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An orthopaedic approach to the treatment of Class III malocclusions in the early mixed dentition

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SUMMARY The aim of this investigation was to study cephalometrically the skeletal, dental and soft tissue modifications induced by a Delaire facemask and Bionator III appliance in a sample of 30 patients (17 boys and 13 girls), aged 4.1–9 years [mean 5.85 years, confidence interval (CI) 5.41–6.29], in the early mixed dentition with a skeletal Class III malocclusion caused by maxillary retrognathism (group 1) and compared with a control sample of 24 subjects (14 boys and 10 girls), aged 4–9 years (mean 5.97 years, CI 5.35–6.58) with untreated Class III malocclusions (group 2). For each patient a lateral cephalogram was taken before treatment (T0), after facemask removal (T1), and at the end of the retention period with a Bionator III (T2). Cephalometric analysis was carried out.

The post-treatment cephalometric values in the treated group showed a forward displacement of the maxilla resulting in a statistically significant increase ($P < 0.001$) in the SNA angle, A–NPg (mm) and PNS–A (mm) linear values. There was a clockwise rotation of the mandible, with a decrease in the SNB angle and a satisfactory correction of the Class III relationship. The beneficial effects on the facial profile were confirmed by an increase in UL–EL distance and in NB^HL and NsPgs^HL angles, and by a decrease in the facial convexity angle.

These findings indicate that the Delaire facemask and Bionator III treatment is effective for correcting skeletal Class III malocclusions caused by maxillary retrognathism in the early mixed dentition.

Introduction

A skeletal Class III malocclusion is one of the most difficult to treat. The incidence of this malocclusion in the Caucasian population has been reported to be 1–5 per cent (Massler and Frankel, 1951; Haynes, 1970; Thilander and Myberg, 1973). In the Chinese and Japanese populations, however, the incidence is approximately 14 per cent (Allwright and Burndred, 1964; Irie and Nakamura, 1975; Iwagaki, 1983) and in Italians about 5 per cent (Cozza *et al.*, 1995).

It has been suggested that a majority of subjects with a Class III malocclusion display maxillary retrusion, or hypoplasia, in combination with a normal or minimally prognathic mandible (Mayor and El-Bradraway, 1993), while Guyer *et al.* (1986) reported that in their total Class III sample, 25 per cent had simple maxillary retrusion and mandibular protrusion.

The results of previous clinical studies have indicated that the application of an orthopaedic force to the craniofacial complex during the early phase of growth can contribute to the treatment of this type of malocclusion (Sakamoto, 1981; Campbell, 1983; Kapust *et al.*, 1998; Baccetti *et al.*, 1998; Saadia and Torres, 2000). In fact, the early interception of a Class III malocclusion is a better alternative to later surgical intervention (Kapust *et al.*, 1998). With the introduction of facemask therapy in the late 1960s (Delaire, 1971) it has become possible to move the maxilla forward with extraoral traction.

Sakamoto (1981) reported that the skeletal improvements resulting from chin cup therapy were more effective in younger patients, which supports early application of a chin cup to correct skeletal Class III malocclusions in the long-term management of the occlusion. However, the use of non-surgical techniques, such as the chin cup alone, has been largely abandoned, mostly because of poor long-term results (Mitani and Fukazava, 1986; Sugawara *et al.*, 1990; Üner *et al.*, 1995).

A protraction facemask in conjunction with a maxillary appliance has been used to correct malocclusions associated with maxillary deficiency and/or mandibular prognathism (Ishii *et al.*, 1987; McNamara, 1987; Mermigos *et al.*, 1990; Kapust *et al.*, 1998; Ngan *et al.*, 1998; Yoshida *et al.*, 1999; Saadia and Torres, 2000). The treatment results produced by this appliance are anterior movement of the maxilla and backward rotation of the mandible. Growth at the circummaxillary sutures has the effect of shifting the maxillary complex downward and forward. These effects suggest that the facemask should especially be used in subjects with a tendency to horizontal growth.

Kapust *et al.* (1998) demonstrated that facemask/expansion therapy produces changes in the dentofacial complex that combine to improve a Class III malocclusion and the results suggest that early treatment may be the most effective.

In a prospective study of 20 young Class III patients treated with maxillary expansion and protraction (Ngan

et al., 1998), the results supported the early treatment of Class III patients and indicated stability of orthopaedic treatment directed at the maxilla. Saadia and Torres (2000) determined the sagittal response of Class III subjects in the primary, mixed, and late mixed dentition phases fitted with a protraction facemask and expansion, without the use of retention appliances. They reported that a definitive reduction in treatment time is achieved when patients are treated at a very young age.

The aim of this investigation was to determine cephalometrically the skeletal, dental and soft tissue effects that occur with facemask and functional appliance (Bionator III) therapy specifically used in children in the early mixed dentition with a skeletal Class III malocclusion caused by maxillary retrognathism compared with a control group of untreated Class III subjects.

