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Soft tissue effects of Twin Block and Herbst appliances in patients with Class II division 1 mandibular retrognathy

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SUMMARY The aim of this study was to evaluate and compare the changes in soft tissue profile related to treatment with Twin Block and Herbst appliances. Sixty Class II, division 1, mandibular retrognathic patients were divided into three groups. Forty patients were randomly allocated to one of two functional appliance treatment groups. The first group comprised 11 girls and 9 boys (mean age= 12.74±1.43 years) treated with the Herbst appliance. The second group comprised 10 girls and 10 boys (mean age = 13.0±1.32 years) who received treatment with Twin Block appliance. The untreated control group included 9 girls and 11 boys with a mean age of 12.17±1.47 years. Mean treatment time was 15.81±5.96 and 16.20±7.54 months for Herbst and Twin Block groups, respectively. The observation period of the control group was 15.58±3.13 months. Pre-treatment (T0) and post-treatment (T1) cephalograms were used to evaluate skeletal, dentoalveolar, and especially soft tissue changes. The groups were compared at T0 and T1 using analysis of variance, and treatment/observation differences (T1 − T0) were evaluated with paired samples *t*-test at $P<0.05$ level. Soft tissue convexity, H angle, and mentolabial angle decreased in both treatment groups compared to control. Statistically significant treatment changes were found for mandibular soft tissue measurements in Twin Block group and to a lesser extend in Herbst group. Both appliances reduced the soft tissue profile convexity when the nose is not taken into consideration. Greater advancement of mandibular soft tissues was observed in Twin Block group.

Introduction

An orthodontic treatment is considered successful when objective treatment goals and subjective patient desires are met (Burstone, 1967). Subjects with Class II malocclusions are referred to orthodontists mainly for aesthetic improvement (Dann *et al.*, 1995). In these patients, increased overjet and unfavourable profile may lead to negative feelings of self-image and self-esteem (Tung and Kiyak, 1998). Thus, the treatment plan of these malocclusions should ideally be directed towards to solve the dentoskeletal disharmony in order to obtain a favourable facial aesthetics (Quintão *et al.*, 2006).

Functional appliance therapy is a commonly used treatment protocol for growing Class II patients. There appears to be a consensus that removable functional appliance therapy leads to improvement on facial appearance in Class II patients (Pancherz and Anehus-Pancherz, 1994).

Twin Block and Herbst appliances are among the most popular functional appliances (Schaefer *et al.*, 2004). Twin Block appliance is the most preferred functional appliance in UK (O'Brien, 2006) and in the USA, the Herbst appliance is most commonly used (McNamara and Brudon, 2001).

There are few studies concerning the soft tissue effects of Herbst appliance (Pancherz and Anehus-Pancherz, 1994; Ruf and Pancherz, 1999, 2004) in the literature and in some of these studies, soft tissue evaluation was performed with only few measurements (Pancherz and Anehus-Pancherz, 1994; Ruf and Pancherz, 1999, 2004). Soft tissue changes after Twin Block appliance treatment were evaluated in greater detail relative to Herbst appliance (Morris *et al.*, 1998; Singh, 2002; Singh and Clark, 2003; Flores-Mir and Major, 2006; Quintão *et al.*, 2006). To our knowledge, dentoskeletal effects of these appliances were compared in two studies (O'Brien *et al.*, 2003; Schaefer *et al.*, 2004) and soft tissue effects were not compared yet.

The aim of this prospective clinical study was to evaluate the soft tissue changes after Twin Block and Herbst appliance therapy and compare these changes with an untreated control sample. The null hypothesis tested was that the soft tissue changes obtained with the Twin Block and Herbst appliance therapies are not significantly different from each other and that of untreated control group.

Subjects and methods

The sample comprised 66 subjects referred to orthodontic clinic, Erciyes University, Faculty of Dentistry.

The sample size for the groups was calculated based on a significance level of 0.05 and a power of 80 per cent to detect a clinically meaningful difference of 1 mm (±1.5 mm) for the distance of the lower lip to E plane between the three groups. The power analysis showed that 18 patients in each group were required.

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

Inclusion and exclusion criteria used in the present study are shown in Table 1. When a patient who met the inclusionary criteria attended to the clinic, patient and parents informed about the study. If they accept to participate, initial records of the patients were taken. Immediately after the initial recording of the data, the patient was randomized to receive treatment with either a Herbst or a Twin Block appliance and their therapy started. Randomization was made at the start of the study with pre-prepared random number tables with block stratification on gender. Patient evaluation was performed by one author and enrolment was performed by the other author. Finally, 40 patients received functional appliance treatment. Control group compromised of 20 untreated subjects. Those were the patients who met the criteria but refused treatment with either appliance after initial records were taken.

Cast splint design of Herbst appliance was used. Cast splints were connected with a lingual arch in mandibular part and a Hyrax screw was welded to the maxillary cast splints. The construction bite was recorded with the mandible forward by edge-to-edge incisor position. After 6 months of treatment, the plunger system was removed and overjet was measured. When a normal or corrected overjet in retruded position was recorded, the active treatment was finished. At the same appointment, Herbst appliance was removed and an acrylic monoblock was delivered to the patient. At the following appointments, acrylic over the mandibular posterior teeth was gradually trimmed to facilitate occlusal settling.

Table 1 Inclusion and exclusion criteria used in the present study.

Inclusion criteria
- Skeletal Class II relationship (ANB > 4°)
- Mandibular retrognathy (SNB < 78°)
- Overjet ≥ 5 mm
- SN–GoGn= 32°±6°
- Minimal crowding in dental arches (≤4 mm)
- Bilateral Class II molar and canine relation (at least 3.5 mm)
- Patients with fourth (S and H2) or fifth (MP3cap, PP1cap ve Rcap) epiphysial stages on hand wrist radiographs as defined by Björk (1972)

Exclusion criteria
- Previous history of orthodontic treatment
- Congenitally missing or extracted permanent tooth (except third molars)
- Posterior crossbites or severe maxillary transverse deficiency
- Severe facial asymmetry determined by clinical or radiographical examination
- Poor oral hygiene
- Systemic diseases that may affect the orthodontic treatment results

Twin Block appliances were manufactured basically according to the original design described by Clark (2002). The construction bite was recorded with the mandible forward by 70 per cent of the maximum protrusive path (Clark, 2002) and 2–4 mm beyond the free way space. The subjects were instructed to wear the appliance full time. In deep overbite patients, upper blocks were trimmed approximately 2 mm in each appointment until the normal overbite recorded. Overjet measurements were performed in each control. When a normal or corrected overjet in retruded position was recorded, the active treatment was finished. At the same appointment, Twin Block appliance was removed and a modified Hawley appliance with anterior inclined plane (Clark, 2002) was delivered to the patient to achieve good posterior interdigitation.

