 3 months. Note successful result at follow-up, with positive overjet.

Figure 4A-F
Cephalograms and study models of a patient treated for Class III malocclusion with protraction headgear. A and D: Pre-treatment, age 6 years 10 months. B and E: Post-treatment, age 8 years 6 months. C and F: At time of follow-up, age 15 years 1 month. Note unsuccessful result at follow-up, with edge-to-edge incisor occlusion.

errors for measurements on superimpositions and study models were 0.59 mm and 0.22 mm, respectively.

Data analysis

Sample means were calculated for each variable at each time period and for changes of each variable from one time period to another. T-tests for unpaired data were used to determine any significant differences between the treated and control subjects for cephalometric variables at T1,

Table 2
Pretreatment cephalometric measurements of cases treated for Class III malocclusion with maxillary protraction headgear, and baseline measurements at comparable time of untreated Class III controls

Variable	Treated (n=16) Mean	S.D.	Control (n=13) Mean	S.D.	Diff.	P value	Sign.
Maxillary skeletal							
SNA	79.31	3.85	80.19	6.03	-0.88	0.6373	NS
Co-Ans' (mm)	79.33	4.12	78.03	2.80	1.30	0.3415	NS
Maxillary dental							
Mx incisor to SN	101.06	8.95	95.23	7.37	5.83	0.0703	NS
Mandibular skeletal							
SNB	79.59	3.61	77.62	4.63	1.97	0.2066	NS
SN-Pg	79.31	3.67	77.04	4.51	2.27	0.1457	NS
Co-Gn (mm)	103.63	5.51	99.37	3.00	4.26	0.0140	*
Ar to SN (mm)	24.21	3.80	24.81	3.46	-0.60	0.6593	NS
Ar to SN perpendicular (mm)	15.44	1.77	15.09	1.87	0.35	0.6098	NS
Mandibular dental							
Mn incisor to Mn plane (Me-Go)	85.75	7.81	87.54	6.68	-1.79	0.5189	NS
Interincisal angle	138.91	11.34	140.04	13.74	-1.13	0.8096	NS
Maxillomandibular relationship							
ANB	-0.28	2.26	2.58	2.34	-2.86	0.0025	*
Wits (mm)	-5.32	2.09	-3.51	2.06	-1.81	0.0275	*
Overjet (mm)	-1.36	1.26	-0.27	1.12	-1.09	0.0221	*
Overbite (mm)	-0.41	2.80	-0.72	1.52	0.31	0.7242	NS
Vertical relationship							
Occlusal plane (to SN)	18.72	3.53	21.77	5.04	-3.05	0.0664	NS
Palatal plane (Ans-Pns to SN)	5.72	3.52	8.77	3.60	-3.05	0.0295	*
Mandibular plane (Me-Go to SN)	34.31	4.89	37.15	6.75	-2.84	0.1998	NS
Gonial angle (Ar-Go-Gn)	134.47	4.51	135.46	6.08	-0.99	0.6178	NS
Anterior facial ht. [N-Me] (mm)	102.33	4.07	103.78	5.60	-1.45	0.4271	NS
Posterior facial ht. [S-Go] (mm)	66.74	4.37	66.45	3.29	0.29	0.8434	NS
Posterior/Anterior facial ht. (%)	65.25	3.85	64.22	5.04	1.03	0.5396	NS

* P<0.05
**Significant with the Bonferroni correction, P<0.0024
NS=not significant

changes in cephalometric variables from T1 to T2, T2 to T3, and T1 to T3, and changes measured from the superimposed tracings from T1 to T2 and T2 to T3.

Bonferroni corrections were carried out to reduce the possibility that any significance was due to chance. P values less than the corresponding Bonferroni correction values were considered significant, while those between P<0.05 and the corresponding Bonferroni correction values were considered suspicious.

Pearson's product-moment correlation coefficients were calculated to determine any associations between changes from T1 to T2 and changes from T2 to T3. A correlation coefficient equal to or greater than 0.70 was considered clinically significant.

Wilcoxon Rank Sums tests were used to test for any differences in cephalometric variables between successes and failures.

Results

Sample characteristics

No pretreatment cephalometric differences were statistically significant between treated and control subjects (Table 2). However, the shorter mandible (Co-Gn), less severe ANB angle, Wits appraisal and overjet, and steeper palatal plane angle in the controls were considered suspicious (P<0.05, Table 2).

