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Soft tissue facial profile changes following functional appliance therapy

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SUMMARY The aim of this study was to evaluate changes in the facial profile resulting from the use of a twin block (TB) functional appliance. The sample comprised 38 patients (24 males and 14 females) with a Class II division 1 malocclusion. Nineteen subjects were treated with a functional appliance while the remaining 19, who did not undergo any intervention, served as the control. The mean age of the treated group was 9.5 years (SD 10 months) and of the control group 9.9 years (SD 13 months). Lateral cephalograms were obtained for all subjects at the initial consultation and again after one year. The changes in facial profile, resulting from treatment with the TB, were analysed after the influence of growth had been taken into account.

The results showed a significant improvement in the facial profile, which closely followed the underlying dentoskeletal changes. Thus, the most significant effects were a total facial profile improvement, retraction of the upper lip and anterior movement of soft tissue pogonion ($P < 0.05$). Subjects treated with a TB appliance achieved improved facial harmony, but such changes were not observed in the control group.

Introduction

Improving facial aesthetics is one of the aims of orthodontic treatment. However, changes in the facial profile may occur due to many factors, such as dental movement or growth (Rains and Nanda, 1982). Subjects presenting with a Class II division 1 malocclusion have specific clinical characteristics, such as an increased overjet, and an unfavourable profile which may produce negative feelings of self-image and self-esteem (Shaw, 1981; Tung and Kiyak, 1998). Appliance therapy to correct such a malocclusion should ideally be directed towards addressing the dentoskeletal disharmony, in order to obtain a favourable facial aesthetic result.

The literature contains a large number of studies investigating the mechanisms of action and the effects of different orthopaedic appliances designed to correct Class II division 1 malocclusions. Most of these, however, have concentrated on recording the dentoskeletal changes (Vargevik and Harvold, 1985) and have ignored the effects on the soft tissue facial profile (Morris *et al.*, 1998). The dentoskeletal effects of the twin block (TB) functional appliance on Class II malocclusions have been well documented (Clark, 1988; Mills and McCulloch, 1998).

The aim of the present study was to evaluate changes in the soft tissue facial profile, in subjects with a Class II division 1 malocclusion, resulting from early treatment with a TB appliance.

Subjects and methods

The sample comprised 38 subjects, prospectively recruited, from those awaiting treatment at the Orthodontic Post Graduate Clinic, Dental School, Universidade do Estado do Rio de Janeiro. Nineteen patients were treated with a TB functional appliance and the other 19 formed the control group. Ethical approval for the study was obtained from the Ethical Committee of the University of Rio de Janeiro. The following inclusion criteria were applied:

1. Skeletal Class II relationship (ANB > 4 degrees).
2. Class II incisor (overjet ≥ 6 mm), canine and molar relationship.
3. No previous history of orthodontic treatment.
4. Patients in the following epiphyseal stages, as defined by Ferreira (1998): FP, FM, G1 and Psi. These all characterize the initial stages of the pubertal growth spurt.

The treated group comprised 12 boys and seven girls with a mean age of 9.5 years (SD 10 months), and the control group 12 boys and seven girls with a mean age of 9.9 years (SD 13 months). The difference in the mean age of subjects in each group was not statistically significant ($P = 0.28$). The active treatment time was 12 months (SD 1 month).

The design of the TB, used in the present study (Figure 1) has been previously described (Brunharo and Quintão, 2001). The initial working bite was recorded with the mandible postured forward by 4 mm. However, in those with large overjets, the TB was re-activated six months after the start of treatment, by addition of acrylic to the upper block. The subjects were instructed to wear the appliance full-time and asked to complete a time sheet to monitor compliance. The control group underwent treatment at the