For both treatment groups, treatment was finished when the occlusal settling and good posterior interdigitation was achieved. Only the records of patients who completed the treatment were analysed. We did not carry out an intention to treat analysis of the data.

Cephalometric measurements

Lateral cephalometric radiographs were taken with Instrumentarum Cephalometer (Ortoceph OC100; Tuusula, Finland). All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the x-rays, the Frankfort plane was parallel to the horizontal, the teeth were in centric occlusion, and the lips were lightly closed. Radiographic records were taken before treatment (prior to the placement of the appliance) and after the active treatment (when the occlusion had settled).

All radiographs were traced manually and whole angular and linear measurements were recorded by a single author (AB) and were reviewed twice by other investigator for accurate landmark identification. Thirty-four measurements, 14 angular and 20 linear, were measured on each radiograph (Tables 2 and 3). Landmarks used in the study are shown in Figure 1.

Soft tissue linear measurements were traced according to a vertical reference line. A horizontal reference line was constructed 7° less than sella–nasion line. Then, a vertical reference line perpendicular to horizontal reference line and passing through sella was drawn (Illing *et al.*, 1998). Soft tissue linear measurements are shown in Figure 2.

Statistical analysis

All statistical analyses were performed with Statistical Package for Social Sciences, 15.0 software for Windows (SPSS Inc, Chicago, Illinois, USA). Arithmetic means and standard deviations were calculated for each measurement. The normality test of Shapiro–Wilks and Levene's variance homogeneity test were applied to the data. The data were found normally distributed, and there was homogeneity of variance among the groups. Thus, the statistical evaluation

Table 2 Definition of skeletal and dental cephalometric measurements.

Skeletal angular and linear measurements
SNA angle (SNA): inward angle towards the cranium between the NA line and the sella–nasion (SN) plane
SNB angle (SNB): inward angle towards the cranium between the NB line and the SN plane
ANB angle (ANB): angle between the NA and NB lines, obtained by subtracting SNB from SNA
N–A–Pog (Hard tissue convexity angle): inward angle towards the cranium between the NA line and the A–pogonion (A–Pog) plane
SN plane to mandibular plane angle (SN–GoGn): angle between the SN plane and the mandibular plane (Go–Gn)
Dental angular and linear measurements
Maxillary incisor to SN plane (U1–SN): most inferior inward angle formed by the extension of the long axis of the maxillary incisor to the SN plane
Maxillary incisor to NA plane (U1–NA): distance between the tip of the upper incisor and a line from N to point A
Maxillary incisor to NA angle (U1–NA): angle formed by the long axis of the upper incisor to a line from N to point A
Mandibular incisor to NB (L1–NB): distance between the tip of the mandibular incisor and a line from nasion to point B
Mandibular incisor to NB angle (L1–NB): angle formed by the long axis of the mandibular incisor to a line from N to Point B
Mandibular incisor to mandibular plane (L1–MP): long axis of the mandibular incisor is measured to the mandibular plane; the most inward angle towards the body of the mandible is measured.

Table 3 Definition of soft tissue angular and linear measurements.

Soft tissue angular measurements
Convexity angle, including the nose: the angle formed between soft tissue nasion, nasal tip, and soft tissue pogonion
Convexity angle, excluding the nose: the angle formed between soft tissue nasion, subnasale, and soft tissue pogonion
Nasolabial angle: the angle formed between columella, subnasale, and soft tissue pogonion
Mentolabial angle: the angle formed between labrale inferioris, sulcus inferioris, and soft tissue pogonion
H angle: the angle formed between soft tissue nasion, soft tissue pogonion, and labrale superioris
Soft tissue linear measurements
Maxillary soft tissue measurements
1. VRL–prn: horizontal distance between vertical reference plane and pronasale
2. VRL–sn: horizontal distance between vertical reference plane and subnasale
3. VRL–Ss: horizontal distance between vertical reference plane and sulcus superioris
4. VRL–ls: horizontal distance between vertical reference plane and labrale superioris
5. E–ls: the distance from labrale superioris to a line joining the nasal tip and soft tissue pogonion
6. Basic upper lip thickness: the dimension measured approximately 3 mm below point A and the drape of the upper lip
7. Upper lip thickness: the dimension between the vermilion point and the labial surface of the maxillary incisor
8. Upper lip strain measurement: the difference between between the basic upper lip thickness and the upper lip thickness.
9.Upper lip length: vertical distance between upper lip stomion and subnasale
10. Interlabial gap: vertical distance between upper lip stomion and subnasale
Mandibular soft tissue measurements
11. VRL–li: horizontal distance between vertical reference plane and labrale inferioris
12. VRL–Si: horizontal distance between vertical reference plane and sulcus inferioris
13. VRL–pog′: horizontal distance between vertical reference plane and soft tissue pogonion
14. E–li: the distance from labrale inferioris to a line joining the nasal tip and soft tissue pogonion
15.Soft tissue chin thickness (Pog–pog′): horizontal distance between hard and soft tissue pogonion
16. Lower lip thickness at sulcus inferioris level (Si–B): horizontal distance between sulcus inferioris and point B
17. Lower lip thickness: horizontal distance between labrale inferioris and the most prominent point on buccal surface of lower incisor
18. Lower lip length: vertical distance between lower lip stomion and soft tissue menton

of cephalometric values between test groups was performed using parametric tests.