Subjects and methods

The treatment group (group 1) comprised 30 subjects (17 boys, 13 girls), with an age range from 4.1 to 9 years [mean 5.85 years; confidence interval (CI) 5.41–6.29]. All patients presented a skeletal Class III relationship caused by maxillary retrognathism without other craniofacial anomalies or a history of orthodontic treatment. The patients were treated with an orthopaedic facemask to correct the antero-posterior dimension. The intraoral part of the appliance was constructed with a 1 mm stainless steel arch (buccal and lingual), with two hooks in the maxillary canine region to attach the elastics (Figure 1). The intraoral appliance was soldered to bands placed on the upper second primary molars. The duration of treatment ranged from 7 to 10 months (mean 8 months). The patients were instructed to wear the facemask for 14 hours a day. The amount of force used was 400 g for each side, which was directed forward and downward to the occlusal plane, to avoid opening the bite.

After facemask removal each patient wore a skeletally based retention appliance (Bionator III), constructed with bite blocks between all the posterior teeth (Figure 2). They were instructed to wear the Bionator for 14 hours a day during the retention period of 1 year.

For each patient a lateral cephalogram was obtained before treatment (T0), after facemask removal (T1), and at the end of the retention period (T2). Cephalometric analysis was undertaken.

The control group (group 2) comprised 24 (14 male, 10 female) untreated Caucasian subjects with a Class III malocclusion, who were closely matched in age (range from 4 to 9 years, mean 5.97 years, CI 5.35–6.58), sex and pre-treatment skeletal morphology to the treatment group. The data for the control group consisted of three series of cephalometric registrations with an interval of 1 year between each series. Changes in cephalometric values in the control and treatment groups during the 2 year period were calculated and compared.

Each cephalogram was traced and 34 variables (19 linear and 15 angular) were measured. The cephalometric measurements used were:

1. Sagittal analysis: SNA angle, SNB angle, ANB angle, AoBo mm (distance between the two points of intersection of the two perpendicular line from points A and B to the functional occlusal plane), NperpA mm (point A to a line drawn perpendicular to Frankfort horizontal from nasion), NperpPg mm (point Pg to a line drawn perpendicular to the Frankfort horizontal from nasion), A–NPg mm, PNS–A mm.
2. Vertical analysis: SN^OP angle (OP: functional occlusal plane, a line drawn through the occlusal surfaces of the maxillary and mandibular first permanent molars and first and second premolars or first and second primary molars), SN^GoGn angle, OP^GoGn angle, PP^GoGn angle (PP: palatal plane), FMA angle, S–Go mm, N–Me mm, (SGo)/

Figure 1 The intraoral part of the Delaire facemask.

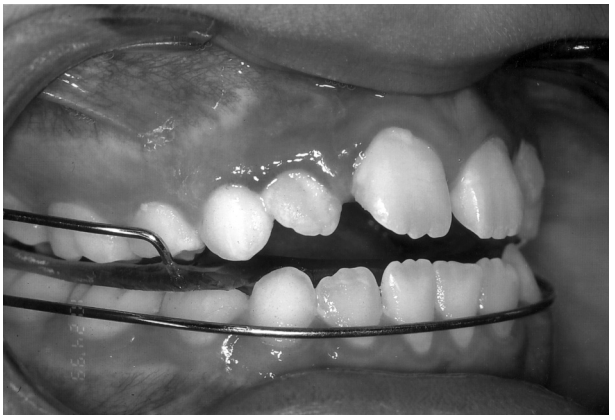

Figure 2 The Bionator III appliance.

(NMe)%, Ar–Go mm, PP–Me mm, (ArGo)/(PP–Me)%, (N–ANS)/(N–Me)%, (ANS–Me)/(N–Me)%.
3. Dental analysis: IMPA angle, Inc. sup.^FH angle, interincisal angle.
4. Aesthetic analysis: NLA angle (nasolabial angle), UL–EL mm, LL–EL mm, NB^HL angle (nasion–point B to a line tangent to the upper lip and soft tissue pogonion), facial convexity angle (soft tissue nasion–pronasale–soft tissue pogonion), NsPgs^HL angle (soft tissue nasion–soft tissue pogonion to a line tangent to the upper lip and soft tissue pogonion), upper lip thickness mm (point A to point sls), upper lip strain mm (point U1 to point UL).

The reference points used for the cephalometric analysis are illustrated in Figure 3.

Method error

Each cephalogram was traced and measured by one author (AM). The measurements were repeated after a period of 7 days and the mean value of the two measurements was used.

The measurement error coefficient was found with IC (all examiners $r = 0.97–0.99$; $P = 0.0001$). All values were found to be close to 1.00 and within acceptable limits.