Cephalometric changes from T1 to T2

Treatment resulted in significant changes in ANB angle and overjet relationship (Bonferroni correction, P<0.0024, Table 3). Also, the treated subjects had significantly less increase in mandibular length or distance Co-Gn (Bonferroni correction, P<0.0024, Table 3). Changes in Wits appraisal, mandibular and gonial angles, distance of articulare to SN perpendicular, and posterior-to-anterior facial height ratio were considered suspicious (P<0.05, Table 3). The treated subjects also showed an increase in SNA

Table 3
Changes of cephalometric measurements from pre- (T1) to post- (T2) treatment of cases treated for Class III malocclusion with protraction headgear, and during similar time periods for untreated Class III controls

Variable	Treated (n=16) Mean change	S.D.	Control (n=13) Mean change	S.D.	Diff.	P value	Sign.
Maxillary skeletal							
SNA	0.91	1.04	-0.31	2.29	1.22	0.0955	NS
Co-Ans' (mm)	1.84	1.39	2.30	1.38	-0.46	0.3817	NS
Maxillary dental							
Mx incisor to SN	2.38	7.52	5.38	4.41	3.00	0.1920	NS
Mandibular skeletal							
SNB	-1.13	1.10	0.19	2.16	-1.32	0.0616	NS
SN-Pg	-0.50	1.21	0.73	2.15	-1.23	0.0819	NS
Co-Gn (mm)	1.87	1.52	4.38	2.31	-2.51	0.0016	**
Ar to SN (mm)	0.63	1.22	0.79	1.62	-0.16	0.7568	NS
Ar to SN perpendicular (mm)	0.33	0.92	1.19	0.86	-0.86	0.0154	*
Mandibular dental							
Mn incisor to Mn plane (Me-Go)	-1.69	5.56	0.50	3.51	-2.19	0.2285	NS
Interincisal angle	-1.66	10.02	-5.12	7.48	3.46	0.3116	NS
Maxillomandibular relationship							
ANB	2.03	1.62	-0.42	1.47	2.45	0.0002	**
WITS (mm)	1.91	2.42	-0.13	2.12	2.04	0.0246	*
Overjet (mm)	4.76	1.96	1.19	1.67	3.57	0.0000	**
Overbite (mm)	0.84	3.22	0.21	2.04	0.63	0.5405	NS
Vertical relationship							
Occlusal plane (to SN)	0.53	3.34	1.00	3.35	1.53	0.2319	NS
Palatal plane (Ans-Pns to SN)	-0.41	2.14	-0.62	1.65	0.21	0.7745	NS
Mandibular plane (Me-Go to SN)	0.94	1.09	-0.77	2.39	1.71	0.0298	*
Gonial angle (Ar-Go-Gn)	-1.94	1.52	-0.58	1.93	-1.36	0.0429	*
Anterior facial ht. [N-Me] (mm)	3.93	1.56	4.05	2.29	-0.12	0.8767	NS
Posterior facial ht. [S-Go] (mm)	1.44	1.61	3.19	1.92	-1.75	0.0130	*
Posterior/Anterior facial ht (%)	-1.06	1.10	0.50	1.70	-1.56	0.0059	*

* P<0.05; **Significant with the Bonferroni correction, P < 0.0024; NS = not significant

angle and a decrease in SNB angle, although the changes were not different from those in the controls (Table 3).

Overall superimposition indicated significant posterior movement of the mandibular incisors in the treated subjects relative to the controls (Bonferroni correction, P<0.0038, Table 4). Changes in positions of nasion, B point, and pogonion were considered suspicious (P<0.05, Table 4).

The posterior movement of B point and the mandibular incisors, and reduced translation of condylion measured on mandibular superimposition of the cases in the treated group relative to the controls were considered suspicious (P<0.05, Table 4).

Cephalometric changes from T2 to T3

Changes in position or length of either the maxilla or mandible were not found to be different between the two groups (Tables 5 and 6). Increased anterior movement of the mandibular incisors and reduction in overjet among the treated cases were considered suspicious (P<0.05, Table 5). The reduced translation of condylion on the mandibular superimposition in the treated cases was also considered suspicious (P<0.05, Table 6).

Cephalometric changes from T1 to T3

The ANB angle and overjet increased suspiciously more in the treated cases compared with the controls from start of treatment to end of follow-up (P<0.05, Table 7). At T3 the ANB angle and overjet were 0.13 deg (SD 2.91) and 2.21 mm (SD 1.40) in the treated cases and 1.42 deg (SD 3.47) and 1.08 mm (SD 1.59) in the controls, respectively. The reduced increase in mandibular length (Co-Gn) and the decrease in gonial angle in the treated subjects compared with the controls were also considered suspicious (P<0.05, Table 7).