To determine gender differences, independent sample *t*-test was performed. All variables were tested for group differences with respect to their pre-treatment (T0) and post-treatment (T1) values and the differences during study period (T1 − T0). Intra-group comparisons were determined with paired samples *t*-test, inter-group comparisons were determined with one-way analysis of variance (ANOVA), and multiple comparisons were determined with Tukey honestly significant difference (HSD) test.

Comparison of groups for mean skeletal and chronological age was made using one-way analysis of (ANOVA) variance. Treatment/observation period of three groups were evaluated using one-way ANOVA. Statistical difference with number of visits between two treatment groups were analysed with Mann-Whitney U test. Gender distribution, supporting and fixed appliance treatment need were evaluated by chi-square test.

To determine the errors associated with radiographic measurements, 20 radiographs were selected randomly. Their tracings and measurements were repeated 1 month after the first measurements. A paired *t*-test was applied to the first and second measurements, and the differences between the measurements were insignificant. Correlation analysis applied to the same measurements showed the highest *r* value (0.994) for the VRL–prn and the lowest *r* value (0.900) for SNB, L1–MP, and si–B measurements. Probability values less than 0.05 were accepted as significant.

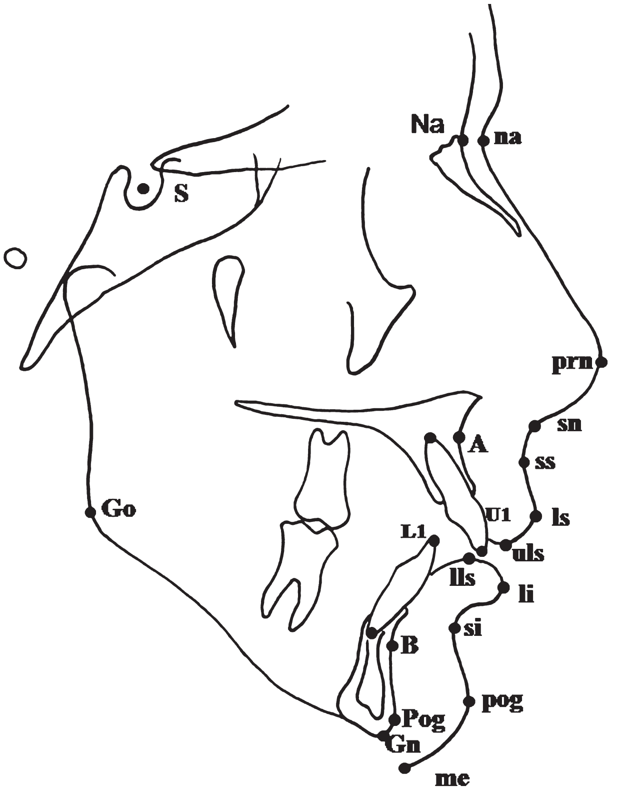

Figure 1 Landmarks used in the study: S = sella, Na = nasion, Go=gonion, Gn=gnathion, Pog = pogonion, A = point A, B = point B, U1=upper incisor, L1=lower incisor, na = soft tissue nasion, prn=pronasale, sn=subnasale, ss=sulcus superior, ls=labrale superior, li=labrale inferior, si=sulcus inferior, pog=soft tissue pogonion, me=soft tissue menton.

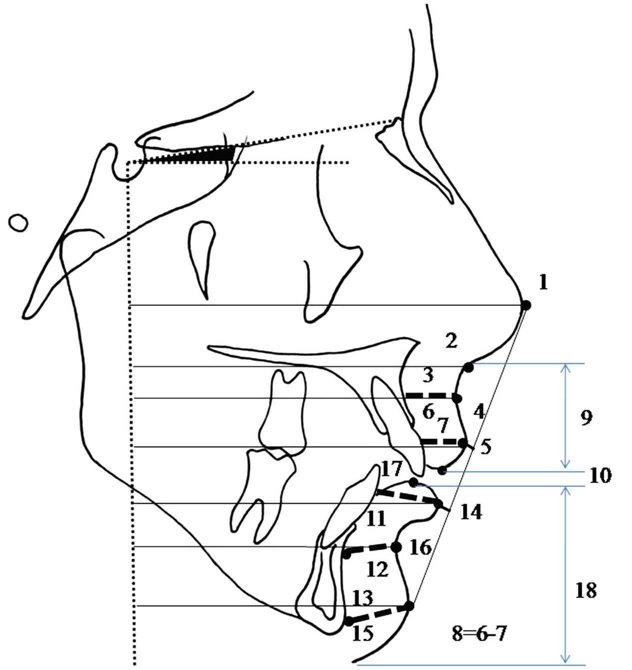

Figure 2 Soft tissue linear measurements: (1) VRL-prn, (2) VRL-sn, (3) VRL-ss, (4) VRL-ls, (5) E-ls, (6) basic upper lip thickness, (7) upper lip thickness, (8) upper lip strain= difference between 6th and 7th measurements, (9) upper lip length, (10) interlabial gap, (11) VRL-li, (12) VRL-si, (13) VRL-pog, (14) E-li, (15) soft tissue chin thickness (Pog-pog), (16) si-B, (17) lower lip thickness, (18) lower lip length.

Results

Total of 67 patients were enrolled in the study. Enrolment started in February 2007 and was completed by June 2009. Forty-seven subjects were randomized, and all of them began study. After initiation of functional appliance treatment, seven patients (three patients from Herbst and four patients from Twin Block group) were discarded because of poor oral hygiene, diagnose of a metabolic disease, insufficient cooperation of appliance wear, and patient request to terminate treatment (Figure 3). There were no significant differences initially in the gender distribution and skeletal and chronological mean age of the subjects in each group (Table 4). Details of the treatment process are given in Table 5.

Gender differences were evaluated statistically and no significant differences were found, so the data pooled. Statistical comparison of the baseline variables of the groups is presented in Table 6.

The results of the descriptive statistics and intra-group comparisons of cephalometric variables are presented in Table 7. Table 8 shows the inter-group comparison of the mean changes between T0 and T1.

