The European Journal of Orthodontics Advance Access published April 24, 2013

European Journal of Orthodontics
doi:10.1093/ejo/cjt013

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

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SUMMARY

OBJECTIVE: The aim of this study is to evaluate dentoskeletal effects of Herbst and Twin Block (TB) appliance therapies in Skeletal Class II malocclusion.

SUBJECTS AND METHODS: Herbst group consisted of 11 girls and 9 boys (mean age = 12.74 ± 1.43 years), TB group comprised of 10 girls and 10 boys (mean age = 13.0 ± 1.32 years), and control group included 9 girls and 11 boys (mean age = 12.17 ± 1.47 years). Mean treatment/observation times were 15.81 ± 5.96 months for Herbst, 16.20 ± 7.54 months for TB, and 15.58 ± 3.13 months for control group. Pre-treatment (T0) and post-treatment (T1) lateral cephalograms were traced using a modified Pancherz's cephalometric analysis. Inter-group differences were evaluated with one-way analysis of variance, and intra-group differences were assessed with paired samples *t*-test at the $P < 0.05$ level.

RESULTS: In control group, all sagittal and vertical skeletal measurements increased as a result of continuing growth. However, skeletal discrepancy and overjet remained unchanged. After functional appliance therapy, greater increases were recorded in TB group for all mandibular skeletal measurements compared with those in control group. Upper dental arch distalization and lower incisor protrusion were significant in Herbst group, compared with control. All face height measurements increased after functional appliance therapy.

IMPLICATIONS AND CONCLUSIONS: In TB group, the treatment effects were mainly due to mandibular skeletal changes. Both skeletal and dental changes contribute to Class II correction with Herbst appliance therapy. Herbst appliance may be especially useful in Skeletal Class II patients with maxillary dentoalveolar protrusion and mandibular dentoalveolar retrusion, whereas TB appliance may be preferred for skeletal mandibular retrognathy patients.

Introduction

Patient cooperation is one of the most important factors for successful functional appliance treatment. Need for cooperation is reduced with the use of fixed functional appliances. The Herbst appliance has gained widespread acceptance and is suggested to be the most effective appliance in correcting Class II malocclusions (Pancherz, 1997).

Although fixed functional appliances reduce the need for patient cooperation, they are tooth-borne appliances. On the other hand, removable functional appliances are more tissue borne and they are more likely to produce skeletal changes (Mills and McCulloch, 1998).

Twin Block (TB) can be worn for 24 hours and takes the advantage of all functional forces applied to dentition (Clark, 1982, 2002). Because of its small size, patients adopt it easily and speech disturbance is minimized (Mills and McCulloch, 1998).

The cast splint design is one of the most recent designs of Herbst appliance (Pancherz, 2003). Treatment effects of cast splint Herbst appliance (Ruf and Pancherz, 1998; Hägg *et al*., 2002; Weschler and Pancherz, 2005; Martin and Pancherz, 2009) and TB appliance (Illing *et al*., 1998; Lund and Sandler, 1998; Toth and Mcnamara, 1999; Bacetti *et al*., 2000; Mills and McCulloch, 2000; Trenouth, 2000) were evaluated in adolescents.

Schaefer *et al*. (2004) compared the treatment effects of TB and Herbst appliances. They found that molar relationship and sagittal maxillomandibular discrepancy correction were greater for TB appliance. O'Brien *et al*. (2003a) evaluated the efficacy of Herbst and TB appliances and reported similar dental and skeletal effects. Because of high cooperation rates, they suggested that Herbst appliance could be a good treatment alternative for treating adolescents with Class II division 1 malocclusions (O'Brien *et al*., 2003a). Neither of the studies included a control group to compare the effects of the appliances with an untreated sample.

In the literature, there seems to be a consensus on the effectiveness of both appliances, but the lack of comparable studies leaves questions regarding which appliance is more effective. Thus, the aim of this prospective clinical study is to compare the dentoskeletal effects of TB and Herbst appliances in patients with Class II division 1 mandibular retrognathy. The study also includes an untreated control sample to be compared with treatment groups.