Study model changes

Evaluation of sample means indicated that the

Table 4
Changes measured along averaged occlusal plane on superimposed tracings of cephalograms made pre- (T1) and post- (T2) treatment of cases treated with protraction headgear, and on similar superimposed tracings of untreated Class III controls

Variable	Treated (n=16) Mean change	S.D.	Control (n=13) Mean change	S.D.	Diff.	P value	Sign.
Overall superimposition							
N	0.53	0.43	1.20	0.82	-0.67	0.0164	*
Ans'	1.94	1.14	1.45	1.29	0.49	0.2888	NS
A	1.66	0.87	1.22	1.16	0.44	0.2500	NS
U1	4.02	1.86	2.95	2.24	1.07	0.1709	NS
L1	-0.74	2.17	1.96	2.22	-2.70	0.0028	**
B	-0.45	1.81	1.73	2.10	-2.18	0.0056	*
Pg	0.23	2.35	2.55	2.37	-2.32	0.0139	*
Maxillary superimposition							
Ans'	0.68	0.79	0.79	0.76	-0.11	0.7140	NS
A	0.41	0.64	0.51	0.76	-0.10	0.6844	NS
U1	2.41	1.38	2.12	1.72	0.29	0.6178	NS
Mandibular superimposition							
B	-0.51	0.46	-0.16	0.31	-0.35	0.0292	*
L1	-0.96	1.34	0.39	1.18	-1.35	0.0086	*
Co	0.38	0.72	1.69	1.32	-1.31	0.0047	*

* P < 0.05; ** Significant with the Bonferroni correction, P < 0.0038; NS = not significant

treated cases had a more pronounced mesial step in the postlactal plane than the controls at T1 (Table 8). Treatment induced a change toward establishing a flush postlactal plane. At T3, the configuration of the postlactal plane was similar in the two groups.

Only minor intergroup differences in intermolar width changes were found for any time period (Table 8).

Associations

Correlation coefficients between treatment and follow-up changes in ANB (r = -0.71), palatal plane angle (r = -0.70), and mandibular incisor to mandibular plane angle (r = -0.72) were statistically (Bonferroni correction, P < 0.0024) as well as clinically significant.

Successes vs failures

The successful cases had larger changes in overjet from T1 to T3 than the failures (Bonferroni correction, P<0.0024, Table 9). The differences in overjet change from T1 to T2 and mandibular incisor inclination at T2 between the groups were considered suspicious (P<0.05, Table 9).

Discussion

These results confirm that treatment with maxillary protraction headgear induces significant skeletal and dentoalveolar changes.[19-26] In keeping with previous studies[22,23,26] the major reason for the improvement in maxillomandibular relationship was downward and backward translation of the mandible. One reason for the observed repositioning may be a temporary growth retardation at the condyles due to the reciprocal forces from the chin-cup component of the facemask.[35] This explanation is supported by the fact that mandibular length increased less in the treated patients than in the controls during a similar time period (Table 3). Another possibility is that the condyles were located more posteriorly in the fossa after treatment than before due to elimination of any anterior shift. Maxillary protraction treatment was intended only for patients with true anterior crossbites. However, radiographic documentation of condylar position in centric occlusion was not available, and inclusion of patients with a component of shift to the negative overjet cannot, therefore, be ruled out. We may have overestimated pretreatment mandibular length in such cases, due to an erroneous location of the landmark condylion in a normal rather than distracted distance from the glenoid fossa. Such bias may reduce the confidence in our finding of less than expected increase in mandibular length during the protraction phase.