Treatment/observation intra-group comparisons

Herbst group. The skeletal Class II relation was corrected by reduction in SNA angle ($P<0.001$) and increase in SNB angle ($P=0.002$). Hard tissue convexity angle was increased ($P<0.001$). Upper incisor retroclination (U1–SN: $P=0.001$; U1–NA: $P=0.013$) and lower incisor protrusion and proclination ($P<0.001$) were found. Soft tissue convexity angle excluding nose ($P<0.001$) and mentolabial angle were increased ($P=0.002$) and H angle was decreased ($P=0.001$). Except lip strain and interlabial gap measurements, changes in all maxillary soft tissue measurements were found statistically significant. Lower lip ($P<0.001$) and pogonion were moved anteriorly ($P=0.001$); lower lip length ($P<0.001$) and thickness (Si–B, $P<0.001$) were increased with Herbst treatment.

Twin Block group. Similar to Herbst group, decrease in SNA ($P=0.004$) and ANB ($P<0.001$) and increase in Na–A–Pog ($P<0.001$) and SNB ($P<0.001$) angles were found. Lower incisor protrusion was the only statistically significant dental change ($P<0.001$). Soft tissue convexity angles (na–prn–pog: $P=0.005$; na–sn–pg $P<0.001$) and mentolabial angle ($P<0.001$) were increased and H angle ($P<0.001$) was decreased. Upper lip was moved anteriorly relative to VRL ($P=0.013$). Distance between upper lip and E plane was increased ($P<0.001$) and interlabial gap was

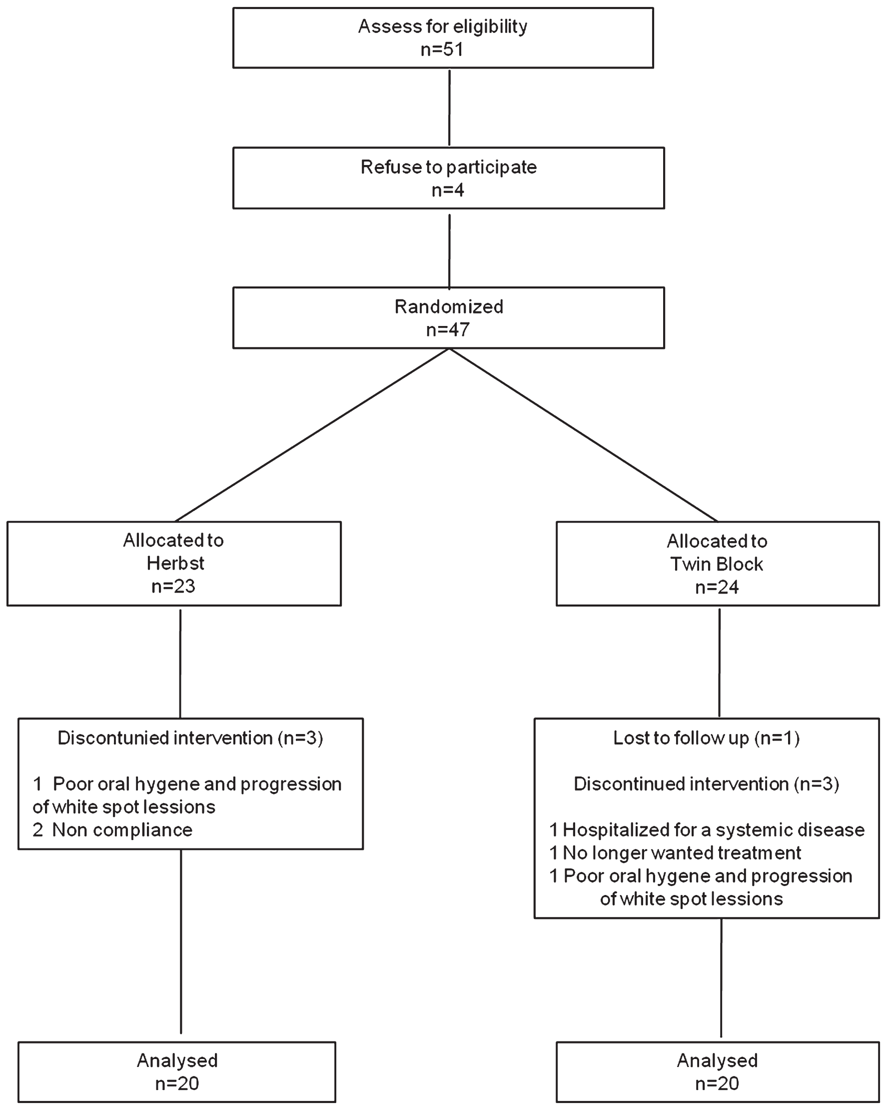

Figure 3 Flow chart of patients in study.

Table 4 Mean ages and gender distribution of the subjects.

Parameters	Herbst	Twin Block	Control	Significance
Chronological age in baseline (in years)	12.74±1.43	13±1.32	12.17±1.47	0.178
Skeletal age in baseline (in years)	12.20±0.82	12.26±0.79	11.45±0.95	0.786
Gender				
Female, *n* (%)	11 (55)	10 (50)	9 (45)	0.819
Male, *n* (%)	9 (45)	10 (50)	11 (55)	

Chronological and skeletal ages were compared with ANOVA. Gender distribution were compared with chi-square test.

decreased ($P=0.011$). Statistically significant treatment changes were observed for all mandibular soft tissue measurements at the end of Twin Block therapy.

Control group. During the observation period, SNB angle was increased ($P=0.049$) and mentolabial angle was decreased ($P=0.012$). Soft tissues related to nose and upper lip were moved anteriorly ($P<0.001$). Basic upper lip thickness (P=0.013), upper lip thickness ($P=0.001$), and upper lip strain ($P=0.018$) were increased. The only statistically significant change in mandibular soft tissues was found for soft tissue pogonion that was moved anteriorly ($P=0.007$).

Inter-group comparisons

Inter-group comparisons were given in Table 8. Decrease in SNA and ANB measurements and increase in hard tissue convexity angle were similar between treatment groups. However, significant differences were found between treatment and control groups for these measurements

Table 5 Treatment process data.