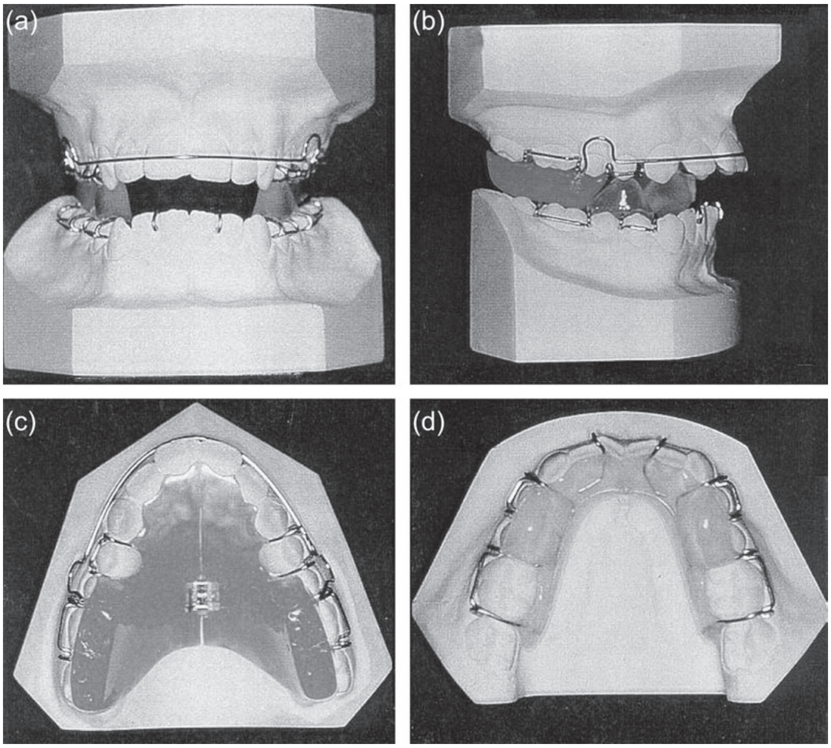

Figure 1 The twin block functional appliance used. (a) anterior, (b) lateral, (c) upper occlusal, and (d) lower occlusal views.

'ideal' stage of development, conforming to the approval granted by the local ethical committee.

Cephalometric radiographs were taken four weeks before the start of active treatment (T1) and 12 months (SD one month) later (T2), for all subjects in the study. At T2, care was taken to ensure the subjects did not posture their mandibles.

Cephalometric radiographs were taken in profile (Broadbent, 1931). The subjects were positioned in the natural head posture with the mid sagittal plane 90 degrees to the X-rays and Frankfort plane. The lips were relaxed and lying in a rest position (Yoshida machine, model Panoura 10 CSU with variations of 10 mAs and 0.8 and 1.2 seconds, with 85 and 90 Kvp).

The lateral cephalogram was subsequently scanned using an Epson Expression 1680 scanner (resolution 1600 × 3200 dpi) transparency unity (Epson American Inc., Long Beach, California, USA). The radiographs were analysed using the Radiocef 2.0® Memory studio computer program (Radiocef, Floresta, Belo Horizonte, Minas Gerais, Brazil). This program generated a customized analysis for each cephalometric radiograph (Figures 2 and 3). A total of 31 variables were evaluated.

A vertical reference line (VL), originating from sella turcica (S) and perpendicular to the sella–nasion (S–N) line was constructed. Both lines were used for superimposition of the cephalometric tracings. A mean tracing for the treatment and control groups was produced at T1 and T2, applying the principles of Holdaway's visual treatment objective (Holdaway, 1983, 1984). The mean change was used at T2 in order to visualize the alterations (Figure 4). The cephalometric analyses applied to the radiographs were based on the analyses of Steiner (1953, 1960) and Ricketts (1960, 1961).

All measurements obtained were tabulated for evaluation and statistical analysis using the Primer of Biostatistics version 4.0 (© 1996 McGraw Hill) for Windows. To standardize measurements and minimize error, the digitization was performed by a single operator (RCM). The angular and linear measurements were recorded in degrees and millimetres, respectively.

To evaluate the method error, 10 pairs of radiographs (T1 and T2) were randomly selected. The mean error and the SD between the paired tracings were obtained. An intraclass correlation coefficient (ICC) was calculated and a value higher than 0.810, for a confidence interval of 95 per cent, was found for SNA, L–HF variables and nasolabial angle. The mean variation coefficient for these variables was 0.96, 1.88 and 4.66 per cent, respectively, demonstrating a low method error.

