Very early face mask therapy in Class III children

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Abstract: The purpose of this study was to examine the effects of very early face mask therapy in children with Class III malocclusion. At pretreatment (T0), 40 female subjects who were eventually treated showed a more severe Class III pattern (ANB 0.1°) than did 28 skeletal Class III female subjects who remained untreated (ANB 0.4°), as observed in the Wits analysis. Posttreatment results (T1) showed significant ($p<0.01$) anterior advancement of the maxillary components, backward rotation of the mandible without increased lower anterior facial height, and an improved incisor relationship. Comparison of posttreatment (T1) and postretention (T2) records, however, revealed no increase in SNA in the treated group. SNA did increase in the untreated group, with no significant difference in ANB angle. The x-components of B-point and Me showed a significant ($p<0.05$) difference between the two groups. At postretention (T2), N-S-Ba, N-S-Ar, and CC-Ba tended to increase more in the treated group than in the untreated group.

Key Words: Anterior crossbite, Skeletal Class III malocclusion, Early treatment, Maxillary protraction, Face mask therapy

In about half of all skeletal Class III malocclusions, the maxilla is retrognathic and/or the mandible is prognathic.[1-5] Because chin pads around the mandible act as anchorage for the counterforce, a face mask appliance affects all the skeletal components that contribute to Class III discrepancies.[6-9] Early face mask treatment has been reported to be very effective.[10-14] Ngan et al.[15] recently reported significant dentofacial changes associated with improvements in the soft tissue profile after 6 months use of a face mask with expansion in Chinese children included in a 1-year posttreatment study.[16]

Although moderately severe skeletal Class III malocclusion can be treated during late pubertal growth using a face mask[9] and chin cup[17] to minimize total treatment time, many orthodontists prefer to treat the condition early because they believe the skeletal improvement will be greater if treatment is initiated early. Face mask treatment, therefore, is generally started when the central incisors erupt[18] or when the four maxillary incisors and the maxillary first molars erupt.[11]

The present study focused on the effects of very early (4 years 2 months, T0) face mask treatment and the posttreatment (3 years 3 months, T1) and postretention (3 years 7 months, T2) results in Class III primary dentition children. Untreated skeletal Class III subjects (mean age 4 years 2 months) were matched for age and sex to serve as controls.

Materials and methods

Forty female subjects were chosen at random from 96 female subjects who had been treated with face mask therapy and without extractions. All subjects had full retention records taken a mean of 3 years 7 months after treatment. The force of maxillary protraction was around 150 gm per side and patients had been instructed to wear the mask for 14 hours per day until acceptable posterior occlusion was obtained. The anterior crossbite was corrected an average of 6 months (range 3 months to 11 months) after face mask therapy had been started. Immediately after face mask use was discontin-

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ued, a Hawley-type removable retainer was placed and the patient's parents were told to make sure the appliance was worn, during sleep, for 1 year. The removable retainer was incorporated with a posterior acrylic resin bite block, and .016 stainless steal wire loops were applied when needed to correct any anterior crossbite (Figure 1A-B).

Twenty-eight untreated Class III females, 15 with longitudinal records and 13 with semilongitudinal records (pairs of films at T0 and T1 or at T1 and T2), constituted the control group (Table 1). The average time interval between films in the treated group was 3 years 3 months for the T1-T0 period and 3 years 7 months for the T2-T1 films; in the control group, the average T1-T0 period was 3 years 3 months, and the T2-T1 period was 4 years 1 month (Table 1). Criteria for the present case selection included mild skeletal Class III malocclusion, mandibular symmetry, overbite greater than 2 mm, and mild diverse pressure habits (e.g., thumb sucking) without airway problems such as mouth breathing, associated with adenoids and tonsils.

Cephalometric analysis

For each subject, lateral cephalometric measurements were obtained at T0, T1, and T2. It was not possible to note cephalometric variables relating to the position of the mandible because many Class III children tend to bite in a forward direction when the initial (pretreatment) headfilms are taken. The axis of the maxillary and mandibular central incisors without formation of their respective roots at T0 was obtained by superimposition at T1[19] (Figure 2).