	Herbst	Twin Block	Control	Significance
Treatment/ observation period (months)	15.81±5.96	16.2±7.54	15.58±3.13	0.942
Number of visits (mean±SD)				
Regular	16.30±5.86	16.70±7.48		0.883
Emergency	0.95±1.09	0.40±0.59		0.149
Supporting phase need, *n* (%)				
Yes	18 (90)	17 (85)		0.661
No	2 (10)	3 (15)		
Fixed phase need, *n* (%)				
Yes	16 (80)	17 (85)		0.999
No	4 (20)	3 (15)		

Treatment/observation period compared with ANOVA, number of visits were compared with Mann–Whitney *U*-test, supporting and fixed phase need were compared with chi-square test.

($P<0.001$). SNB angle was increased in Twin Block group and this increase was greater than Herbst (P=0.009) and control groups ($P<0.001$). Upper incisor retroclination (U1–SN: $P=0.003$; U1–NA: $P=0.010$), lower incisor protrusion (L1–NB: $P=0.004$), and proclination (L1–NB: $P<0.001$; IMPA: $P=0.003$) were greater for Herbst group than control group. Greater increase in lower incisor to mandibular plane angle was found in Herbst group compared to Twin Block group ($P=0.007$). No statistically significant differences were found for dental measurements between Twin Block and control groups.

Greater increase was found in soft tissue convexity angles for Twin Block group compared to control (na–prn–pog: $P=0.011$; na–sn–pog: $P<0.001$). For Herbst group, the increase in convexity measurement (when nose excluded) was found statistically significant, compared to control group ($P=0.001$). H angle was decreased in both treatment groups (Herbst/control: $P=0.036$, Twin Block/control: $P<0.001$). Mentolabial angle was decreased in both treatment groups compared to control group ($P<0.001$).

Upper lip was positioned backwards relative to E plane in both treatment groups. Greater differences were found among Herbst, Twin Block, and control groups for mandibular soft tissue measurements.

Lower lip length was increased in both treatment groups compared to control group (Herbst/control: $P=0.020$; Twin Block/control: $P<0.001$). Lower lip thickness at sulcus inferioris level was greater in Herbst group than Twin Block and control groups (Herbst/Twin Block: $P=0.025$, Herbst/control: $P<0.001$). Lower lip, sulcus inferioris, and soft tissue pogonion were moved more anteriorly in Twin Block group than Herbst and control groups.

Thus, according to statistically significant differences between control and treatment groups, the null hypothesis of the present study could be rejected.

Discussion

Twin Block and Herbst appliances are among the most popular functional appliances (Schaefer *et al.*, 2004). To our knowledge, soft tissue effects of these appliances were not compared to date. Thus, the aim of this prospective study was to evaluate the soft tissue effects of these appliances and to compare with an untreated control.

Proffit and Fields (2000) stated that the best method to evaluate the treatments effects of a procedure is to compare the treated samples with an untreated control group. In this study, the subjects in control group were initially called from the waiting list of the clinic for functional treatment. All the subjects in this group met the inclusion criteria. But they refused the treatment after initial treatment records were taken. The excuses of the patients and parents were as follows: worry about the performance of the subject in college entrance examination, patient refusal to wear functional appliance, and problems in medical insurance system. The patients who declined the treatment were placed on the department's waiting list and instructed to attend the clinic when they solve their problem or when the patients were persuaded to receive treatment. All patients in control group received orthodontic treatment and records were renewed. These first and second pre-treatment records were used as control records.

One of the major concerns for functional appliance treatment is the treatment timing. Maximum treatment effects with functional appliances could be achieved when mandibular growth spurt was included in the treatment period (Baccetti *et al.*, 2000). Petrovic *et al.* (1991) reported that the treatment effects of activator, Frankel, and bionator appliances were most favourable when the patient is in the ascending portion of pubertal growth spurt. Malmgren *et al.* (1987) found greater skeletal response to Bass appliance therapy in boys treated during peak period compared to those treated in pre-peak period. Hägg and Pancherz (1988) reported two times more sagittal condylar growth in patients treated in the pubertal peak than patients treated 3 years before or after the peak. Baccetti *et al.* (2000) evaluated the treatment effects of Twin Block appliance in two groups of subjects (early- and late-treated group). In the early-treated group, the peak growth velocity was not included in the treatment period. The therapy was performed during or slightly after the onset of the pubertal growth spurt in the second group. Larger increments in total mandibular length and ramus height, more posterior direction of condylar growth and greater skeletal contribution to molar correction were found in the late-treated group compared to early-treated group (Baccetti *et al.*, 2000). In this study, skeletal maturation was evaluated according to the method described by Björk (1972). The subjects were in the fourth and fifth stages. These stages include the appearance of ulnar sesamoid; appearance of hooking of the hamate; capping of ephyphysis to its diaphysis of middle phalanx of third finger, proximal phalanx of first finger, and radius, respectively.

Table 6 Comparison of starting forms of treated and control subjects.