Descriptive statistics included the mean and SD. A non-paired Student's t-test was used to verify the homogeneity of the analysed groups, and the changes resulting from growth and treatment at the end of the study period were evaluated.

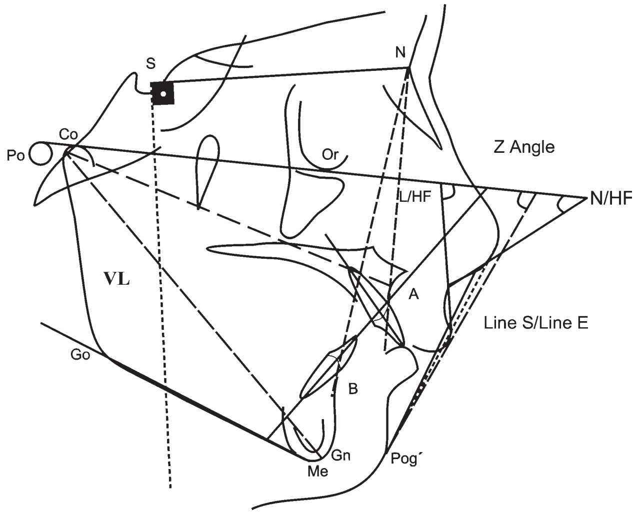

Figure 2 Linear and angular cephalometric points measured: SNA, sella–nasion–point A angle; SNB, sella–nasion–point B angle; ANB, point A–nasion–point B angle; Co–A, maxillary length; Co–Gn, mandibular real length; 1/NA, upper incisor–nasion/point A line (angle and mm); lower incisor–nasion/point B line (angle and mm); Z angle, porion point/orbital point (Frankfort plane)–line E (Ricketts line profile) angle; L/HF, Frankfort plane to most anterior point of the upper lip; N/HF, Frankfort plane–nose base angle.

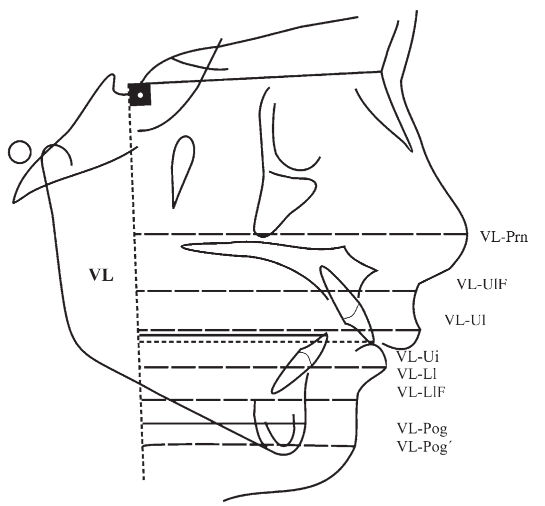

Figure 3 Linear cephalometric profile changes measured: VL to SN, vertical line to sella–nasion line (90 degrees); VL–Prn, distance of the most anterior point of the nose to VL; VL–UlF, distance of most posterior point of the lower border of the nose to VL; VL–Ul, distance of the most anterior point of the upper lip to VL; VL–Ui, distance of the most anterior point of the upper incisor to VL; VL–Ll, distance of the most anterior point of the lower lip to VL; VL–LlF, distance of the most posterior point of the lower border of the lip to VL; VL–pog, distance of pogonion point to VL; VL–pog', distance of tegumental pogonion to VL.

The linear correlation coefficient (r) was used to evaluate the correlation between the variables being studied and the paired Student's *t*-test to verify their significance. The level of significance was $P < 0.05$.