Our results also indicate a tendency for growth stimulation at the circummaxillary sutures, as reflected by a greater amount of forward translation of the anterior outline of the maxilla (Tables 3 and 4) in the treated patients compared with the controls. However, it should be stressed that the intergroup difference was not statistically significant. Similarly, a small but insignificant increase in maxillary prognathism of 0.3 degree was reported in one previous study,[22]

Table 5
Changes in cephalometric measurements from posttreatment (T2) to a minimum of 1 year follow-up (T3) of Class III cases treated with protraction headgear, and during similar time periods for untreated Class III controls

	Treated (n=16)		Control (n=13)				
Variable	Mean change	S.D.	Mean change	S.D.	Diff.	P value	Sign.
Maxillary skeletal							
SNA	0.00	2.27	1.31	1.35	-1.31	0.0660	NS
Co-Ans' (mm)	4.70	3.61	5.20	2.14	-0.50	0.6448	NS
Maxillary dental							
Mx incisor to SN	2.78	7.70	3.81	4.04	-1.03	0.6492	NS
Mandibular skeletal							
SNB	1.63	1.22	1.96	1.46	-0.33	0.5047	NS
SN-Pg	1.88	1.26	2.23	1.75	-0.35	0.5300	NS
Co-Gn (mm)	9.30	5.36	10.46	3.32	-1.16	0.5032	NS
Ar to SN (mm)	1.83	2.09	2.25	1.83	-0.42	0.5715	NS
Ar to SN perpendicular (mm)	2.16	2.47	1.29	1.03	0.87	0.2174	NS
Mandibular dental							
Mn incisor to Mn plane (Me-Go)	3.34	6.22	-0.15	2.20	3.49	0.0497	*
Interincisal angle	-4.38	8.97	-2.96	3.76	-1.42	0.5736	NS
Maxillomandibular relationship							
ANB	-1.63	2.13	-0.73	1.24	-0.90	0.1708	NS
Wits (mm)	-0.79	2.25	-0.60	2.59	-0.19	0.8346	NS
Overjet (mm)	-1.19	1.73	0.16	0.85	-1.35	0.0120	*
Overbite (mm)	1.32	1.56	0.78	1.31	0.54	0.3299	NS
Vertical relationship							
Occlusal plane (to SN)	-2.22	3.20	-2.38	3.04	0.16	0.8883	NS
Palatal plane (Ans-Pns to SN)	1.44	2.54	0.00	2.13	1.44	0.1157	NS
Mandibular plane (Me-Go to SN)	-1.75	1.74	-0.73	1.79	-1.02	0.1329	NS
Gonial angle (Ar-Go-Gn)	-2.47	1.90	-1.31	1.98	-1.16	0.1204	NS
Anterior facial ht. [N-Me] (mm)	7.92	4.18	8.82	2.08	-0.90	0.4574	NS
Posterior facial ht. [S-Go] (mm)	7.50	3.89	6.84	3.09	0.66	0.6210	NS
Posterior/Anterior facial ht. (%)	2.16	1.73	1.00	2.19	1.16	0.1232	NS

* $P < 0.05$; ** Significant with the Bonferroni correction, $P < 0.0024$; NS = not significant

while a significant increase of 0.8 degree during treatment with maxillary protraction headgear was found in another.[25] One reason experimental studies[8-11] constantly demonstrate pronounced forward movement of the maxilla could be that heavy and continuous protraction forces are used. The need for maxillary advancement in our sample was limited because the downward and backward repositioning of the mandible aided in the relatively rapid establishment of a positive overjet. Evaluation of cases treated for cleft lip and palate[29,30] indicates that more significant maxillary effects may be expected if longer periods of protraction are required to correct greater skeletal discrepancies.

Evaluation of our superimpositions indicates that the major dental contribution to the significant increase in overjet was retroclination of the mandibular incisors, despite the fact that no appliances were attached to these teeth. Similar findings have been reported in a previous study.[22] This suggests the production of distally directed occlusal forces to the mandibular incisors, probably during intermediate stages of overjet correction. Another possibility is soft tissue pressure from the chin-cup component of the protraction headgear. The maxillary incisors were only slightly proclined during treatment in our sample. An even greater proclination occurred in the controls during a similar observation period. However, these findings were not significant (Table 3), and may have been biased by differences in frequency of eruption of permanent incisors during the observation periods of the two groups. The maxillary deciduous incisors were present in 4 of the 16 treated patients and in 11 of the 13 controls at the start of the observation, and were replaced by permanent incisors in only one of the treated patients and in as many as 10 of the controls. A spontaneous proclination of the permanent incisors relative to the deciduous predecessors is well docu-

Table 6
Changes measured along averaged occlusal plane on superimposed tracings of cephalograms made posttreatment (T2) and a minimum of 1 year follow-up (T3) of cases treated with protraction headgear and on similar superimposed tracings of untreated Class III controls