Subjects and methods

The study was ethically approved by the Ethical Committee of the University of Erciyes. Totally, 67 subjects who were referred to the Orthodontic Clinic of Erciyes University, Faculty of Dentistry, were included in the study. All subjects included in the study and their parents were informed about the study and they signed an informed consent.

The inclusion and exclusion criteria are presented in Table 1. The sample, appliance designs, and the treatment techniques were all identical to those described in a previous article (Baysal and Uysal, 2013). Briefly, the patients who met the inclusion criteria and accepted to participate were randomized to groups receiving treatment with either Herbst or TB appliance. Randomization was made at this stage according to previously prepared random number tables with block stratification on gender. Twenty-three patients were included in the Herbst group and 24 patients were enrolled in the TB group. The control group comprised 20 subjects who refused treatment after initial records were taken with excuses such as college entrance examination, problems in medical insurance system, or refusal to wear appliance. They were put in the waiting list again and instructed to attend the clinic when the patient was willing to undergo functional appliance treatment or after they solved the medical insurance problem. The patients who accepted treatment received orthodontic treatment and initial records were taken. These first and second pre-treatment records were used as control records.

Cast splint Herbst appliances were adjusted to hold the mandible in an edge-to-edge incisor position. TB appliances were constructed according to the 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. All patients were asked to wear the appliance full time, including during eating. Active therapy was finished when a normal or overcorrected overjet was obtained in retruded mandibular position. Immediately after appliance removal, in order to achieve occlusal settling and retention, an acrylic monoblock was used in the Herbst group and a modified Hawley appliance with anterior inclined plane (Clark, 2002) was employed in the TB group. For the Herbst group, the acrylic over the mandibular posterior teeth was gradually trimmed to achieve occlusal settling. After 4–6 months of retention and supporting phases, treatments were finished when good cuspal interdigitation was provided. Three patients from the Herbst group and four patients from the TB group were excluded from the study because of following reasons: lost to follow-up, poor oral hygiene and progression of white spot lesions, non-compliance, no longer wanted treatment, and hospitalization for a systemic disease. We did not carry out an intention-to-treat analysis of the data; thus, only the records of the patients who completed treatment were analysed.

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, Rcap) epiphyseal stages on handwrist radiographs, as defined by Björk (1972)
Exclusion criteria
No history of orthodontic treatment either prior to or during functional appliance therapy
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

Cephalometric measurements

Lateral cephalometric radiographs were taken at the start (T0; before appliance placement) and end (T1; after occlusion settled into Class I or super Class I molar relationship) of treatment using the same machine (Instrumentarum cephalometer, Ortoceph OC100, Tuusula, Finland). The patients were positioned in the cephalostat so that the path of X-rays was at a right angle to the sagittal plane and the Frankfort plane was parallel to the horizontal plane. They were instructed to stay with their teeth in centric occlusion and the lips lightly closed (Hillesund *et al*., 1978). Cephalometric tracings were performed by the same author (AB) manually.

The following landmarks were used: condylion (co), incision inferius (ii), incision superius (is), molar inferius (mi), molar superius (ms), pogonion (pg), A point, anterior nasal spine (ANS), posterior nasal spine (PNS), menton (me), gnathion (Gn), and gonion (Go).

Superimposition procedure and Pancherz's cephalometric analysis

A modified sagittal–occlusal analysis of Pancherz (Pancherz 1982a) was used. The reference grid was composed of the occlusal line (OL) and a perpendicular-to-occlusion line (OLp) through the sella point. Pre- and post-treatment radiographs were superimposed on the stable bone structures of the anterior cranial base (Björk and Skieller, 1983). After superimposition, the reference grid was transferred to post-treatment cephalometric radiograph. The cephalometric measurements are shown in Figure 1 and descriptions are given in Table 2.