A computerized x-y coordinate system (Win Ceph, Hoya, Japan) was used for the cephalometric analysis. The reference lines (x- and y-axes) consisted of the Frankfort plane and a line perpendicular to Frankfort passing through sella, according to the method of Sakamoto;[20] landmarks were then identified and digitized (Figure 3).

Cephalometric measurements were used to identify differences in maxillary, mandibular, dentoalveolar, and cranial base structures between the untreated and the treated groups at T0, T1, and T2 (Tables 2 through 7). Horizontal and vertical changes in ANS, A-point, B-point, and Me were also calculated (Table 8) and summarized graphically (Figure 4).

Cephalometric values were calculated using a two-tailed independent two-group Student's *t*-test after comparison by *F*-test (Tables 2 through 8).

To evaluate overall changes in cephalometric measurements, average profilograms of the two groups were constructed and superimposed (Figures 5 and 6).

Results

At T1, 21 of 28 untreated skeletal Class III subjects showed a natural correction of the original anterior crossbite, but they continued to exhibit many characteristics of Class III malocclusion.

Cephalometric analysis

Maxilla and mandible (Tables 2, 4, and 6)

At T0, the maxillomandibular sagittal relationship, as indicated by the ANB angle, tended more toward a skeletal Class III pattern in the treated group (0.1° ± 1.7°) than in the untreated group (0.4° ± 1.3°), as observed in the Wits analysis.

At T1, a significant difference was seen between the two groups in the variables of the angle ANB ($p<0.01$). This was interpreted as an improvement in the skeletal Class III pattern in the treated group. FMA (28.9°) showed a 0.7° decrease in the treated group (Table 4). At T2, the T2-T1 difference in facial angle showed a significantly ($p<0.05$) smaller increase in the treated group (1.2°) than in the untreated group (2.5°); this was also observed in the value of the ANB angle. The T2-T1 difference in ANB angle was zero (0.7°-0.7°) in the untreated group, but a 0.5° (1.4°-1.9°) decrease was seen in the treated group. FMA was significantly increased in the treated group (30°) compared with the untreated group (26.5°).

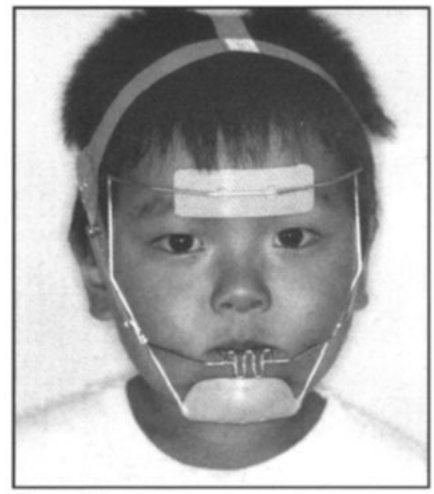

Figure 1A
A patient wearing face mask appliance

Figure 1B
A removable retainer incorporated with the hooks, posterior acrylic resin bite block, and .016 ss wire loops

Dentoalveolar adaptation (Tables 2, 4, and 6).

In the value of L1-to-mandibular-plane angle (IMPA), the lower incisors were more upright at T0 in the treated group (84.8°) than in the controls (87.5°). At T1, IMPA had increased in both groups, and at T2, IMPA was 90° in the treated group and 91° in the untreated group. U1-to-FH was smaller in the treated group (115.4°) than in the

Table 1
Characteristics of facemask-treated and untreated skeletal Class III subjects

n	T0 mean (range)	n	T1 mean (range)	n	T2 mean (range)	Period of facemask use
Facemask-treated group						
40	4 years 2 months (3 y 3 m - 5 y 3 m)	40	7 years 5 months (6 y 2 m - 8 y 5 m)	40	11 years 0 months (10 y 2 m - 12 y 5 m)	6 months (3 m - 11 m)
Age-matched untreated group						
23*	4 years 2 months (3 y 1 m - 5 y 5 m)	28*	7 years 5 months (6 y 3 m - 8 y 3 m)	20	11 years 6 months (9 y 11 m - 13 y 3 m)	—