Measurements	Herbst group		Twin Block group		Control group		Analysis of variance	Multiple comparison		
	Mean	SD	Mean	SD	Mean	SD		Herbst/Twin Block	Herbst/control	Twin Block/control
Hard tissue measurements										
SNA	80.92	1.13	80.72	0.99	81.15	1.31	0.514			
SNB	74.1	2.08	74.7	1.77	74.22	1.55	0.548			
ANB	6.77	1.56	6.02	1.17	6.9	1.58	0.130			
Na–A–Pog	168.82	3.91	171	4.31	168.37	3.87	0.099			
SN–GoGn	34.3	3.66	31.2	4.54	32.77	2.29	0.048	*		
U1–SN	106	4.31	103.37	7.24	108.6	6.17	0.030			*
U1–NA (mm)	5.4	1.66	4.4	2.07	5.87	2.02	0.189			
U1–NA	25.47	4.65	23.12	7.86	27.27	6.26	0.130			
L1–NB (mm)	6.25	2.17	4.72	2.4	4.65	1.78	0.055			
L1–NB	29.12	5.35	26.6	5.67	25.97	4.61	0.140			
IMPA	100.57	5.13	100.62	6.09	99.2	3.51	0.599			
Soft tissue angular measurements										
na–prn–pog	124.85	4.19	127.77	4.39	125.5	3.68	0.069			
na–sn–pog	151.15	7.7	155.85	4.15	152.05	4.36	0.026	*		
H angle	19.95	6.05	20.6	5.59	24.97	4.15	0.008		*	*
Nasolabial angle	103.6	9.58	105.12	9.38	104.62	12.16	0.896			
Mentolabial angle	98.85	18.12	80.67	22.75	99.42	25.7	0.015	*		*
Soft tissue linear measurements										
Maxillary soft tissue measurements										
VRL–prn	103.4	6.18	103.47	5.81	100.65	4.42	0.193			
VRL–sn	88.07	5.66	88.7	5.02	85.57	3.87	0.113			
VRL–ss	86.1	5.25	87.72	5.65	84.35	3.52	0.102			
VRL–ls	89.45	5.28	90.62	4.68	86.9	3.88	0.042			*
E–ls	0.1	2.7	-0.02	2.08	0.9	1.88	0.376			
Basic upper lip thickness	14.02	1.92	14.37	1.31	13.3	1.73	0.127			
Upper lip thickness	13.75	2.84	14.15	2.22	11.97	2.09	0.014			*
Lip strain	-0.42	1.87	-0.22	2.13	-1.32	1.43	0.140			
sn–uls	21.22	3.02	22.15	2.63	21.3	2.51	0.497			
Interlabial gap	2.2	2.93	1.35	2.1	2	2.35	0.532			
Mandibulary soft tissue measurements										
VRL–li	82.37	6.54	83.77	5.33	79.45	3.72	0.039			*
VRL–si	70.3	6.42	70.7	6.45	68.1	3.23	0.292			
E–li	1.47	2.96	0.42	2.82	0.65	3.81	0.561			
VRL–pog	71.02	6.6	74.67	6.66	69.6	3.05	0.019			*
Pog–pog	12.97	2.13	13.42	2.47	13.05	2.68	0.823			
si–B	11.4	2.05	11.17	1.38	11	1.48	0.751			
Lower lip thickness	17.12	2.08	17.57	1.8	16.52	2.47	0.342			
lls–me	44.25	3.48	43.92	4	41.35	3.6	0.031		*	

Grave and Brown (1976) reported that these events coincide with peak growth in most children. In the light of the literature, to achieve maximum therapeutic effects of Herbst and Twin Block appliances, subjects who were at pubertal stage in skeletal maturation were included in this study.

The design of the Twin Block appliance had minor differences compared to the original design described by Clark (2002). A labial bow was added to the upper part of the appliance to increase the retention of the appliance. Similarly, buccal coverage of the maxillary posterior teeth was performed for anchorage purposes. Acrylic capping of mandibular incisor teeth is a common modification to prevent protrusion of these teeth (Clark, 2002). Similarly, Toth and McNamara (1999) added a labial bow and acrylic pad to the lower part of the appliance. In Twin Block group, although lower incisors were protruded after treatment, the change was not statistically different compared to control group. It may be discussed that lower incisor protrusion was prevented due to the acrylic capping of these teeth. In contrast, Mills and McCulloch (1998) and Toth and McNamara (1999) found lower incisor protrusion although a labial bow had been used.

Table 7 Pre- and post-treatment/observation values of each group.