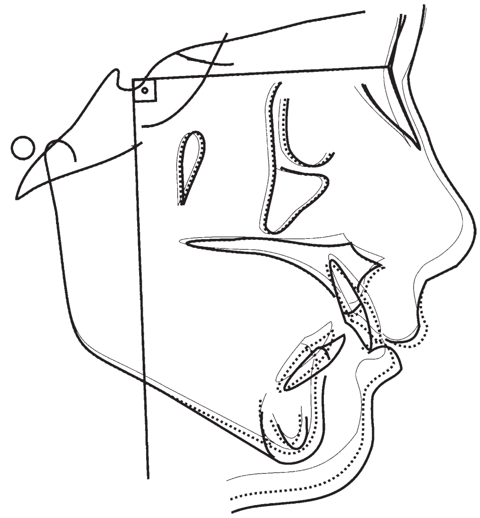

Figure 4 Pre-treatment superimposed mean cephalometric tracings for both groups (grey), after a 12-month study period for the control group (dotted line), and post-treatment for the twin block group (black).

Results

The cephalometric variables used for both the treated and control group at T1 are listed in Table 1. The non-paired Student's *t*-test demonstrated that there were no significant differences between the groups at T1, highlighting the homogeneity of the groups.

Changes in the variables used at T2 (T2–T1) resulting from growth and treatment are listed in Table 2 and shown in Figures 5 and 6. These demonstrate the significance of the variable VL–Ul ($P < 0.05$), indicating that the upper lip was retropositioned following TB therapy. The upper incisor position (1/NA, mm and angle) also demonstrated significant differences ($P < 0.001$), which may be correlated with the change in upper lip position. In the treated group (Table 2) 1/NA angle changed significantly, as did the VL–Ui distance, characterizing upper incisor retroclination, which also produced a significant change in upper lip inclination (L/HF angle). A vertical positioning of the upper incisors occurred, followed by the upper lip, confirmed by a statistically significant linear correlation (r = +0.75) between the VL–Ul/VL–Ui variables. The change in upper lip position was not believed to be induced by skeletal changes (SNA and maxillary length, defined by Co–A distance, did not change significantly between T1 and T2). Furthermore, none of the variables used to evaluate maxillary changes (SNA and Co–A) showed any significant differences at T2.

The TB appliance significantly improved the Z angle ($P < 0.01$), reflected in reduced soft tissue facial convexity. The significant increase in mandibular length, measured by Co–Gn ($P < 0.05$), between T1 and T2, may have contributed to this improvement in profile. The variable L/HF increased significantly between T1 and T2 ($P < 0.05$) contributing to

Table 1 Descriptive statistics for the skeletal variables at the initial (T1) and final (T2) time-points for the control and the twin block (TB) groups.

Cephalometric variable	TB (*n* = 19)				Control (*n* = 19)				*P* value	Significance
	T1		T2		T1		T2			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Linear measurements										
VL–Prn	92.83	4.81	95.40	4.70	90.11	5.04	93.01	5.30	0.097	ns
Vertical line–upper lip sulcus (VL–UlS)	77.56	4.90	79.61	5.12	75.60	4.84	77.84	5.09	0.223	ns
Vertical line–upper lip (VL–Ul)	81.09	6.48	82.41	6.64	77.45	5.31	80.24	5.54	0.066	ns
Vertical line–lower lip (VL–Ll)	71.56	7.50	75.48	8.13	69.27	5.61	71.48	6.83	0.294	ns
Vertical line–lower lip sulcus (VL–LlS)	58.38	7.74	62.00	8.50	56.70	5.95	58.48	7.43	0.459	ns
VL–pog’	58.21	8.93	61.45	9.33	56.84	7.19	58.68	8.56	0.605	ns
Angular measurements										
Z angle	66.43	5.06	69.22	4.68	67.87	4.61	67.73	5.35	0.366	ns
L/HF	68.89	14.08	72.40	12.29	75.89	8.64	73.92	8.02	0.075	ns
N/HF	31.79	6.90	29.98	6.75	32.13	7.29	32.31	6.70	0.885	ns
Nasolabial angle	100.68	16.55	102.38	12.40	108.33	10.92	106.23	9.88	0.103	ns
Steiner										
(Line S)–upper lip	4.25	2.27	2.84	2.22	3.17	2.18	3.23	2.40	0.160	ns
(Line S)–lower lip	3.76	3.45	4.42	3.11	3.07	3.62	3.47	3.63	0.552	ns
Ricketts										
Upper labial position	2.39	2.39	0.95	2.07	1.45	2.61	1.45	2.65	0.271	ns
Lower labial position	2.88	3.51	3.43	3.05	2.30	3.75	2.33	3.53	0.623	ns
Skeletal component										
ANB	6.98	1.68	5.65	1.75	6.56	1.72	6.60	1.88	0.455	ns
SNA	82.30	4.12	82.35	4.58	81.57	4.39	82.52	4.72	0.598	ns
SNB	75.32	3.75	76.70	4.02	75.00	3.49	75.92	3.72	0.789	ns
Maxillary length	93.83	3.18	96.05	3.83	91.07	5.04	93.49	4.36	0.052	ns
Mandibular length	113.25	4.03	118.47	3.84	110.6	5.73	113.42	6.14	0.108	ns
Dental component										
l/NA (º)	28.96	6.30	20.99	4.85	27.44	7.24	27.40	6.72	0.495	ns
l/NA (mm)	5.59	2.28	3.64	1.96	5.34	2.93	5.54	2.50	0.773	ns
/l–NB (º)	31.55	5.26	34.67	4.16	31.33	5.51	32.04	5.66	0.901	ns
/l–NB (mm)	5.80	2.73	6.95	2.39	5.78	2.28	6.06	2.6	0.983	ns