*Untreated data consist of 15 longitudinal sets of records and 13 semilongitudinal (8 at T0 and T1, 5 at T1 and T2)

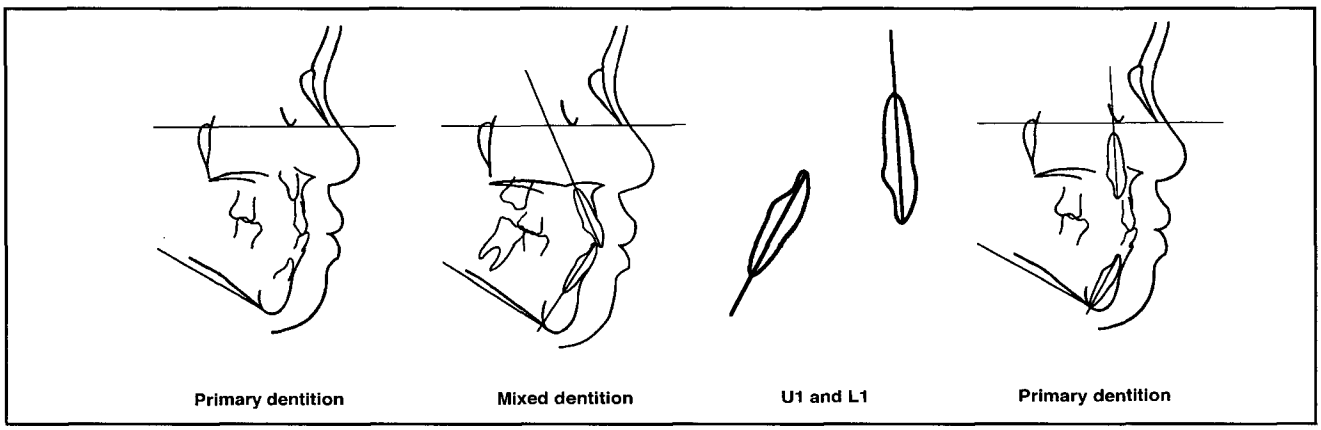

Figure 2
A construction axis of maxillary and mandibular centrals

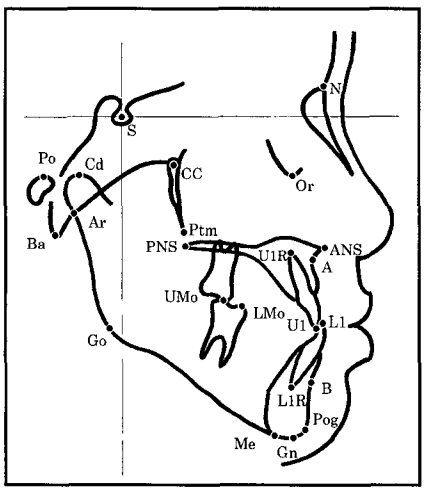

Figure 3
Cephalometric landmarks

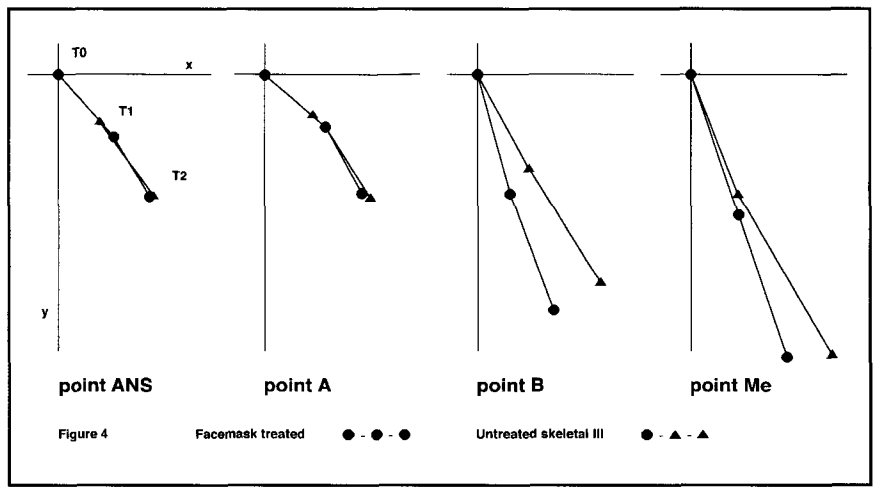

Figure 4
Changes in ANS, A-point, B-point, and Me summarized graphically

untreated group (118.1°, $p<0.05$). The T2-T0 differences in U1-to-FH increased in both groups (Table 6).