Variable	Treated (n=16) Mean change	S.D.	Control (n=13) Mean change	S.D.	Diff.	P value	Sign.
Overall superimposition							
N	1.79	1.05	1.52	0.77	0.27	0.4402	NS
Ans'	2.17	2.04	2.99	1.13	-0.82	0.1819	NS
A	2.23	1.62	2.90	1.12	-0.67	0.2131	NS
U1	3.89	2.81	5.20	1.48	-1.31	0.1202	NS
L1	5.15	2.52	5.02	1.85	0.13	0.8761	NS
B	4.16	2.08	4.60	1.88	-0.44	0.5608	NS
Pg	5.41	2.98	5.45	2.59	-0.04	0.9719	NS
Maxillary superimposition							
Ans'	1.37	1.60	1.29	0.79	0.08	0.8647	NS
A	1.31	1.18	1.18	0.83	0.13	0.7364	NS
U1	2.75	2.38	3.37	1.21	-0.62	0.3692	NS
Mandibular superimposition							
B	-0.07	0.35	-0.11	0.39	0.04	0.7469	NS
L1	2.07	1.51	1.06	1.04	1.01	0.0507	NS
Co	2.94	2.32	4.58	1.35	-1.64	0.0253	*

* P < 0.05; ** Significant with the Bonferroni correction, P < 0.0038; NS = not significant

mented.[36] Such proclination may also be associated with a more forward position of point A, which was one of the two landmarks used to represent the anterior outline of the maxilla. Accordingly, we may have underestimated the amount of forward movement of the maxilla during maxillary protraction in our study.

Study model measurements indicated that treatment induced a change toward establishing a flush postlactal plane (Table 8), favoring the potential for first molar eruption into a Class I rather than a Class III relationship.[37] Inferences from our cephalometric analyses (Tables 3 and 4) suggest that the major reason for this improvement was the downward and backward repositioning of the mandible. However, some mesial movement of the maxillary molars may also have occurred.

The lack of significant differences between the patients and controls during the follow-up period (Tables 5 and 6) suggests that the favorable treatment effect on the maxillomandibular relationship was maintained. However, improvement in the maxillomandibular relationship was less significant at the time of follow-up than immediately after treatment. Similarly, the treatment effect of increased overjet was diminished, mainly due to proclination of the mandibular incisors. Such relapse has been demonstrated in a previous study,[22] and may be due to removal of the restricting forces from the chin-cup portion of the protraction headgear. Despite this, a positive overjet was maintained at the end of follow-up in the patients. However, in some cases, we considered the relapse in overjet to be of such degree that we classified the treatment as unsuccessful at the time of follow-up (Figure 4). We considered the treatment successful if an overjet of 2 mm or greater was maintained (Figure 3). The successfully treated cases demonstrated a significantly greater change in overjet during treatment, suggesting that some overcorrection may be necessary for maintenance of a successful correction. A similar recommendation has been made previously.[38] Also, achievement of a positive overbite has been shown to be important for maintenance of a positive overjet after treatment.[39] We did not find any significant difference in overbite between the successes and failures at the end of follow-up. However, it should be stressed that the small sample size limited the chance of detecting significances. Despite this, we did find that the mandibular incisors at the end of active treatment were more retroclined among the successes compared with the failures. This finding supports a previous conclusion,[39] and may suggest that retroclination of mandibular incisors during treatment is important for maintenance of the overjet correction. We also found that treatment and follow-up changes in maxillomandibular skeletal relationship, palatal plane, and mandibular incisor inclination were negatively associated. This may imply that the greater the treatment change, the greater the tendency for relapse.

Every effort was made to match controls with

Table 7
Changes of cephalometric measurements from pretreatment (T1) to a minimum of 1 year follow-up (T3) of Class III cases treated with protraction headgear, and during similar time periods for untreated Class III controls