ns, non significant.
VL–Prn, distance of the most anterior point of the nose to the vertical line; VL–pog’, distance of tegumental pogonion to the vertical line; L/HF, Frankfort plane to the most anterior point of the upper lip; N/HF, Frankfort plane–nose base angle.

the change in soft tissue profile. The significant increase in S line–upper lip ($P < 0.001$) and upper labial position ($P < 0.001$) further contributed to the changes observed in the Z angle and consequent reduction in facial convexity. Thus, it would appear that the change in soft tissue profile was primarily the result of upper lip modification. However, skeletal variable changes also contributed to this profile change, as the ANB angle significantly reduced ($P < 0.001$) and mandibular length increased ($P < 0.05$).

Whilst a significant increase in lower incisor projection occurred (1/NB angle; $P < 0.05$), no change was observed in lower lip position. A correction in the molar relationship was obtained in 15 of the 19 treated patients (80 per cent).

Discussion

Soft tissue facial profile

It could be expected that the skeletal changes achieved would result in similar changes taking place in the soft tissues (Riedel, 1957; Rains and Nanda, 1982). However, some authors have stated that proportional changes or facial profile improvement do not necessarily follow marked dental/skeletal changes (Burstone, 1959; Subtelny, 1959). There is also a large degree of individual variation with regard to treatment response (Pangrazio-Kubersh, 1985). Subjects with Class II malocclusions generally present with convex facial profiles and a retrognathic soft tissue pogonion associated with mentalis activity to achieve an anterior lip seal (Ward, 1994). There was an increase in the VL-Prn measurements in both groups, due to nasal growth alone. The mean increase of 2.5 mm/year was greater than the 1mm/year suggested by Subtelny (1961).

Upper and lower lip

In the treated group, a significant change in upper lip inclination and position was observed due to upper incisor retroclination. There was a statistically significant linear

Table 2 Descriptive statistics of the differences between the mean cephalometric values for the initial (T1) and final (T2) measurements in the control and the twin block (TB) groups.