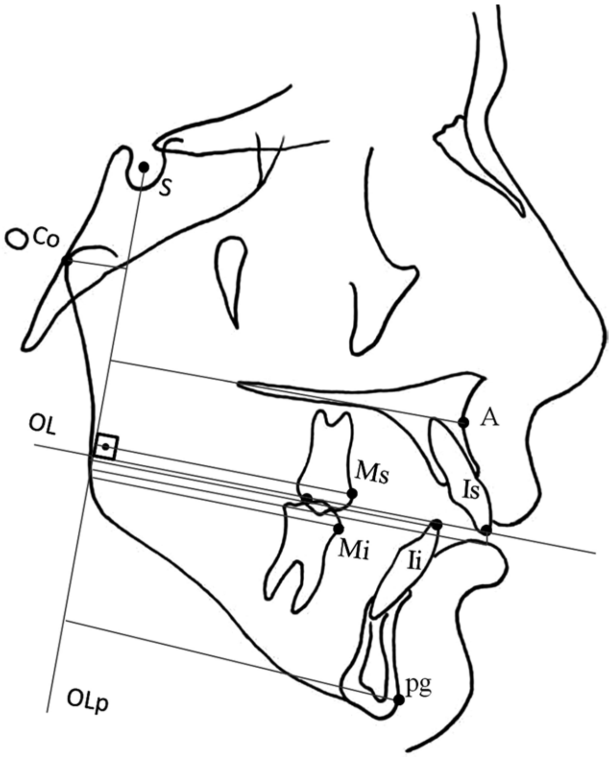

Figure 1 Modified Pancherz analysis. Co, condylion; Ii, incision inferius; Is, incision superius; Mi, molar inferius; Ms, molar superius; pg, pogonion; A, point A; S, sella; OL, occlusal line; OLp, occlusal line perpendicular; me, menton; Gn, gnathion; Go, gonion.

Mandibular dimensions, skeletal vertical, and dental vertical measurements

Measurements (Figure 2) were separately obtained from pre- and post-treatment radiographs independently without using superimposition and reference grid system.

Statistical analysis

All statistical analyses were performed with SPSS (version 15.0, SPSS Inc., Chicago, Illinois, USA). The data were found to be normally distributed and there was homogeneity of variance among groups according to the normality test of Shapiro–Wilks and Levene's test. Gender differences within groups were evaluated using independent-sample *t*-test. The differences were not statistically significant, and the data were therefore pooled. The groups were compared with respect to their pre-treatment values and the differences during treatment/observation period were determined using one-way analysis of variance (ANOVA) and multiple comparisons used Tukey test. Paired-samples *t*-test was used to evaluate intra-group comparisons.

Twenty randomly selected radiographs were again traced 1 month after the first measurements. The first and second measurements were compared using the paired *t*-test and the differences were found to be insignificant. Correlation analysis was applied to the same measurements and all *r* values were found to be higher than 0.900. Statistical significance was set at $P < 0.05$.

Table 2 Definition of the sagittal–occlusal analysis measurements.

is/OLp minus ii/OLp	Overjet
ms/OLp minus mi/OLp	Molar relationship (distal relationship: positive value; a mesial relationship: negative value)
A point/OLp	Sagittal position of the maxillary base
pg/OLp	Sagittal position of the mandibular base
A point/OLp - pg/OLp	Skeletal discrepancy
co/OLp	Sagittal position of the condylar head
pg/OLp + co/OLp	Composite mandibular length
is/OLp minus A point/OLp	Sagittal position of the maxillary central incisor within the maxilla
ii/OLp minus pg/OLp	Sagittal position of the mandibular central incisor within the mandible
ms/OLp minus A point/OLp	Sagittal position of the maxillary permanent first molar within the maxilla
mi/OLp minus pg/OLp	Sagittal position of the mandibular permanent first molar within the mandible

OLp, occlusal line perpendicular

Results

Statistical comparison of the pre-treatment variables of the groups is presented in Table 3. Statistically significant differences were found between TB and control groups regarding ramus ($P = 0.021$), corpus ($P = 0.021$), composite mandibular ($P = 0.006$) and effective mandibular lengths ($P = 0.005$) which were greater in the TB group than the control group. In the control group, molar relation was more Class II compared to TB group ($P = 0.047$), and the overjet was greater than both treatment groups ($P = 0.003$). Compared to the control group, SN-GoGn ($P = 0.037$) and effective mandibular length ($P = 0.040$) measurements were higher in the Herbst group.