	Herbst group				t-test	Twin Block group				t-test	Control group				t-test
	T1		T2			T1		T2			T1		T2		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Hard tissue measurements															
SNA	80.92	1.13	79.57	1.85	$P<0.001$	80.72	0.99	79.97	1.59	0	81.15	1.31	81.35	1.39	0.214
SNB	74.10	2.08	75.02	1.98	0	74.70	1.77	76.77	2.65	$P<0.001$	74.22	1.55	74.67	1.56	0.049
ANB	6.77	1.56	4.40	1.72	$P<0.001$	6.02	1.17	3.17	1.68	$P<0.001$	6.90	1.58	6.67	1.46	0.243
Na–A–Pog	168.82	3.91	171.82	4.37	$P<0.001$	171.00	4.31	176.25	4.76	$P<0.001$	168.37	3.87	168.75	4.06	0.437
SN–GoGn	34.30	3.66	34.40	4.02	0.79	31.20	4.54	30.95	5.20	0.67	32.77	2.29	32.15	3.67	0.110
U1–SN	106.00	4.31	102.05	4.26	0	103.37	7.24	101.90	5.97	0.33	108.60	6.17	110.22	6.76	0.063
U1–NA (mm)	5.40	1.66	5.02	1.88	0.39	4.40	2.07	4.50	2.07	0.79	8.80	13.38	6.35	2.27	0.426
U1–NA	25.47	4.65	22.65	4.51	0.01	23.12	7.86	21.80	5.34	0.37	27.27	6.26	29.10	6.74	0.006
L1–NB (mm)	6.25	2.17	7.95	2.14	$P<0.001$	4.72	2.40	5.75	2.47	$P<0.001$	4.65	1.78	5.10	2.23	0.077
L1–NB	29.12	5.35	34.32	5.18	$P<0.001$	26.60	5.67	29.30	5.87	0.01	25.97	4.61	26.47	5.63	0.332
IMPA	100.57	5.13	104.77	4.78	$P<0.001$	100.62	6.09	101.55	6.94	0.29	99.20	3.51	99.77	4.72	0.364
Soft tissue angular measurements															
na–prn–pog	124.85	4.19	125.60	5.02	0.16	127.77	4.39	129.77	4.97	0.01	125.50	3.68	125.10	4.73	0.47
na–sn–pog	151.15	7.70	153.62	6.68	$P<0.001$	155.85	4.15	159.87	5.30	$P<0.001$	152.05	4.36	152.17	4.59	0.84
H angle	19.95	6.05	17.20	6.27	0	20.60	5.59	16.00	6.15	$P<0.001$	24.97	4.15	25.10	3.76	0.86
Nasolabial angle	103.60	9.58	103.15	9.12	0.8	105.12	9.38	104.77	12.57	0.9	104.62	12.16	102.27	14.17	0.28
Mentolabial angle	98.85	18.12	113.02	13.57	0	80.67	22.75	103.27	18.16	$P<0.001$	99.42	25.70	89.42	19.40	0.01
Soft tissue linear measurements															
Maxillary soft tissue measurements															
VRL–prn	103.40	6.18	106.82	6.88	$P<0.001$	103.47	5.81	106.20	7.56	0.05	100.65	4.42	103.62	5.45	$P<0.001$
VRL–sn	88.07	5.66	89.65	6.14	0.01	88.70	5.02	90.40	7.64	0.22	85.57	3.87	88.10	4.56	$P<0.001$
VRL–ss	86.10	5.25	87.07	5.14	0.04	87.72	5.65	89.00	5.34	0.07	84.35	3.52	86.40	4.54	$P<0.001$
VRL–ls	89.45	5.28	90.70	5.71	0.02	90.62	4.68	92.22	6.14	0.01	86.90	3.88	89.82	4.17	$P<0.001$
E–ls	0.10	2.70	-1.45	2.50	$P<0.001$	-0.02	2.08	-2.75	2.39	$P<0.001$	0.90	1.88	0.67	1.57	0.47
Basic upper lip thickness	14.02	1.92	15.10	1.75	$P<0.001$	14.37	1.31	14.75	1.74	0.22	13.30	1.73	14.00	1.57	0.01
Upper lip thickness	13.75	2.84	15.32	2.60	0.01	14.15	2.22	14.92	2.93	0.08	11.97	2.09	13.30	2.35	0
Lip strain	-0.42	1.87	0.32	1.53	0.09	-0.22	2.13	0.17	2.05	0.27	-1.32	1.43	-0.72	1.90	0.02
sn–uls	21.22	3.02	22.15	2.48	0.04	22.15	2.63	22.27	3.04	0.73	21.30	2.51	21.72	2.95	0.25
Interlabial gap	2.20	2.93	1.75	2.33	0.36	1.35	2.10	0.22	1.00	0.01	2.00	2.35	2.47	2.96	0.39
Mandibular soft tissue measurements															
VRL–li	82.37	6.54	86.05	5.76	$P<0.001$	83.77	5.33	88.72	6.01	$P<0.001$	79.45	3.72	81.35	4.44	0.180
VRL–si	70.30	6.42	72.85	5.45	0.01	70.70	6.45	77.40	6.26	$P<0.001$	68.10	3.23	69.32	3.97	0.520
E–li	1.47	2.96	1.32	3.12	0.81	0.42	2.82	-0.47	2.89	0	0.65	3.81	0.32	3.02	0.528
VRL–pog	71.02	6.60	73.80	7.22	0	74.67	6.66	80.12	8.49	$P<0.001$	69.60	3.05	71.55	4.48	0.007
Pog–pog	12.97	2.13	13.85	2.55	0.040	13.42	2.47	14.57	2.80	0.01	13.05	2.68	13.60	2.73	0.940
si–B	11.40	2.05	13.42	1.61	$P < 0.001$	11.17	1.38	12.10	1.18	0	11.00	1.48	11.17	0.92	0.535
Lower lip thickness	17.12	2.08	16.50	2.42	0.31	17.57	1.80	16.52	1.78	0.01	16.57	2.47	17.30	2.12	0.176
lls–me	44.25	3.48	48.50	3.69	$P < 0.001$	43.92	4.00	49.45	4.17	$P < 0.001$	41.35	3.60	42.27	3.06	0.150

For each group cephalometric values at T0 and T1 were examined by paired sample *t*-test.

Table 8 Comparison of mean differences between treated and control subjects.

	Herbst group		Twin Block group		Control group		One-way analysis of variance	Multiple comparison		
	Mean	SD	Mean	SD	Mean	SD		Herbst/Twin Block	Herbst/control	Twin Block/control
Hard tissue measurements										
SNA	−1.35	1.11	−0.75	1.03	0.20	0.69	0.000		***	**
SNB	0.92	1.18	2.07	1.36	0.45	0.95	0.000	**		***
ANB	−2.37	1.51	−2.85	1.26	−0.22	0.83	0.000		***	***
Na–A–Pog	4.00	2.30	5.25	2.29	0.37	2.11	0.000		***	***
SN–GoGn	0.10	1.67	−0.25	2.57	−0.62	1.66	0.529			
U1–SN	−3.95	4.52	−1.47	6.61	1.62	3.68	0.004		**	
U1–NA (mm)	−0.37	1.89	0.10	1.66	0.47	0.99	0.559			
U1–NA	−2.82	4.60	−1.32	6.44	1.82	2.63	0.011		*	
L1–NB (mm)	1.70	1.38	1.02	1.08	0.45	1.07	0.006		**	
L1–NB	5.20	3.45	2.70	4.39	0.50	2.24	0.000		***	
IMPA	4.20	3.20	0.92	3.77	0.57	2.76	0.001	**	**	
Soft tissue angular measurements										
na–prn–pog	0.75	2.3	2	2.84	−0.4	2.42	0.015			*
na–sn–pog	2.47	2.85	4.02	2.46	0.12	2.67	0.000		*	***
H angle	−2.75	2.96	−4.6	4.48	0.12	3.05	0.000		*	***
Nasolabial angle	−0.45	7.75	−0.35	12.39	2.35	9.49	0.779			
Mentolabial angle	14.17	17.97	22.6	13.27	−10	16	0.000		***	***
Soft tissue linear measurements										
Maxillary soft tissue measurements										
VRL–prn	3.42	2.12	2.72	5.9	2.97	2.27	0.844			
VRL–sn	1.57	2.19	1.7	5.95	2.52	2.29	0.705			
VRL–ss	0.97	1.91	1.27	2.97	2.05	1.72	0.311			
VRL–ls	1.25	2.21	1.6	2.6	2.92	2.04	0.060			
E–ls	−1.55	1.52	−2.72	1.6	0.22	1.36	0.000	*	*	***
Basic upper lip thickness	1.07	1.07	0.37	1.32	0.7	1.14	0.184			
Upper lip thickness	1.57	2.32	0.77	1.83	1.32	0.15	0.418			
Lip strain	0.75	1.88	0.4	1.57	0.6	1.03	0.772			
sn–uls	0.92	1.82	0.12	1.57	0.42	1.59	0.316			
Interlabial gap	−0.45	2.13	−1.12	1.79	0.47	2.38	0.065			
Mandibular soft tissue measurements										
VRL–li	3.67	3.38	4.95	2.76	1.9	3.28	0.013			**
VRL–si	2.55	3.67	6.7	4.07	1.22	2.64	0.000	**		***
E–li	−0.15	2.67	−0.9	1.20	−0.32	2.26	0.514			
VRL–pog	2.77	3.15	5.45	3.8	1.95	2.86	0.004	*		**
Pog–pog	0.87	1.77	1.15	1.77	0.55	1.39	0.522			
si–B	2.02	1.58	0.92	0.99	0.17	1.23	0.000	*	***	
Lower lip thickness	−0.62	2.66	−1.05	1.59	0.72	2.3	0.039			*
lls–me	4.25	2.7	5.52	3.12	0.92	2.75	0.000		**	***