Cranial base (Table 3, 5, and 7)

At T0, a significant difference existed between the two groups for the variables of cranial base angle (N-S-Ba) and the distance between the center of the pterygomaxillary fissure and basion (CC-Ba, $p<0.05$). In the treated group, N-S-Ba (132.9°), N-S-Ar (122.2°), and CC-Ba (41.3 mm) were all significantly smaller than in the untreated group (136.5°, 124.7°, and 42.9 mm, respectively). At T2, however, N-S-Ba and N-S-Ar showed no significant difference between the two groups.

Horizontal and vertical changes in landmark positions (Table 8, Figure 4)

To evaluate the movement of individual landmarks over time, the movement of landmarks from T0 to T1 and from T1 to T2 were measured on headfilms relative to the x- and y-axes. Values were analyzed for comparison between groups. T1-T0 differences in ANS (y) and A-point (y) showed significantly more vertical changes (-4.9 mm, -4.1 mm) in the treated group than in the untreated group (-3.7 mm, -3.1 mm), as observed at B-point (y) and Me (y). The x-components of B-point and Me showed a significant difference between the two groups from T2-T1.

Profilograms (Figures 5 and 6)

Figures 5 and 6 show overall changes in the skeletal framework originating from sella for T1-T0 and T2-T1 differences. Treated subjects showed a significant advancement of the maxilla at T1 and a backward rotation of the mandible at T2.

Discussion

Because the internal arrangement of the craniofacial sutures and periodontal membrane are similar

Table 2
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at pretreatment (T0)

Variable	Treated group (n=40) Mean	SD	Untreated (n=23) Mean	SD	(mm or degrees) *p*-value
Maxilla and mandible					
SNA	79.2	3.4	78.2	3.0	0.253
SNB	79.1	3.0	77.8	2.7	0.096
ANB	0.	1.7	0.4	1.3	0.474
Facial angle	83.6	2.6	83.5	2.7	0.887
FMA	29.6	4.2	28.3	4.4	0.257
Ramus angle (FH)	81.2	4.0	81.2	4.3	1.000
Gonial angle	128.4	6.	127.2	5.8	0.459
NF (FH)	-1.9	2.7	-1.6	2.3	0.661
Functional OP	12.7	3.9	12.6	3.1	0.918
Gn-Cd	91.9	3.9	91.1	4.1	0.452
Denture					
U1 to FH	107.5	7.3	108.8	8.2	0.547
IMPA	84.8	5.4	87.5	5.7	0.070
Interincisal angle	138.1	8.5	135.4	11.3	0.295
Wits	-4.5	1.9	-4.0	1.4	0.283

Table 3
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at pretreatment (T0)

Variable	Treated group (n=40) Mean	SD	Untreated (n=23) Mean	SD	(mm or degrees) *p*-value
Cranial base					
S-N	61.3	2.5	61.9	2.2	0.350
SN to FH	6.0	2.2	6.6	2.4	0.325
N-Ba	91.1	3.9	92.8	3.5	0.094
N-CC	49.8	2.8	49.9	2.2	0.885
CC-Ba	41.3	2.6	42.9	2.4	0.021*
NSBa	132.9	4.4	136.5	4.2	0.003**
NSAr	122.2	4.8	124.7	4.5	0.049*

Table 4
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at posttreatment (T1)