Cephalometric variable	TB		Control		Difference	Significance *P*
	T1	T2	T1	T2		
	Mean	SD	Mean	SD		
Linear measurements						
VL–Prn	2.57	1.66	2.90	2.61	–0.34	ns
Vertical line–upper lip sulcus (VL–UlS)	2.05	1.32	2.24	2.56	–0.19	ns
Vertical line–upper lip (VL–Ul)	1.31	2.05	2.79	2.42	–1.48	*
Vertical line–lower lip (VL–Ll)	3.92	3.16	2.21	4.54	1.70	ns
Vertical line–lower lip sulcus (VL–LlS)	3.63	2.25	1.78	4.05	1.85	ns
VL–pog'	3.24	2.08	1.84	3.76	1.40	ns
Angular measurements						
Z angle	2.79	2.95	–0.14	3.86	2.93	*
L/HF	3.50	5.09	–1.97	4.76	5.47	**
N/HF	–1.80	5.23	0.13	6.35	–1.93	ns
Nasolabial angle	1.70	7.68	–2.09	8.70	3.79	ns
Steiner						
(S Line)–upper lip	–1.24	0.98	0.27	1.00	–1.51	***
(S Line)–lower lip	0.66	1.94	0.21	2.34	0.45	ns
Ricketts						
Upper labial position	–1.38	0.98	–0.08	1.19	–1.29	***
Lower labial position	0.55	1.95	0.03	2.38	0.52	ns
Skeletal component						
ANB	–1.33	0.68	0.03	1.20	–1.36	***
SNA	0.05	1.07	0.95	2.37	–0.90	ns
SNB	1.38	1.05	0.92	2.01	0.46	ns
Maxillary length	2.22	2.89	2.42	2.31	–0.20	ns
Mandibular length	5.22	3.26	2.82	2.80	2.40	*
Dental component						
l/NA (º)	–7.98	4.79	–0.05	3.37	–7.93	***
l/NA (mm)	–2.04	2.10	0.20	1.21	–2.24	***
/l–NB (º)	3.13	3.04	0.71	3.15	2.41	*
/l–NB (mm)	1.15	1.21	0.27	1.44	0.87	ns

ns, non significant; $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.
VL–Prn, distance of the most anterior point of the nose to the vertical line; VL–pog', distance of tegumental pogonion to the vertical line; L/HF, Frankfort plane to the most anterior point of the upper lip; N/HF, Frankfort plane–nose base angle.

correlation (r = +0.75) between the VL–Ul/VL–Ui variables. Similarly, Roos (1977) demonstrated a high correlation between incisor retraction and upper lip movement. No statistically significant change occurred in any of the lower lip variables in relation to the treated or control group.

Menton

There was a mean increase of 1.29 degrees ($P < 0.05$) in the S–N/Go–Me angular measurement. There was also a small increase in lower anterior face height, resulting from a clockwise rotation of the mandible, with a downward and backward displacement of pogonion. However, the mandibular plane increase did not reduce the Vl–pog' linear measurement which showed an insignificant increase of 0.70 mm. There was a strong linear correlation (r = +0.75) with the VL–pog' linear measurement, but this was not statistically significant.

Total facial profile

A significant improvement was seen in the profile of the treated group (Figure 4). Only minor facial changes were observed in the control group during the study period, which did not reach statistical significance. Conversely, the treated group exhibited greater changes, thus characterising the effects of treatment (the upper lip retraction and forward advancement of soft tissue pogonion; Figure 4). The variables associated with the lower third (VL–Ll, VL–LlF and VL–pog') showed forward movement in relation to the middle third (VL–Prn, VL–UlF and VL–Ul) of the face. A positive correlation was found between these variables (r = +0.84), with the largest changes observed in the soft tissues of the treated group. Rabie *et al.* (2003) showed that, in animals, anterior mandibular positioning accelerates and increases chondrocyte differentiation as well as cartilaginous matrix formation in the mandibular condyle, implying that functional appliance therapy may induce a true increase in mandibular growth.

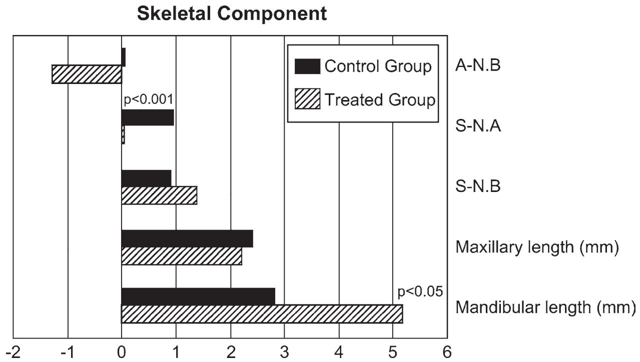

Figure 5 Mean skeletal changes at the end of the study period for the control and treated groups.