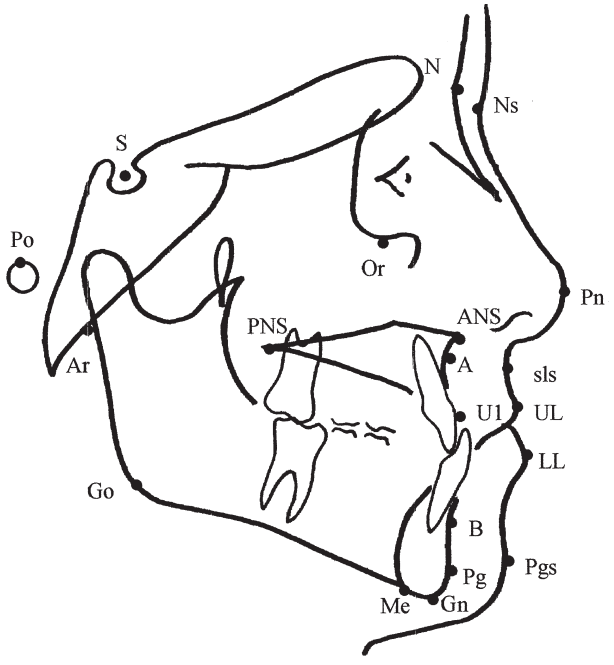

Figure 3 The cephalometric landmarks used: S, sella; N, nasion; Or, orbitale; Po, porion; Ar, articulare; PNS, posterior nasal spine; ANS, anterior nasal spine; A, point A; B, point B; U1, maxillary incisor; Go, gonion; Me, menton; Gn, gnathion; Pg, pogonion; Ns, soft tissue nasion; Pn, pronasale; sls, superior labial sulcus; UL, upper lip; LL, lower lip; Pgs, soft tissue pogonion.

Statistical method

Descriptive statistics included means and standard deviations (SD). The mean differences in cephalometric measurements at T0, T1 and T2 were examined using Friedman's two-way ANOVA and Wilcoxon's ranked sum test. A non-parametric test was used as the studied variables were not normally distributed. A Mann–Whitney test was applied to compare the mean differences in cephalometric measurements between groups 1 and 2.

Results

Cephalometric changes from T0 to T1 (Table 1)

At T0 the control and treatment groups were closely matched with regard to skeletal morphology. The results are reported as mean ± 1 SD and as degrees, unless stated.

There was a significant increase in SNA angle (2.04 ± 1.96), PNS–A (2.08 ± 1.60 mm) and A–NPg (2.34 ± 2.07 mm) distances in group 1, indicating that the maxilla moved anteriorly, because of the orthopaedic force delivered by the facemask.

The correction of the Class III relationship was due to maxillary protraction associated with a significant decrease in SNB angle (–1.31 ± 1.76). As a result of the differential movement of the two jaws, ANB angle (3.31 ± 2.26) and the AoBo linear measurement (3.04 ± 2.27 mm) increased significantly. Sagittal analysis did not show significant differences in the control group.

There was no significant difference in the skeletal divergency angles (FMA, SN^GoGn) between the groups. The only exception was for PP^GoGn, which increased 1.81 ± 2.78 in group 1.

Dental analysis did not show significant differences in group 1, but in group 2 dental compensation was characterized by a decrease in IMPA (–0.81 ± 0.75) and an increase in Inc. sup.^FH (0.73 ± 1.01).

The effects of treatment (group 1) on facial profile were emphasized by an increase in UL–EL distance (+1.54 ± 1.48 mm), an increase in NB^HL and NsPgs^HL angles (+3.73 ± 3.50 and +3.92 ± 3.13, respectively) and a decrease in the facial convexity angle (–3.77 ± 3.54).

In group 2 the significant increase in NLA angle (0.77 ± 0.83) and the decrease in NB^HL (–0.5 ± 0.55) and NsPgs^HL (–0.58 ± 0.64) angles and the upper lip strain value (–0.69 ± 0.72 mm) indicated an improvement in facial profile.

Cephalometric changes from T1 to T2 (Table 2)

The maxillary complex was positioned further forward in group 1. There were increases in SNA angle (0.65 ± 0.47) and in the distances PNS–A (1.15 ± 0.55 mm), point A

Table 1 Cephalometric changes with the Delaire facemask in the treated group (n = 30) before treatment (T0) and after facemask removal (T1).