Descriptive statistics, statistical intra-group comparisons of cephalometric variables, and the inter-group comparisons of the changes between T0 and T1 are shown in Table 4.

Intra-group changes

Changes between baseline and post-treatment/post-observation readings are given in Table 4.

Herbst group

Significant differences were found for all cephalometric variables, except for co/OLp and L1-MP measurements. Overjet and overbite were reduced and the distal molar relation was corrected. Maxillary and mandibular bases were moved anteriorly and composite mandibular length was increased. Forward movement of mandibular dentition and distalization of maxillary dentition were found. All face height measurements and mandibular length measurements were increased. Eruption of upper and lower molars and upper incisors was observed.

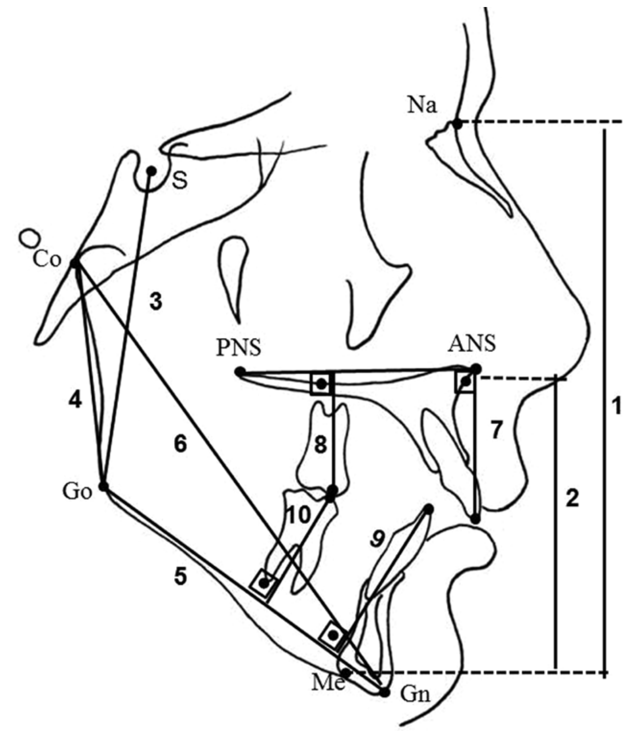

Figure 2 1, total anterior face height (Na-Me); 2, lower anterior face height (ANS-Me); 3, lower posterior face height (S-Go); 4, ramus height (Co-Go); 5, corpus length (Go-Gn); 6, effective mandibular length (Co-Gn); 7, upper incisor to palatal plane (U1-PP); 8, upper molar to palatal plane (U6-PP); 9, lower incisor to mandibular plane (L1-MP); and 10, lower molar to mandibular plane (L6-MP).

TB group

Similar reduction in overjet, overbite, and correction of molar relation was observed as in the Herbst group. Mandibular base was moved anteriorly, composite mandibular length was increased, and skeletal discrepancy was improved. Maxillary base measurement remained unchanged. Changes in sagittal dental measurements were not statistically significant. All measurements of face height and mandibular length were increased. Eruption of upper and lower molars and upper incisors was observed.

Control group

Maxillary and mandibular bases moved in anterior direction, but no change was found in the correction of skeletal discrepancy. Changes in overjet and molar relation were not statistically significant. Composite mandibular length increased despite non-significant change in co/OLp measurement. The only significant change in sagittal dental variables was upper incisor protrusion. All measurements of face height and mandibular length increased. Upper and lower molars and lower incisors erupted. Overbite remained unchanged.