	Treated (n=16)		Control (n=13)				
Variable	Mean change	S.D.	Mean change	S.D.	Diff.	P value	Sign.
Maxillary skeletal							
SNA	0.91	1.93	1.00	2.64	-0.09	0.9129	NS
Co-Ans' (mm)	6.54	3.85	7.51	2.75	-0.97	0.4553	NS
Maxillary dental							
Mx incisor to SN	5.16	7.55	9.19	5.84	-4.03	0.1260	NS
Mandibular skeletal							
SNB	0.50	1.47	2.15	2.77	-1.65	0.0687	NS
SN-Pg	1.38	1.47	2.96	2.82	-1.58	0.0834	NS
Co-Gn (mm)	11.17	5.21	14.83	3.03	-3.66	0.0263	*
Ar to SN (mm)	2.46	1.87	3.05	2.38	-0.59	0.4621	NS
Ar to SN perpendicular (mm)	2.49	2.71	2.48	1.44	0.01	0.9982	NS
Mandibular dental							
Mn incisor to Mn plane (Me-Go)	1.66	4.48	0.35	3.70	1.31	0.4056	NS
Interincisal angle	-6.03	9.07	-8.08	7.79	2.05	0.5259	NS
Maxillomandibular relationship							
ANB	0.41	1.51	-1.15	2.23	1.56	0.0334	*
WITS (mm)	1.12	2.75	-0.73	3.46	1.85	0.1201	NS
Overjet (mm)	3.57	2.19	1.35	1.85	2.22	0.0072	*
Overbite (mm)	2.16	2.89	0.99	1.77	1.18	0.1889	NS
Vertical relationship							
Occlusal plane (to SN)	-1.69	3.88	-3.38	2.84	1.69	0.1999	NS
Palatal plane (Ans-Pns to SN)	1.03	1.84	-0.62	2.98	1.65	0.0978	NS
Mandibular plane (Me-Go to SN)	-0.81	1.80	-1.50	2.75	0.69	0.4249	NS
Gonial angle (Ar-Go-Gn)	-4.41	2.80	-1.88	3.34	-2.53	0.0355	*
Anterior facial ht. [N-Me] (mm)	11.85	3.78	12.87	2.78	-1.02	0.4275	NS
Posterior facial ht. [S-Go] (mm)	8.95	4.02	10.03	2.87	-1.08	0.4237	NS
Posterior/Anterior facial ht. (%)	1.09	1.88	1.49	1.90	-0.40	0.5770	NS

* $P < 0.05$; ** Significant with the Bonferroni correction, $P < 0.0024$; NS = not significant

treated patients, selecting all cases with a negative overjet and/or a mesial step in the postlactal plane in the age range of 4 to 9 years from the Burlington and the Bolton-Brush Growth Centers. Despite this, the treated patients had longer and more prognathic mandibles and slightly more retrusive maxillae. They also presented with a greater negative overjet and a more pronounced mesial step in the postlactal plane. Accordingly, any significant treatment or overall changes may have been masked by the fact that the controls did not possess the same severity of Class III malocclusion as the treated patients at the start of the observation period. However, our attempt to identify matched controls for evaluation of the effects of early Class III correction represents a definite improvement over previous studies.[21-26] Our observed differences are therefore likely to represent actual treatment effects, with minimal bias due to growth differences.

Another potential problem may be that the actual treatment time was shorter than the time period between the T1 and T2 cephalograms (Table 1). Accordingly, the reported changes from T1 to T2 were not entirely generated by treatment.

Our findings indicate that early intervention with maxillary protraction headgear for a short period in Class III malocclusion cases is beneficial. The major treatment effects were repositioning of the mandible and retroclination of the mandibular incisors. However, any skeletal and dentoalveolar advancement of the maxilla contributed to the clinically significant improvement in the maxillomandibular relationship and correction of the negative overjet (Figure 2). As a result, an environment that is conducive to the development of favorable occlusal relationships may be established. The need for retention during the follow-up period before initiation of a second treatment phase may be minimal, particularly if the overjet is overcorrected.

Table 8
Model measurements made at pre- (T1) and post- (T2) treatment and a minimum of 1 year follow-up (T3) of Class III cases treated with protraction headgear, and at similar time periods for untreated Class III controls

Variable	Mean	S.D.	Mean	S.D.	Diff.
T1	Treated (n=16)		Control (n=10)		
Lower E-E Width (mm)	35.91	1.85	36.38	2.38	-0.47
Upper E-E Width (mm)	42.19	3.41	42.86	2.27	-0.67
Right postlactal plane (mm)	-3.00	1.27	-2.27	1.22	-0.73
Left postlactal plane (mm)	-2.59	1.26	-1.92	1.45	-0.67
T2	Treated (n=8)		Control (n=9)		
Lower E-E Width (mm)	37.37	1.56	36.57	2.15	0.80
Upper E-E Width (mm)	43.45	2.60	43.50	2.33	-0.05
Right postlactal plane (mm)	-0.43	1.42	-2.20	1.10	1.77
Left postlactal plane (mm)	-0.69	1.25	-2.23	1.55	1.54
T3	Treated (n=7)		Control (n=3)		
Lower E-E Width (mm)	37.98	2.48	36.77	5.70	1.21
Upper E-E Width (mm)	43.84	2.71	43.88	3.53	-0.04
Right postlactal plane (mm)	-1.84	0.79	-1.58	0.59	-0.26
Left postlactal plane (mm)	-1.51	1.27	-0.91	1.00	-0.60