Variable	T0	SD	T1	SD	Mean difference	SD	*P*-value
SNA (°)	78.46	3.50	80.50	3.05	2.04	1.96	***
SNB (°)	78.85	3.37	77.54	3.02	–1.31	1.76	*
ANB (°)	0.31	2.13	3.00	1.06	3.31	2.26	***
AoBo mm	–5.19	1.51	–2.15	2.03	3.04	2.27	***
N–perpA mm	–1.77	4.84	–0.81	3.84	0.96	3.27	ns
N–perpPg mm	–2.56	6.04	–5.04	4.99	–2.46	5.44	ns
A–NPg mm	–0.42	2.91	1.92	2.33	2.34	2.07	***
PNS–A mm	43.15	2.91	45.23	3.06	2.08	1.60	***
SN^OP (°)	19.54	2.99	19.69	3.42	0.15	2.97	ns
OP^GoGn (°)	16.69	5.33	17.69	2.87	1.00	3.69	ns
SN^GoGn (°)	35.50	3.85	36.88	3.84	1.38	2.35	ns
PP^GoGn (°)	27.23	4.98	29.04	3.98	1.81	2.78	*
FMA (°)	28.54	4.23	30.23	4.01	1.70	3.22	ns
S–Go mm	64.58	4.14	66.38	3.80	1.81	1.30	***
N–Me mm	108.35	7.21	111.00	7.36	2.65	2.05	***
(S–Go)/(N–Me)%	59.54	2.14	59.85	2.19	0.31	1.38	ns
Ar–Go mm	38.15	2.67	38.92	2.25	0.77	1.74	ns
PP–Me mm	59.35	4.25	60.73	5.15	1.38	2.43	ns
(Ar–Go)/(PP–Me)%	64.31	5.27	64.46	5.50	0.15	3.21	ns
(N–ANS)/(N–Me)%	44.04	2.70	44.46	1.81	0.42	2.45	ns
(ANS–Me)/(N–Me)%	55.96	2.70	55.54	1.81	–0.42	2.45	ns
IMPA (°)	84.58	4.59	84.42	4.57	–0.15	3.65	ns
Inc. sup.^FH (°)	109.00	8.90	112.77	7.46	3.77	7.59	ns
Interincisal (°)	137.85	12.35	133.46	8.32	–4.38	9.49	ns
NLA (°)	85.65	5.16	83.46	8.98	–2.19	11.44	ns
UL–EL mm	–3.73	2.10	–2.19	2.40	1.54	1.48	***
LL–EL mm	0.35	2.62	0.27	2.67	–0.08	2.13	ns
NB^HL (°)	7.50	5.20	11.23	4.33	3.73	3.50	***
Facial convexity (°)	141.85	4.34	138.10	3.38	–3.77	3.54	***
NsPgs^HL (°)	10.50	4.00	14.42	3.67	3.92	3.13	***
Upper lip thickness mm	13.38	2.26	14.19	1.63	0.81	2.17	ns
Upper lip strain mm	13.23	1.64	13.15	1.57	–0.08	2.33	ns

*P < 0.05; ***P < 0.001 (Wilcoxon's rank sum test).
ns, not statistically significant; SD, standard deviation.

to nasion perpendicular (0.88 ± 0.36 mm) and A–NPg (0.61 ± 0.42 mm). The sagittal relationship improved: AoBo increased by 0.88 ± 0.30 mm.

In group 2, the maxillo-mandibular relationship, as indicated by the ANB angle (–0.38 ± 0.51), the AoBo linear measurement (–0.38 ± 0.22 mm) and the distance NperpA (–0.31 ± 0.38 mm), tended more towards a skeletal Class III relationship.

The skeletal divergency angles were significantly decreased in group 1 as a result of functional appliance therapy: SN^OP (–0.77 ± 0.44); OP^GoGn (–0.61 ± 0.46); SN^GoGn (–1.11 ± 0.58); PP^GoGn (–1.04 ± 0.52) and FMA (–1.38 ± 0.84). Group 2, on the other hand, displayed an increase in some vertical values: (SN^OP: 0.46 ± 0.48; OP^GoGn: 0.42 ± 0.40; PP^GoGn: 0.42 ± 0.49).

There were no significant differences for the dental values in the treated patients, whereas the control group displayed dental compensation: an increase in Inc. sup.^FH angle (1.00 ± 0.93) and a decrease in IMPA angle (–0.88 ± 0.77).

Similar changes were found in corresponding lip structures (lower lip): an increase in the distance LL–EL (0.54 ± 0.48 mm). Moreover, a significant increase was observed in the facial convexity angle (1.00 ± 0.79).

In the treatment group, all aesthetic angles showed significant changes except for the distance LL–EL: a decrease in UL–EL distance (1.38 ± 0.58 mm); an increase in NB^HL and NsPgs^HL angles (1.35 ± 0.59 and 1.11 ± 1.16, respectively) and a decrease in the facial convexity angle (–1.46 ± 0.52)

Cephalometric changes from T0 to T2 (Table 3)

Comparison of the cephalometric measurements before treatment (T0) and after (T2) the retention period with the Bionator III in group 1 showed that the maxilla was positioned further forward due to increases in SNA (2.67 ± 1.97) and the distances PNS–A (3.23 ± 1.74 mm) and A–NPg (2.96 ± 2.15 mm). There was a decrease in the SNB angle (–1.08 ± 0.45). Correction of the Class III antero-posterior relationship was achieved by an increase

Table 2 Cephalometric changes in the treated group (n = 30) after facemask removal (T1) and at the end of the retention period with the Bionator III appliance (T2).