Inter-group comparison

Multiple comparisons of the groups after treatment/observation period are given in Table 4. Overjet and overbite decreased and molar relation was corrected in both treatment groups ($P < 0.001$), but the changes were not statistically significant for the control group. Increases in mandibular base (pg/OLp) and composite mandibular lengths were highest in the TB group, and the increases in the TB group were significantly greater compared with the control group ($P = 0.009$ and $P = 0.027$, respectively). TB treatment resulted in greater improvement in skeletal discrepancy compared with the result in the Herbst ($P = 0.033$) and control groups ($P < 0.001$). No difference was found between the Herbst and control groups regarding skeletal discrepancy. Maxillary molars were placed in more distal position ($P = 0.012$) and maxillary incisors ($P = 0.004$) retracted with Herbst treatment when compared with untreated control. Lower incisors exhibited more protrusion with Herbst treatment compared with those in the TB ($P = 0.027$) and control ($P = 0.011$) groups. Statistically significant increases were observed for all face height measurements in treatment groups compared with the measurements in the control group. Increases in ramus and effective mandibular lengths were similar between Herbst and control groups. TB therapy resulted in greater increases in ramus and effective mandibular lengths compared with the changes in the control group. These changes were statistically significant ($P = 0.001$ and $P = 0.002$, respectively).

Skeletal and dental components contributing to overjet and molar correction in treatment groups compared with the control group are shown in Figures 3 and 4. During Herbst therapy, overjet and molar corrections were mainly based on dental changes; dental contribution was 71 per cent for overjet correction and 63.3 per cent for molar correction. In the TB group, overjet and molar corrections mainly resulted from skeletal changes; dental contribution percentages were 30 and 28.5 per cent, respectively.

Discussion

According to Bacetti *et al*. (2000), functional appliance therapies would have maximum therapeutic effects if the mandibular growth spurt was included. Greater sagittal–condylar growth was found in patients treated with the Herbst appliance in pubertal peak compared with those who were treated before or after the peak (Hägg and Pancherz, 1988). According to Bacetti *et al*. (2000), the optimal treatment timing for TB therapy is during or slightly after the onset of the pubertal peak in growth velocity. The subjects in this study were in the fourth and fifth epiphyseal stages according to the method described by Björk (1972). These stages show the initiation and peak of growth spurt, respectively. Thus, in this study, treatments were performed including the peak of pubertal growth in order to achieve maximum therapeutic effects of both appliances.

The three sample groups were almost equal in terms of gender distribution and maturity status. However, the baseline cephalometric variables showed statistically significant differences between treatment and control groups. Although no statistically significant difference was found between

Table 3 Comparison of baseline cephalometric measurements of treated and control subjects.