Table 9
Significant results of Wilcoxon Rank Sums tests of cephalometric variables of successful (T3 OJ > 2 mm) and failed (T3 OJ < 2 mm) Class III cases treated with protraction headgear

	Success (n=11)			Failure (n=5)			
Variable	Mean	S.D.	Median	Mean	S.D.	Median	P value / Sign.
T2: Mn incisor to Mn Plane (Me-Go)	81.27	5.68	80.00	90.20	7.95	93.00	0.0353 *
T1-T2: Mean change in overjet	5.54	1.82	4.80	3.06	0.96	3.11	0.0127 *
T1-T3: Mean change in overjet	4.71	1.56	4.51	1.09	0.85	1.21	0.0022 **

P< 0.05; ** Significant with the Bonferroni correction, P < 0.0024

Conclusions

The early correction of Class III malocclusion with maxillary protraction headgear induces significant skeletal and dentoalveolar change. The major reason for negative overjet correction in our sample was downward and backward movement of the mandible combined with retroclination of the mandibular incisors. However, skeletal and dentoalveolar advancement of the maxilla added to the improvement. Treatment consistently induced clinically significant changes toward establishing a positive overjet and a flush postlactal plane, favoring eruption of first molars into a Class I rather than Class III relationship.

We observed no differences between treated patients and controls during the posttreatment follow-up period. Despite some relapse, the patients demonstrated a net improvement in maxillomandibular relationship, and a positive overjet was maintained at the end of the follow-up period. Overcorrection of the overjet during treatment may be important for maintenance of a successful correction.

Acknowledgments

The authors would like to thank Dr. Vincent G. Kokich for providing part of the treated sample. This research was supported by the University of Washington Orthodontic Alumni Association.

Author Address

Dr. Jon Årtun
Department of Orthodontics
University of Washington, SM-46
Seattle, WA 98195

Y-H. Chong is in private practice in Singapore. This paper is based on her research for the degree of Master of Science in Dentistry at the University of Washington, Seattle.

J.C. Ive is in private practice in Bothell, Washington.