Variable	T1	SD	T2	SD	Mean difference	SD	*P*-value
SNA (°)	80.50	3.05	81.15	3.02	0.65	0.47	***
SNB (°)	77.54	3.02	77.77	2.77	0.23	0.44	ns
ANB (°)	3.00	1.06	3.38	0.77	0.38	0.74	ns
AoBo mm	–2.15	2.03	–1.27	2.05	0.88	0.30	***
N–perpA mm	–0.81	3.84	0.08	3.68	0.88	0.36	***
N–perpPg mm	–5.04	4.99	–4.96	4.81	0.08	0.67	ns
A–NPg mm	1.92	2.33	2.54	2.14	0.61	0.42	***
PNS–A mm	45.23	3.06	46.38	3.28	1.15	0.55	***
SN^OP (°)	19.69	3.42	18.92	3.15	–0.77	0.44	***
OP^GoGn (°)	17.69	2.87	17.08	2.79	–0.61	0.46	***
SN^GoGn (°)	36.88	3.84	35.77	3.94	–1.11	0.58	***
PP^GoGn (°)	29.04	3.98	28.00	3.83	–1.04	0.52	***
FMA (°)	30.23	4.01	28.85	3.48	–1.38	0.84	***
S–Go mm	66.38	3.80	66.77	3.81	0.38	0.51	ns
N–Me mm	111.00	7.36	110.69	7.77	–0.31	0.85	ns
(S–Go)/(N–Me)%	59.85	2.19	60.23	2.13	0.38	0.65	ns
Ar–Go mm	38.92	2.25	39.38	2.18	0.46	0.52	*
PP–Me mm	60.73	5.15	60.77	5.10	0.04	0.77	ns
(Ar–Go)/(PP–Me)%	64.46	5.50	64.85	5.11	0.38	0.77	ns
(N–ANS)/(N–Me)%	44.46	1.81	44.92	1.25	0.46	0.88	ns
(ANS–Me)/(N–Me)%	55.54	1.81	55.08	1.25	–0.46	0.88	ns
IMPA (°)	84.42	4.57	84.31	4.19	–0.11	0.87	ns
Inc. sup.^FH (°)	112.77	7.46	112.50	7.05	–0.27	1.13	ns
Interincisal (°)	133.46	8.32	133.77	8.11	0.31	0.78	ns
NLA (°)	83.46	8.98	82.54	8.34	–0.92	0.76	***
UL–EL mm	–2.19	2.40	–0.81	2.09	1.38	0.58	***
LL–EL mm	0.27	2.67	0.50	2.06	0.23	0.69	ns
NB^HL (°)	11.23	4.33	12.58	4.43	1.35	0.59	***
Facial convexity (°)	138.10	3.38	136.61	3.28	–1.46	0.52	***
NsPgs^HL (°)	14.42	3.67	15.54	3.78	1.11	1.16	**
Upper lip thickness mm	14.19	1.63	15.04	1.85	0.85	0.51	***
Upper lip strain mm	13.15	1.57	14.08	1.34	0.92	0.53	***

*P < 0.05; **P < 0.01; ***P < 0.001 (Wilcoxon's rank sum test).
ns, not statistically significant; SD, standard deviation.

in the angles ANB and AoBo (3.69 ± 2.33 and 3.92 ± 2.43 mm, respectively).

There was no significant difference in skeletal divergency angles.

There was a statistically significant effect on facial profile: a decrease in the distance UL–EL (2.92 ± 1.15 mm); an increase in NB^HL and NsPgs^HL angles (5.08 ± 3.57 and 5.04 ± 2.93, respectively); a decrease in the facial convexity angle (–5.23 ± 3.85) and an increase in upper lip thickness (1.65 ± 2.21 mm).

The same comparisons in the control group (Table 4) showed: the skeletal relationship tended more towards a Class III pattern (AoBo: –0.42 ± 0.19 mm; NperpA: –0.35 ± 0.37 mm); an increase in skeletal divergency angles (SN^OP: 0.54 ± 0.48; OP^GoGn: 2.00 ± 5.43); dental compensation with proclined maxillary incisors and retroclined mandibular incisors (Inc. sup.^FH: 1.73 ± 0.78; IMPA: –1.69 ± 0.78); the prognathic facial profile became more prominent (NLA: 1.04 ± 0.83; NB^HL: –0.69 ± 0.43; facial convexity angle: 1.46 ± 0.85; NsPgs^HL: –0.88 ± 0.51; upper lip thickness: –0.50 ± 0.50 mm; upper lip strain: –0.88 ± 0.74 mm).

Discussion

The results of the present investigation show that Delaire facemask and Bionator III therapy can result in beneficial effects on the maxillofacial complex and skeletal and facial soft tissues.

All measurements (linear and angular) in group 1 showed that the maxilla was positioned significantly forward; even the comparison between treated and untreated patients displayed a forward position of the maxilla complex in the treatment group at T2 (SNA control group: 78.31; treatment group: 81.15; A–NPg control group: –0.65 mm; treatment group: 2.54 mm; Table 5).