Measurements	Herbst		TB		Control		Significance	Multiple comparison		
	Mean	SD	Mean	SD	Mean	SD		Herbst / control	TB / control	Herbst / TB
SNA	80.92	1.13	80.72	0.99	81.15	1.31	0.514	NS	NS	NS
SNB	74.10	2.08	74.70	1.77	74.22	1.55	0.548	NS	NS	NS
ANB	6.77	1.56	6.02	1.17	6.90	1.58	0.130	NS	NS	NS
SN-GoGn	34.30	3.66	31.20	4.54	32.77	2.29	0.048	0.037	NS	NS
Overjet (is/OLp minus ii/OLp)	8.68	2.84	8.42	2.35	11.02	2.43	0.003	0.014	0.006	NS
Molar relation (ms/OLp minus mi/OLp)	0.78	1.87	0.58	1.53	2.08	2.37	0.037	NS	0.047	NS
Maxillary base (A point/OLp)	80.95	4.82	81.55	5.18	79.60	3.31	0.382	NS	NS	NS
Mandibular base (pg/OLp)	81.82	4.85	83.32	6.69	79.75	4.76	0.129	NS	NS	NS
Skeletal discrepancy	-0.87	3.17	-1.77	4.00	-1.05	2.52	0.302	NS	NS	NS
Condylar head (co/Olp)	11.08	2.62	12.05	3.47	10.70	3.49	0.399	NS	NS	NS
Composite mandibular length (pg/OLP+co/OLp)	92.90	3.99	95.38	4.99	90.45	5.38	0.008	NS	0.006	NS
Maxillary incisor (is/Olp minus A point/OLp)	10.18	2.37	9.05	1.82	10.40	1.80	0.086	NS	NS	NS
Mandibular incisor (ii/OLp minus pg/OLp)	0.62	3.41	-1.15	4.56	-0.78	2.87	0.284	NS	NS	NS
Maxillary molar (ms/Olp minus A point/OLp)	-23.90	2.05	-24.27	2.25	-24.70	2.13	0.503	NS	NS	NS
Mandibular molar (mi/Olp minus pg/OLp)	-25.55	3.21	-26.62	4.03	-26.92	3.18	0.431	NS	NS	NS
Total anterior face height (Na-Me)	121.85	6.95	119.90	6.54	118.52	6.66	0.298	NS	NS	NS
Lower anterior face height (ANS-Me)	68.12	5.54	66.35	5.62	65.70	4.86	0.340	NS	NS	NS
Lower posterior face height (S-Go)	77.82	4.93	78.22	4.93	76.50	4.41	0.493	NS	NS	NS
Ramus height (Co-Go)	52.78	4.95	54.92	3.61	51.35	3.60	0.027	NS	0.021	NS
Corpus length (Go-Gn)	74.00	4.86	75.88	4.63	71.98	3.89	0.029	NS	0.021	NS
Effective mandibular length (Co-Gn)	113.08	5.18	114.38	5.53	101.88	5.22	0.005	0.040	0.005	NS
U1-PP (mm)	30.90	3.89	30.00	3.95	29.55	3.15	0.503	NS	NS	NS
U6-PP (mm)	22.78	2.90	22.38	2.90	21.88	2.56	0.597	NS	NS	NS
L1-MP (mm)	41.32	2.92	39.90	3.55	39.05	2.65	0.690	NS	NS	NS
L6-MP (mm)	29.90	2.76	29.82	2.71	28.12	1.91	0.051	NS	NS	NS
Overbite (mm)	4.25	1.57	4.42	1.87	4.42	2.13	0.944	NS	NS	NS

SD, standard deviation; NS, non-significant

groups in terms of mandibular prominence (sella-nasion-B point) and skeletal discrepancy measurements, the mandibular dimensions were greater in the TB group compared with the control group. According to Patel *et al*. (2002), patients who have smaller and retrusive mandibles respond more favourably to functional appliance therapy. It should be taken into account during the interpretation of the results.

In the present study, removable appliances were delivered to patients after finishing the active treatment period and the patients were instructed to wear the appliance until occlusion settled in order to achieve stable mandibular position. In this way, we intended to show the pure effects of functional therapy and to eliminate the effects of fixed orthodontic treatment. Meanwhile, during the retention phase, interocclusal clearance and incisor edge-to-edge position was eliminated probably due to the relapse of incisor protrusion and the posterior teeth intrusion. These changes should be taken into account when the treatment effects of the appliances were evaluated.

The effects of Herbst appliance therapy have been evaluated by an analysis described by Pancherz (1982a). It has been used by many authors (Croft *et al*., 1999; Franchi *et al*., 1999; O'Brien *et al*., 2003b; VanLaecken, 2006). In the present study, Pancherz cephalometric analysis with superimposition was used because it is an accepted "gold standard" for Herbst appliance studies.

Sagittal skeletal changes

Maxillary changes

Functional appliances produce a distally directed force to maxilla as the mandible reposition forward (Hotz, 1970). In our study, neither of the appliances restricted maxillary growth. In several studies, 6 months or longer periods of Herbst treatment resulted in decreases in SNA angle (Pancherz 1979, Pancherz 1985, Valant and Sinclair, 1989). On a short-term basis, Herbst appliance results in restriction of maxillary growth, whereas on a long-term basis, it does not affect the maxillary complex (Pancherz, 1997). Controversial results exist for the restraining effect of TB therapy on maxilla. Some studies showed restriction (Toth and McNamara, 1999; Tumer and Gultan, 1999; Mills and McCulloch, 2000; Trenouth, 2000; O'Brien *et al*., 2003a), whereas others did not (Clark, 1982; Illing *et al*., 1998).