J. Årtun is professor in the Department of Orthodontics, University of Washington, Seattle, Washington.

References

1. Janzen EK, Bluher JA. The cephalometric, anatomic, and histologic changes in Macaca mulatta after application of a continuous-acting retraction force on the mandible. Am J Orthod 1965; 51:823-855.
2. Joho JP. The effects of extraoral low-pull traction to the mandibular dentition of Macaca mulatta. Am J Orthod 1973; 64:555-577.
3. Asano T. The effects of mandibular retractive force on the growing rat mandible. Am J Orthod Dentofac Orthop 1986; 90:464-474.
4. Sakamoto T, Iwase I, Uka A, Nakamura S. A roentgenocephalometric study of skeletal changes during and after chin cup treatment. Am J Orthod 1984; 85:341-350.
5. Wendell PD, Nanda R, Sakamoto T, Nakamura S. The effects of chin cup therapy on the mandible: A longitudinal study. Am J Orthod 1985; 87:265-274.
6. Mitani H, Fukazawa H. Effects of chincup force on the timing and amount of mandibular growth associated with anterior reversed occlusion (Class III malocclusion) during puberty. Am J Orthod Dentofac Orthop 1986; 90:454-463.
7. Sugawara J, Asano T, Endo N, Mitani H. Long-term effects of chincup therapy on skeletal profile in mandibular prognathism. Am J Orthod Dentofac Orthop 1990; 98:127-133.
8. Dellinger EL. A preliminary study of anterior maxillary displacement. Am J Orthod 1973; 63:509-516.
9. Kambara T. Dentofacial changes produced by extraoral forward force in the Macaca irus. Am J Orthod 1977; 71:249-277.
10. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. Am J Orthod 1978; 74:121-141.
11. Jackson GW, Kokich VG, Shapiro PA. Experimental and postexperimental response to anteriorly directed extraoral force in young Macaca nemestrina. Am J Orthod 1979; 75:318-333.
12. Dietrich UC. Morphological variability of skeletal Class III relationships as revealed by cephalometric analysis. Trans Eur Orthod Soc 1970; 46:131-143.
13. Ellis E III, McNamara JA Jr. Components of adult Class III malocclusion. J Oral Maxillofac Surg 1984; 42:295-305.
14. Williams S, Andersen CE. The morphology of the potential Class III skeletal pattern in the growing child. Am J Orthod 1986; 89:302-311.
15. Guyer EC, Ellis EE III, McNamara JAJr, Behrents RG. Components of Class III malocclusion in juveniles and adolescents. Angle Orthod 1986; 56:7-30.
16. Chang H-P, Kinoshita Z, Kawamoto T. Craniofacial pattern of Class III deciduous dentition. Angle Orthod 1992; 62:139-144.
17. Delaire J. La croissance maxillaire: Deductions therapeutiques. Trans Eur Orthod Soc 1971; 47:81-102.
18. Cozzani G. Extraoral traction and Class III treatment. Am J Orthod 1981; 80:638-650.
19. Rygh P, Tindlund R. Orthopedic expansion and protraction of the maxilla in cleft palate patients - a new treatment rationale. Cleft Palate J 1982; 19:104-112.
20. McNamara JA. An orthopedic approach to the treatment of Class III malocclusion in young patients. J Clin Orthod 1987; 21:598-608.
21. Irie M, Nakamura S. Orthopedic approach to severe skeletal Class III malocclusion. Am J Orthod 1975; 67:377-392.
22. Wisth PJ, Tritrapunt A, Rygh P, Böe OE, Norderval K. The effect of maxillary protraction on front occlusion and facial morphology. Acta Odontol Scand 1987; 45:227-237.
23. Ishii H, Morita S, Takeuchi Y, Nakamura S. Treatment effect of combined maxillary protraction and chincup appliance in severe skeletal Class III cases. Am J Orthod Dentofac Orthop 1987; 92:304-312.
24. Mermigos J, Full CA, Andreasen G. Protraction of the maxillofacial complex. Am J Orthod Dentofac Orthop 1990; 98:47-55.
25. Ngan P, Wei SHY, Hägg U, Yiu CKY, Merwin D, Stickel B. Effect of protraction headgear on Class III malocclusion. Quintessence Int 1992; 23:197-207.
26. Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal Class III children treated by a modified maxillary protraction headgear and a chin cup: a longitudinal cephalometric appraisal. Eur J Orthod 1993; 15:211-221.
27. Sakamoto T. Effective timing for the application of orthopedic force in the skeletal Class III malocclusion. Am J Orthod 1981; 80:411-416.
28. Tindlund RS. Orthopaedic protraction of the midface in the deciduous dentition. J Craniomaxillofac Surg 1989; 17(suppl. 1):17-19.
29. Tindlund RS, Rygh P, Böe OE. Orthopedic protraction of the upper jaw in cleft lip and palate patients during the deciduous and mixed dentition periods in comparison with normal growth and development. Cleft Palate Craniofac J 1993; 30:182-194.
30. Tindlund RS. Skeletal response to maxillary protraction in patients with cleft lip and palate before age 10 years. Cleft Palate Craniofac J 1994; 31:295-308.
31. Elmajian KE. A serial study of facial growth as related to cranial base morphology. M.S.D. Thesis, University of Washington, 1959.
32. Doppel DM, Damon WM, Joondeph DR, Little RM. An investigation of maxillary superimposition techniques using metallic implants. Am J Orthod Dentofac Orthop 1994; 105:161-168.
33. Björk A. Variations in the growth pattern of the human mandible: Longitudinal radiographic study by the implant method. J Dent Res 1963; 42(suppl. 1):400-411.
34. Dahlberg G. Statistical methods for medical and biological students. London: George Allen & Unwin Ltd., 1940:122-132.
35. Campbell PM. The dilemma of Class III treatment. Early or late? Angle Orthod 1983; 53:175-191.
36. Riolo ML, Moyers RE, McNamara JAJr, Hunter WS. An atlas of craniofacial growth, 2nd ed. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1979:77-84.
37. Bishara SE, Hoppens BJ, Jakobsen JR, Kohout FJ. Changes in the molar relationship between the deciduous and permanent dentitions: A longitudinal study. Am J Orthod Dentofac Orthop 1988; 93:19-28.
38. Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. J Clin Orthod 1988; 22:314-325.
39. Stensland A, Wisth PJ, Böe OE. Dentofacial changes in children with negative overjet treated by combined orthodontic and orthopaedic approach. Eur J Orthod 1988; 10:39-51.