Variable	Treated group (n=40) Mean	SD	Untreated (n=28) Mean	SD	(mm or degrees) p-value
Maxilla and mandible					
SNA	80.2	3.2	78.8	3.6	0.102
SNB	78.3	2.8	78.1	3.1	0.786
ANB	1.9	1.6	0.7	1.5	0.003**
Facial angle	84.4	2.3	85.0	2.5	0.318
FMA	28.9	4.7	27.9	3.6	0.354
Ramus angle (FH)	85.0	3.7	83.9	3.8	0.244
Gonial angle	123.9	6.3	124.0	5.2	0.946
NF (FH)	-1.9	2.6	-1.0	2.7	0.178
Functional OP	12.4	4.1	11.7	3.0	0.426
Gn-Cd	102.5	3.8	101.5	3.9	0.302
Denture					
U1 to FH	112.1	7.9	111.3	6.3	0.662
IMPA	92.2	6.2	93.3	7.4	0.515
Interincisal angle	126.7	11.6	127.5	10.5	0.775
Wits	-3.3	2.8	-4.4	2.3	0.096

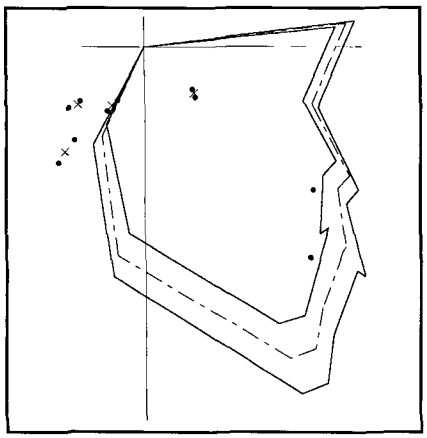

Figure 5
Superimposed profilogram of the treated group at T0, T1, and T2

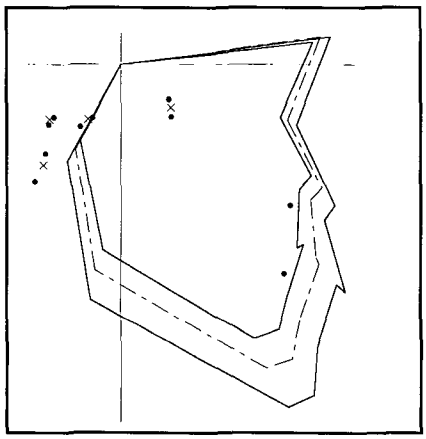

Figure 6
Superimposed profilogram of the untreated group at T0, T1, and T2.

histologically in their response to applied forces,[21-23] early face mask therapy can be very effective in protracting the maxilla, leading to improvement of the skeletal Class III morphology. Even if the overall effects of face mask therapy in advancing the maxilla are unclear,[14] it can create a backward and downward rotation of the mandible with retroclination of the mandibular incisors.[14-16] The unfavorable direction of force of maxillary protraction results in counterclockwise rotation of the maxillary components, which may biomechanically induce compressive stresses at the sutures.[24,25]

In this study, face mask hooks were attached to a removable bite

Table 5
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at posttreatment (T1)

Variable	Treated group (n=40) Mean	SD	Untreated (n=28) Mean	SD	(mm or degrees) p-value
Cranial base					
S-N	65.0	2.6	64.4	2.0	0.315
SN to FH	6.7	2.5	7.8	2.4	0.078
N-Ba	99.1	3.9	97.8	3.0	0.149
N-CC	53.7	2.6	53.0	2.5	0.278
CC-Ba	45.5	2.6	44.9	1.6	0.251
NSBa	133.8	4.1	135.4	3.9	0.116
NSAr	123.4	4.2	125.9	5.0	0.031*

Table 6
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at postretention (T2)