Studies examining changes in the SNA angle have reported mean movements between 1.09 (da Silva Filho *et al.*, 1998) and 2.56 (Kiliçoglu and Kirliç, 1998). The results of the present study for SNA showed mean changes of 2.04 ± 1.96 after facemask therapy and 0.65 ± 0.47 after retention with the Bionator III.

Significant changes in the mandibular position in the treated group from to T0 to T1 (SNB = –1.31 ± 1.76)

Table 3 Cephalometric changes in the treated group (n =30) before treatment (T0) and at the end of the retention period (T2).

Variable	T0	SD	T2	SD	Mean difference	SD	P-value
SNA (°)	78.46	3.50	81.15	3.02	2.67	1.97	***
SNB (°)	78.85	3.37	77.77	2.77	–1.08	0.45	*
ANB (°)	0.31	2.13	3.38	0.77	3.69	2.33	***
AoBo mm	–5.19	1.51	–1.27	2.05	3.92	2.43	***
N–perpA mm	–1.77	4.84	0.08	3.68	1.85	3.20	ns
N–perpPg mm	–2.56	6.04	–4.96	4.81	–2.38	5.25	ns
A–NPg mm	–0.42	2.91	2.54	2.14	2.96	2.15	***
PNS–A mm	43.15	2.91	46.38	3.28	3.23	1.74	***
SN^OP (°)	19.54	2.99	18.92	3.15	–0.61	2.63	ns
OP^GoGn (°)	16.69	5.33	17.08	2.79	0.38	3.58	ns
SN^GoGn (°)	35.50	3.85	35.77	3.94	0.27	2.35	ns
PP^GoGn (°)	27.23	4.98	28.00	3.83	0.77	2.55	ns
FMA (°)	28.54	4.23	28.85	3.48	0.31	3.25	ns
S–Go mm	64.58	4.14	66.77	3.81	2.19	1.39	***
N–Me mm	108.35	7.21	110.69	7.77	2.35	2.28	***
(S–Go)/(N–Me)%	59.54	2.14	60.23	2.13	0.69	1.49	ns
Ar–Go mm	38.15	2.67	39.38	2.18	1.23	1.59	*
PP–Me mm	59.35	4.25	60.77	5.10	1.42	2.41	ns
(Ar–Go)/(PP–Me)%	64.31	5.27	64.85	5.11	0.54	3.18	ns
(N–ANS)/(N–Me)%	44.04	2.70	44.92	1.25	0.88	2.35	ns
(ANS–Me)/(N–Me)%	55.96	2.70	55.08	1.25	–0.88	2.35	ns
IMPA (°)	84.58	4.59	84.31	4.19	–0.27	3.09	ns
Inc. sup.^FH (°)	109.00	8.90	112.50	7.05	3.50	7.00	ns
Interincisal (°)	137.85	12.35	133.77	8.11	–4.08	8.98	ns
NLA (°)	85.65	5.16	82.54	8.34	–3.11	11.13	ns
UL–EL mm	–3.73	2.10	–0.81	2.09	2.92	1.15	***
LL–EL mm	0.35	2.62	0.50	2.06	0.15	1.98	ns
NB^HL (°)	7.50	5.20	12.58	4.43	5.08	3.57	***
Facial convexity (°)	141.85	4.34	136.61	3.28	–5.23	3.85	***
NsPgs^HL (°)	10.50	4.00	15.54	3.78	5.04	2.93	***
Upper lip thickness mm	13.38	2.26	15.04	1.85	1.65	2.21	**
Upper lip strain mm	13.23	1.64	14.08	1.34	0.85	2.14	ns

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ (Wilcoxon's rank sum test).
ns, not statistically significant; SD, standard deviation.

also contributed to the skeletal Class III correction. Changes in mandibular position during facemask therapy may be due to various factors. Takada *et al.* (1993) reported a greater change in SNB (–2.11), which was probably due to the chin cup portion of the appliance, which applied a retraction force to the mandible. A downward and backward movement of the chin is consistent with the findings of Nartallo-Turley (1992) and Ngan *et al.* (1992), involving palatal expansion with a facemask. Mandibular rotation may be due to the palatal expansion that disrupts the occlusion.

Mermigos *et al.* (1990), who used only maxillary protraction, reported no significant change in the position of points B or Pg. In contrast to the findings of those authors, a statistically significant decrease in SNB was found in the present study.

No statistically significant changes were observed in the vertical analysis from T0 to T1 or from T0 to T2 in the treated patients. The only exception was for angle PP^GoGn (T0–T1: 1.81 ± 2.78). The total anterior face height (N–Me) increased 2.35 mm and the posterior face height (S–Go) 2.19 mm. Because both increased proportionally, the ratio S–GO/N–Me, on average, did not show significant differences. The increase in PP^GoGn angle could be a direct effect of the increase in total anterior face height (N–Me), due to extrusion of the anchoring upper primary molars.