In this study after active Twin Block and Herbst therapies, a supporting phase was performed in order to achieve good interdigitation and occlusal settling. By this way, stable mandibular position was achieved and final soft tissue profile was evaluated. To evaluate the pure effects of these functional appliances, fixed orthodontic appliances were not placed during the active and supporting phases.

Decrease in soft tissue convexity was reported after Herbst (Pancherz and Anehus-Pancherz, 1994; Ruf and Pancherz, 1999, 2004) and Twin Block (Morris *et al.*, 1998; Sharma and Lee, 2005) therapies. In Twin Block group, both soft tissue convexity measurements were increased with treatment. However, in Herbst group, soft tissue convexity angle including the nose was not different from control group. This may be attributed to nasal growth that was found to be greater in Herbst group than other groups. Pancherz and Anehus-Pancherz (1994) reported similar results. Six months after Herbst treatment finished, soft tissue profile convexity (including the nose) did not differ between treated and control subjects, when the nose excluded, the difference in soft tissue convexity was statistically significant (Pancherz and Anehus-Pancherz, 1994).

Holdaway related H angle with facial convexity (Holdaway, 1983). He stated that, ‘as the skeletal convexity increases the angle must also increase’. Thus, decrease in facial convexity may result in concomitant decrease in H angle. In the present study, skeletal convexity and H angle were decreased in both treatment groups. Although an improvement existed for H angle, the post-treatment H angle values were not within the ideal range as stated by Holdaway (1983).

In Class II, division 1 malocclusions, the lower lip was distorted behind or under the upper incisors. This results in deep labiomental sulcus and acute mentolabial angle. In our study, the increase in mentolabial angle is an evident result for both treatment groups. Lange *et al.* (1995) reported similar results after bionator therapy and suggested two possible explanations for this change: the first one is the elimination of overjet and the second is the change in the tonicity and posture of perioral muscles. When the overjet was reduced with functional appliance treatment, physical obstruction of upper incisors is removed and the distortion of lower lip could be prevented. If the patient is instructed to maintain lip seal while wearing the appliance, lip strain is increased and this results in change in the posture and tonicity of perioral muscles. As a result, the lower lip distortion is eliminated; lower lip thickness, lower lip length, and mentolabial angle increased.

Upper lip was positioned backwards relative to E plane in both treatment groups. In Twin Block group, mandibular advancement was greater than control and Herbst groups. Forward position of soft tissue pogonion results in concomitant forward positioning of E plane. Although Herbst appliance treatment did not result in statistically significant increase in soft tissue pogonion to VRL measurement, the increase in nose projection would result with retruded position of upper lip relative to E plane (Pancherz and Anehus-Pancherz, 1994). Similar (Pancherz and Anehus-Pancherz, 1994; Lee *et al.*, 2007; Alves and Oliveira, 2008; Varlık *et al.*, 2008) and contrary (Morris *et al.*, 1998; Sharma and Lee, 2005) results were reported in the literature.

No significant changes were found in the position of lower lip and soft tissue pogonion relative to VRL between Herbst and control groups. Similar results were reported by Ursi *et al.* (2000) and Pancherz and Anehus-Pancherz (1994). According to the results of a systematic review, Flores-Mir *et al.* (2006) concluded that fixed functional appliances did not result in a change in the antero-posterior position of lower lip and soft tissue menton.

In Twin Block group, lower lip, lower lip sulcus, and soft tissue pogonion moved anteriorly. Similar changes were found after Twin Block therapy by Varlık *et al.* (2008) but the amounts were less than our results. According to the changes in SNB angle, the degree of mandibular advancement seems to be greater in Twin Block group than other groups. This protrusion in soft tissues may reflect the soft tissue adaptability to hard tissue changes in our Twin Block group. Based on these findings, it may be stated that Twin Block therapy results in forward movement of lower third of the face's soft tissues.

The soft tissue effects of Twin Block therapy were studied in detail with different analyses and imaging systems. Morris *et al.* (1998) evaluated treatment effects of three different functional appliances (Bass, Bionator, and Twin Block) with laser scanning system. They reported marked changes in lower face region. Anterior and inferior movement of chin, forward movement of lower lip, and reduction in lower lip curvature were reported. Statistically and clinically significant changes were found for Twin Block group. Singh (2002), using geometric morphometrics, showed antero-inferior displacement of mandibular soft tissues. Singh and Clark (2003), using finite-element scaling analysis, found a reduction in the prominence of lower lip sulcus. Results of our study support the findings of the above-mentioned studies that have used different methods to evaluate the effects of Twin Block appliance.

According to these results, it may be concluded that Twin Block therapy would result in greater advancement of mandibular soft tissues than Herbst and control groups. The soft tissue changes reflect the treatment effects on hard tissues.

Conclusion

1. After Twin Block and Herbst appliance therapy, statistically significant soft tissue changes were observed compared to untreated control sample.
2. The effects of Herbst and Twin Block treatment on the soft tissue profile were similar; they both significantly changed the soft tissue profile.
3. Greater advancement of soft tissue pogonion and lower lip were observed in Twin Block group.

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