Variable	Treated group (n=40) Mean	SD	Untreated (n=20) Mean	SD	(mm or degrees) *p*-value
Maxilla and mandible					
SNA	80.2	3.8	80.9	3.5	0.545
SNB	78.8	3.6	80.2	3.4	0.210
ANB	1.4	1.9	0.7	1.3	0.182
Facial angle	85.6	2.9	87.5	2.2	0.025*
FMA	30.9	4.5	26.5	4.6	0.018*
Ramus angle (FH)	84.8	3.6	83.4	4.2	0.257
Gonial angle	125.2	6.1	123.1	5.6	0.260
NF (FH)	-2.5	2.5	-1.1	2.4	0.076
Functional OP	11.2	4.3	9.5	2.7	0.133
Gn-Cd	113.3	4.5	115.0	4.9	0.254
Denture					
U1 to FH	115.4	4.2	118.1	3.0	0.024*
IMPA	90.0	4.6	91.0	5.7	0.538
Interincisal angle	124.6	6.6	124.4	6.1	0.921
Wits	-3.9	3.2	-4.3	2.4	0.657

Table 7
Cephalometric comparison between facemask treated and untreated skeletal Class III groups at postretention (T2)

Variable	Treated group (n=40) Mean	SD	Untreated (n=20) Mean	SD	(mm or degrees) *p*-value
Cranial base					
S-N	67.8	2.5	67.7	2.4	0.897
SN to FH	7.2	2.6	7.4	2.2	0.793
N-Ba	105.3	3.6	105.4	3.7	0.931
N-CC	56.7	2.5	57.0	3.0	0.729
CC-Ba	48.7	3.2	48.4	2.4	0.739
NSBa	133.7	4.6	133.4	5.4	0.849
NSAr	124.8	4.5	126.0	5.8	0.461

plate at the distal sites of the deciduous first molars (#54 and #64) to obtain a horizontal reaction and favorable clockwise rotation of the maxillary components.

The mean period for face mask use was 6 months, and the children were very cooperative during both the treatment and retention periods.

At retention, most of the treated subjects were at the beginning of the pubertal growth spurt (mean age, 11 years 0 months), so we could not predict the degree of stability of the treatment. However, treatment was considered successful for 85% of 96 children with Class III malocclusion and anterior crossbite. Treatment for the relapsed subjects (15%), which was not analyzed in detail in the present study, might have been compromised by related abnormal functions.[26-32] Abnormal function of the tongue and lips is said to have an aberrant effect on the form of the dentoalveolar complex.[26] Subjects who exhibit complex tongue thrust swallowing with the teeth apart had a higher frequency of mandibular overjet (negative overjet) and mesial molar occlusion.[27] The functionally protrusive or deviated posture of the mandible may be genetic in origin.[28,29] Early orthodontic treatment with appliances or functional training might be a significant factor preventing Class III malocclusion.[30] If age is a factor in the incidence of abnormal habits in children,[31] myofunctional therapy could be effective.[31,32] The primary goal in treating a child with tongue thrust is to establish a proper relationship between the tongue, lips, and jaws.[33] The subjects who relapsed, with or without myofunctional therapy, showed a strong tendency to retain their original abnormal habits, emphasizing the necessity of bite training (mandibular closure) and muscle strengthening. This clinical approach could be supported by the evidence that the advantage of masticatory muscle training is based on the facts that EMG discharge in the corrected tongue thrusters group showed activity similar to that of the normal swallowers group,[34] and that the increased activity of EMG is positively correlated with the intensity of bite force.[35]

Table 8
Horizontal and vertical changes, ANS, A-point, B-point, and ME

Variable	Treated group		Untreated group	
	T1-T0	T2-T1	T1-T0	T2-T1
ANS:X	4.4	7.2	3.3	7.5
ANS:Y	-4.9*	-9.6	-3.7*	-9.5
A:X	4.7	7.5	3.7	8.2
A:Y	-4.1*	-9.3	-3.1*	-9.6
B:X	2.5	5.9*	4.0	9.5*
B:Y	-9.4*	-18.5	-7.4	-16.3
Me:X	3.7	7.4*	3.7	10.9*
Me:Y	-11.0*	-22.2	-9.4*	-22.0

Chong et al.[14] reported at follow-up that acquired positive overjet was diminished mainly by proclination of the mandibular incisors. In the present study, the 40 treated skeletal Class III subjects showed an acceptable occlusion at T2, with normal incisor relationship, a good profile, and a normal tooth-contact swallowing pattern. On the other hand, the 15% (of a total 96 treated subjects) who relapsed showed proclination of the mandibular incisors, which might be related to the presence of abnormal pressure habits remaining at posttreatment.