The findings of the present study show that facemask therapy performed in the early stages of occlusal development did not produce significant differences in skeletal divergency. Contrary to other authors, Ishii *et al.* (1987) observed the effects of a combined maxillary and chin cup appliance in severe skeletal Class III cases and found a backward and downward movement of point Pg, a backward movement of point B and a significant increase in SN^GoMe angle. Nartallo-Turley and Turley (1998), who used palatal expansion/facemask therapy, reported an increase in lower face height and in the mandibular plane to FH angle. Kapust *et al.* (1998) also observed an increase in lower face height. Backward mandibular rotation may be due to a combination of vertical maxillary movement and eruption of maxillary posterior teeth. Deguchi *et al.* (1999), who used only facemask therapy, observed a significant increase in the FMA angle in the treated group compared with the untreated group.

Table 4 Cephalometric changes from T0 to T2 in the control group (n = 24).

Variable	T0	SD	T2	SD	Mean difference	SD	P-value
SNA (°)	78.62	2.81	78.31	2.80	–0.31	0.52	ns
SNB (°)	78.88	3.29	78.81	3.38	–0.08	0.64	ns
ANB (°)	–2.27	2.13	–0.50	2.19	–0.31	0.64	ns
AoBo mm	–4.61	1.49	–5.04	1.55	–0.42	0.19	**
N–perpA mm	–1.50	4.19	–1.85	4.42	–0.35	0.37	*
N–perpPg mm	–2.31	5.54	–2.42	5.44	–0.11	0.71	ns
A–NPg mm	–0.35	2.54	–0.65	2.95	–0.31	0.50	ns
PNS–A mm	40.69	11.26	44.00	2.52	3.31	11.18	ns
SN^OP (°)	19.38	3.15	19.92	3.33	0.54	0.48	**
OP^GoGn (°)	15.38	6.05	17.38	4.87	2.00	5.43	**
SN^GoGn (°)	35.19	3.71	35.65	3.81	0.46	0.72	ns
PP^GoGn (°)	25.46	8.37	27.31	4.65	1.85	5.77	ns
FMA (°)	27.77	4.12	28.31	3.92	0.54	0.85	ns
S–Go mm	63.88	4.64	64.85	4.51	0.96	1.30	*
N–Me mm	107.53	7.67	107.50	8.02	–0.04	0.88	ns
(S–Go)/(N–Me)%	59.23	2.38	60.31	2.17	1.08	1.75	*
Ar–Go mm	37.77	2.83	38.61	2.78	0.84	1.28	*
PP–Me mm	59.08	5.14	58.61	5.54	–0.46	1.26	ns
(Ar–Go)/(PP–Me)%	64.15	4.9	66.15	5.88	2.00	3.32	ns
(N–ANS)/(N–Me)%	44.00	2.68	43.31	3.06	–0.69	1.55	ns
(ANS–Me)/(N–Me)%	56.00	2.68	56.69	3.06	0.69	1.55	ns
IMPA (°)	84.38	3.62	82.69	3.43	–1.69	0.78	***
Inc. sup.^FH (°)	108.62	8.07	110.35	7.74	1.73	0.78	***
Interincisal (°)	137.61	12.83	137.65	12.69	0.04	0.72	ns
NLA (°)	83.92	5.94	84.96	5.82	1.04	0.83	**
UL–EL mm	–3.61	2.11	–3.85	1.96	–0.23	0.60	ns
LL–EL mm	0.15	2.44	0.85	2.18	0.69	0.60	**
NB^HL (°)	8.27	5.49	7.58	5.32	–0.69	0.43	**
Facial convexity (°)	141.00	4.71	142.46	4.28	1.46	0.85	***
NsPgs^HL (°)	11.19	4.62	10.31	4.65	–0.88	0.51	**
Upper lip thickness mm	12.96	2.04	12.46	1.97	–0.50	0.50	*
Upper lip strain mm	13.50	2.02	12.61	1.89	–0.88	0.74	**

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ (Wilcoxon's rank sum test).
ns, not statistically significant; SD, standard deviation.

The results in this investigation may be due to the age of the patients. It is, therefore, important that treatment is initiated at an early age so that adequate root structures are still present on the primary second molars to anchor the appliance. Moreover, the first permanent molars were often not completely erupted, making it impossible to determine molar extrusion with treatment. Furthermore, the skeletal divergency angles showed a statistically significant decrease from T1 to T2, probably due to the control of growth caused by the functional appliance.

The Class III relationship was corrected only by anterior displacement of the maxillary complex; there were no significant changes in the axial inclination of the teeth in the treatment group or in the comparison of the two groups.