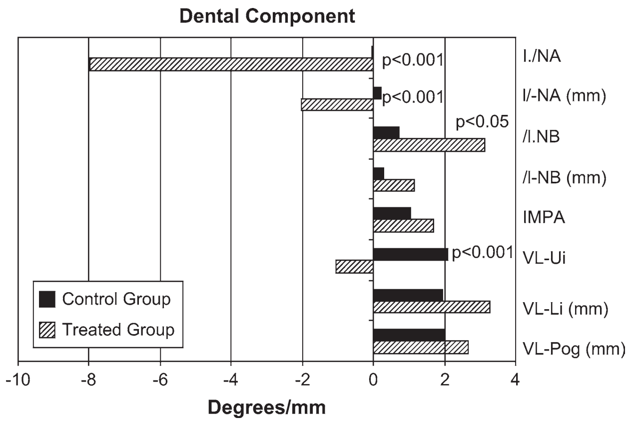

Figure 6 Mean dental changes at the end of the study period for the control and treated groups.

Clinically, the fixed-functional Herbst appliance has been shown to produce an increase in mandibular growth (Pancherz, 1979, 1981). However, such effects with removable functional appliances are questionable, as their action appears to be intermittent. According to Clark (1995), sagittal discrepancy correction is encouraged with the TB appliance by 'release' of the posterior teeth, which is thought to allow the expression of any favourable anterior mandibular growth. Chen *et al.* (2002), in a systematic review of the effects of functional appliances, reported that these appliances have little effect on mandibular length. However, significant methodological differences between the studies make a true comparison difficult. In the current investigation, a mean increase of 5.22 mm per year was observed in mandibular length (Co–Gn) with the TB appliance (Table 2), corroborating the findings of Lund and Sandler (1998) and Toth and McNamara (1999). A statistically significant decrease in ANB angle was found, which led to a reduction in facial convexity. This was due not only to mandibular advancement but also to a degree of maxillary restraint.

The 1/NA variables reduced in the treatment group compared with the control group (Table 2). The upper incisors were retroclined during treatment, which aided overjet reduction. The lower incisors (1/NB) proclined during treatment, further contributing to the reduction in overjet. Lund and Sandler (1998), Mills and McCulloch (1998), Toth and McNamara (1999) and Trenouth (2000) all found similar effects. These may need to be corrected during a second phase of orthodontic treatment, involving premolar extractions, in order to upright the lower incisors and enhance stability (Tulloch *et al.*, 1998).

Timing of treatment

Previous studies have suggested that any attempt to change growth is best achieved at the peak of the pubertal growth spurt (Gianelly, 1995; Baccetti *et al.*, 2000), which is normally 12 and 14 years of age for girls and boys, respectively. However, the mean age of subjects in this study was 9.5 years. There were a perceived number of reasons for the timing of treatment in the current study:

1. It was felt that a greater degree of skeletal correction could be obtained at this stage of development. However, for a complete Class II correction, an extended growth period would be needed (McNamara and Brudon, 1993).
2. The stability and comfort of the TB appliance is greater when the primary molars are present. During the mixed dentition phase of development, it may be difficult to maintain stability of the appliance due to the exfoliation of the primary teeth (Clark, 1995).
3. Younger patients adapt more readily to functional appliances and have fewer problems in relation to speech when compared with adolescent patients (McNamara and Brudon, 1993). As parental authority tends to decrease as patients reach adolescence, this could potentially reduce patient compliance with the appliance (Lund and Sandler, 1998).
4. If some degree of improvement can be achieved at an early age, reducing the risk of upper incisor trauma, then treatment can be justified (Koroluck *et al.*, 2003).

Conclusions

This study evaluated the soft tissue facial profile changes in 38 subjects with Class II division 1 malocclusions, resulting from normal growth and a phase of TB functional appliance therapy, over a period of 12 months. The most notable changes were:

1. A significant improvement in facial profile in the treated group compared with the control group, with a reduction in facial convexity.
2. Evidence of upper lip retraction and anterior displacement of soft tissue pogonion.
3. Upper incisor retroclination in the treated patients, with 'flattening' of the upper lip profile.

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