Although the skeletal profile in Japanese children with normal occlusion becomes straighter with aging,[36,37] the mean ANB angle at 3 years 10 months in Japanese females (4.5°) was maintained until 6 years 11 months, but diminished to 2.9° by 13 years 3 months.[37]

In the present study, treated maxillary components showed significant anterior advancement at T1. The initial ANB angle in the untreated group, 0.4°, increased slightly to 0.7° at 11 years 6 months (T2), maintaining the skeletal Class III pattern.

Susami[37] and Sawa,[38] in studies of Japanese children reported that anterior crossbite subjects showed more labial inclination of the maxillary central incisors than did subjects with normal occlusion. Twenty-one out of 28 untreated subjects showed a natural correction of anterior crossbite by the time the permanent incisors erupted (T1). The eruption of maxillary incisors associated with an increase in labial inclination may contribute to the correction of anterior crossbite.

Posttreatment results at T1 showed that significant ($p<0.01$) anterior advancement of the maxillary components occurred, the mandible rotated backward and downward without increasing the lower anterior facial height, and the incisor relationship improved. The T2-T1 difference, however, indicated that SNA did not increase in the treated group, although the untreated group showed a slight (2.1°) but insignificant increase (Table 8, Figure 4).

Enlow[39] reported that ethnic groups with a brachycephalic headform can have relative retrusion of the nasomaxillary complex with a more anterior relative placement of the entire mandible, resulting in a greater tendency toward a Class III profile. The absence of increase in SNA postretention (T2) in

the treated group indicates that the genetic growth trend in this Japanese Class III sample with a brachycephalic headform predominates over orthopedic effects obtained after treatment.

Conclusions

Cephalometric data of untreated and treated Class III groups were analyzed. The T1-T0 difference in the treated group showed that more advancement of the maxilla occurred, along with backward rotation of the mandible and correction of the anterior crossbite. At postretention (T2), the mandible in the treated group showed significantly less forward growth when compared with the untreated group. Although posttreatment results showed a significant anterior advancement of the maxillary components, there was no increase in SNA angle at postretention. Subjects who relapsed tended to maintain their original abnormal habits.