In the control group, on the other hand, dental compensation, by proclination of maxillary incisors and retroclination of mandibular incisors was found. This is in contrast to several authors (Allen *et al.*, 1993; Ngan *et al.*, 1996, 1998; Kapust *et al.*, 1998; Yoshida *et al.*, 1999) who reported, after facemask therapy, that in addition to maxillary and mandibular skeletal changes, the orthodontic effects included forward movement of the maxillary dentition and a decrease in the inclination of the lower incisors.

The objective of this study was to determine the effects of an orthopaedic approach, performed with a Delaire facemask and Bionator III, on the facial soft tissues. Various soft tissue changes combined to improve the Class III profile: a forward movement of the upper lip (UL–EL T0–T2: 2.92 ± 1.15 mm) together with a backward movement of soft tissue pogonion, contributed to the profile becoming more convex. These results correlate with those of Kiliçoglu and Kirliç (1998) who, in a study of patients with a Class III malocclusion treated with the Delaire facemask, reported a statistically significant increase in the convexity of the soft tissue profile. Forward movement of the maxilla was accompanied by corresponding forward movements of the soft tissues, whereas mandibular repositioning was accompanied by a corresponding backward movement of the soft tissues (Ngan *et al.*, 1996; Kiliçoglu and Kirliç, 1998). This beneficial effect of treatment on the facial profile was shown by an increase in NB^HL and NsPgs^HL angles and a decrease in the facial convexity angle in the

Table 5 Comparison between the control (n = 24) and treated groups (n = 30) at T2.

Variable	T2 control group	SD	T2 treated group	SD	P-value
SNA (°)	78.31	2.80	81.15	3.02	*
SNB (°)	78.81	3.38	77.77	2.77	ns
ANB (°)	–0.50	2.19	3.38	0.77	***
AoBo mm	–5.04	1.55	–1.27	2.05	***
N–perpA mm	–1.85	4.42	0.08	3.68	ns
N–perpPg mm	–2.42	5.44	–4.96	4.81	ns
A–NPg mm	–0.65	2.95	2.54	2.14	**
PNS–A mm	44.00	2.52	46.38	3.28	ns
SN^OP (°)	19.92	3.33	18.92	3.15	ns
OP^GoGn (°)	17.38	4.87	17.08	2.79	ns
SN^GoGn (°)	35.65	3.81	35.77	3.94	ns
PP^GoGn (°)	27.31	4.65	28.00	3.83	ns
FMA (°)	28.31	3.92	28.85	3.48	ns
S–Go mm	64.85	4.51	66.77	3.81	ns
N–Me mm	107.50	8.02	110.69	7.77	ns
(S–Go)/(N–Me)%	60.31	2.17	60.23	2.13	ns
Ar–Go mm	38.61	2.78	39.38	2.18	ns
PP–Me mm	58.61	5.54	60.77	5.10	ns
(Ar–Go)/(PP–Me)%	66.15	5.88	64.85	5.11	ns
(N–ANS)/(N–Me)%	43.31	3.06	44.92	1.25	ns
(ANS–Me)/(N–Me)%	56.69	3.06	55.08	1.25	ns
IMPA (°)	82.69	3.43	84.31	4.19	ns
Inc. sup.^FH (°)	110.35	7.74	112.50	7.05	ns
Interincisal (°)	137.65	12.69	133.77	8.11	ns
NLA (°)	84.96	5.82	82.54	8.34	ns
UL–EL mm	–3.85	1.96	0.81	2.09	**
LL–EL mm	0.85	2.18	0.50	2.06	ns
NB^HL (°)	7.58	5.32	12.58	4.43	*
Facial convexity (°)	142.46	4.28	136.61	3.28	**
NsPgs^HL (°)	10.31	4.65	15.54	3.78	**
Upper lip thickness mm	12.46	1.97	15.04	1.85	**
Upper lip strain mm	12.61	1.89	14.08	1.34	**

*P < 0.05; **P < 0.01; ***P < 0.001 (Mann–Whitney test).
ns, not statistically significant; SD, standard deviation.

treated group. A comparison between the two groups indicated a significant improvement in the convexity of the soft tissue profile in the treated subjects. This is consistent with Nartallo-Turley (1992), Ngan *et al.* (1992), Kapust *et al.* (1998) and Kiliçoglu and Kirliç (1998).

Conclusion

Based on the cephalometric alterations observed after facemask and Bionator III therapy during the mixed dentition, the following can be concluded:

1. In all patients a satisfactory correction of the Class III malocclusion was obtained by a significant amount of maxillary forward movement.
2. No statistically significant changes were observed in the axial inclination of the upper and lower incisors.
3. No statistically significant changes were observed in the vertical analysis.
4. The Class III concave profile became more balanced with an improvement in skeletal convexity.
5. During retention with the Bionator III the sagittal relationship improved and there was good control of growth.
6. Statistical comparison between the control and treated groups showed an improvement in the skeletal Class III pattern, induced by a significant forward movement of point A and corresponding beneficial effects on the facial profile in the treated group.

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