References

1. Sanborn RT. Differences between the facial skeletal patterns of Class III malocclusion and normal occlusion. Angle Orthod 1955;25:208-22.
2. Dietrich UC. Morphologic variability of the skeletal Class III relationship as revealed by cephalometric analysis. Trans Eur Orthod Soc 1970;131-43.
3. Guyer EC, Ellis EE, McNamara JA Jr, Behrents RG. Components of Class III malocclusion in juveniles and adolescents. Angle Orthod 1986;56:7-30.
4. Williams S, Andersen CE. The morphology of the potential Class III skeletal pattern in the young child. Am J Orthod 1986;89:302-11.
5. Chang H, Kinoshita Z, Kawamoto T. Craniofacial pattern of Class III deciduous dentition. Angle Orthod 1992; 62:139-44.
6. Nanda R. Biomechanical and clinical consideration of a modified protraction headgear. Am J Orthod 1980;78:125-39.
7. McNamara JA Jr. An orthopedic approach to the treatment of Class III malocclusion in young patients. J Clin Orthod 1987;21:598-608.
8. Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. J Clin Orthod 1988;22:314-25.
9. 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; 15:211-21.
10. Cozzani G. Extraoral traction and Class III treatment. Am J Orthod 1981; 80:638-50.
11. Campbell PM. The dilemma of Class III treatment: Early or late. Angle Orthod 1983;53:175-91.
12. Petit H. Adaptations following accelerated facial mask therapy. In: McNamara JA, Ribbens KA, Howe RP, eds. Clinical alteration of the growing face. Monograph 14, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, University of Michigan, 1983.
13. Battagel JM, Orton HS. A comparative study of the effects of customized facemask therapy or headgear to the lower arch on the developing Class III face. Eur J Orthod 1995;17:467-82.
14. Chong Y-H, Ive JC, Artun J. Changes following the use of protraction headgear for early correction of Class III malocclusion. Angle Orthod 1996; 66:351-62.
15. Ngan P, Hagg U, Yiu C, Merwin D, Wei SHY. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. Am J Orthod Dentofac Orthop 1996;109:38-49.
16. Shanker S, Ngan P, Wade D, Beck M, Yiu C, Hagg U, Wei SHY. Cephalometric A point changes during and after maxillary protraction and expansion. Am J Orthod Dentofac Orthop 1996; 110:423-30.
17. Deguchi T, Kitsugi A. Stability of changes associated with chin cup treatment. Angle Orthod 1996;66:139-46.
18. McNamara JA Jr, Brudon WL. Orthodontic and orthopedic treatment in the mixed dentition. USA, Needham Press, 1993; 117-29, 283-95.
19. Ohnishi K. Relationships between apical base relation and incisal inclination in school children: A longitudinal study by lateral cephalometric roentgenograms. J Jpn Orthod Soc 1969; 28:12-32.
20. Sakamoto T. A study of the developmental changes of dentofacial complex of Japanese with special reference to sella turcica. J Jpn Orthod Soc 1959;18:1-17
21. Hinrichsen GJ, Storey E. The effect of force on bone and bones. Angle Orthod 1968;38:155-65.
22. Moffet B. Remodelling of the craniofacial articulations by various orthodontic appliances in rhesus monkeys. Trans Eur Orthod 1971;47:207-16
23. Storey E. Growth and remodeling of bone and bones. Am J Orthod 1972;62:142-65.
24. Hata S, Itoh T, Nakagawa M, Kamogashira K, Ichikawa K, Matsumoto M. Biomechanical effects of maxillary protraction on the craniofacial complex. Am J Orthod Dentofac Orthop 1987;91:305-11.
25. Tanne K, Sakuda M. Biomechanical and clinical changes of the craniofacial complex from orthodopedic maxillary protraction. Angle Orthod 1991;61:145-51.
26. Subtelny JD, Subtelny JD. Oral habits: Studies in form, function and therapy. Angle Orthod 1973;43:347-83.
27. Melsen B, Attina L, Santuari M, Attina A. Relationships betwen swallowing pattern, mode of respiration, and development of malocclusion. Angle Orthod 1987;57:113-20.
28. Mew JRC. Factors influencing mandibular growth. Angle Orthod 1986; 56:31-48.
29. Fletcher SG, Casteel RL, Bradley DP. Tongue thrust swallow, speech articulation, and age. J Speech Hear Disord 1961;26:201-8.
30. Hanson ML, Andrianopoulos MV. Tongue thrust and malocclusion: A longitudinal study. Int J Orthod 1982;20:9-18.
31. Case JL. Palatography and myofuctional therapy. Int J Oral Myol 1975; 1:65-71.
32. Cooper JS. A comparison of myofunctional therapy and crib appliance effects with a maturational guidance control group. Am J Orthod 1977; 72:333-34. Abstract.
33. Andrianopoulos MV, Hanson ML. Tongue-thrust and the stability of overjet correction. Angle Orthod 1987; 57:121-35.
34. Overstake CP. Electromyographic study of normal and deviant swallowing. Int J Oral Myol 1975;1:29-60.
35. Proffit WR, Fields HW. Occlusal forces in normal- and long-face children. J Dent Res 1983;62:571-4.
36. Ono H, Sasa R, Noda T. A study on the cephalometric standards of Japanese children, ed. by Jpn Soc Pediatric Dent. J Jpn Soc Pediatric Dent. 1995;33:659-96.
37. Susami R. A cephalometric study of dentofacial growth in mandibular prognathism. J Jpn Orthod Soc 1967;26:1-34.
38. Sawa S. Roentogenocephalometric study of the dentocraniofacial growth of individuals with reversed occlusion. J Jpn Orthod Soc 1978;37:237-268.
39. Enlow DH. Handbook of facial growth. Philadelphia: Saunders; 1975;192.