Table 4 Changes between pre- and post-treatment (in millimetres) and comparison of the treatment effect between the three groups.

Measurements	Herbst			TB			Control			Multiple comparison (P value)		
	Mean	SD	Significance	Mean	SD	Significance	Mean	SD	Significance	Herbst/ Control	TB/ Control	Herbst/ TB
Overjet (is/OLp minus ii/OLp)	–5.08	2.73	0.000	–4.48	2.55	0.000	0.38	1.31	NS	0.000	0.000	NS
Molar relation (ms/OLp minus mi/OLp)	–4.58	1.90	0.000	–5.05	1.89	0.000	–0.28	1.41	NS	0.000	0.000	NS
Maxillary base (A point/OLp)	0.70	1.34	0.031	0.45	1.22	NS	1.35	1.04	0.000	NS	NS	NS
Mandibular base (pg/OLp)	3.05	2.25	0.000	4.62	3.09	0.000	2.12	2.32	0.001	NS	0.009	NS
Skeletal discrepancy	–2.35	2.13	0.000	–4.18	2.68	0.000	–0.77	1.80	NS	NS	0.000	0.033
Condylar head (co/Olp)	0.40	1.07	NS	0.68	1.64	NS	0.75	2.45	NS	NS	NS	NS
Composite mandibular length (pg/OLP+co/OLp)	3.45	2.43	0.000	5.30	3.60	0.000	2.88	2.45	0.000	NS	0.027	NS
Maxillary incisor (is/Olp minus A point/OLp)	–0.95	1.82	0.031	–0.45	1.81	NS	0.75	1.11	0.007	0.004	NS	NS
Mandibular incisor (ii/OLp minus pg/OLp)	1.77	2.29	0.003	–0.15	3.00	NS	–0.40	1.87	NS	0.011	NS	0.027
Maxillary molar (ms/Olp minus A point/OLp)	–1.00	1.29	0.003	–0.52	1.57	NS	0.27	1.15	NS	0.012	NS	NS
Mandibular molar (mi/Olp minus pg/OLp)	1.22	2.23	0.024	0.35	1.79	NS	–0.22	2.06	NS	NS	NS	NS
Total anterior face height (Na-Me)	6.95	2.58	0.000	5.73	2.89	0.000	3.53	2.23	0.000	0.000	0.025	NS
Lower anterior face height (ANS-Me)	4.35	2.27	0.000	3.85	2.17	0.000	2.05	1.73	0.000	0.003	0.022	NS
Lower posterior face height (S-Go)	5.50	2.76	0.000	6.95	2.62	0.000	2.85	2.40	0.000	0.026	0.000	NS
Ramus height (Co-Go)	3.73	3.25	0.000	5.35	2.92	0.000	1.98	2.11	0.001	NS	0.001	NS
Corpus length (Go-Gn)	3.00	2.63	0.000	2.28	2.85	0.002	2.75	2.08	0.000	NS	NS	NS
Effective mandibular length (Co-Gn)	5.65	2.24	0.000	7.20	3.70	0.000	3.83	2.62	0.000	NS	0.002	NS
U1-PP (mm)	1.40	1.05	0.000	0.83	1.31	0.011	0.38	0.97	NS	0.015	NS	NS
U6-PP (mm)	0.80	1.68	0.047	0.95	1.35	0.005	0.83	1.23	0.008	NS	NS	NS
L1-MP (mm)	0.50	1.60	NS	–0.17	1.55	NS	1.07	1.30	0.002	NS	0.030	NS
L6-MP (mm)	2.05	2.21	0.001	1.82	1.77	0.000	0.90	1.03	0.001	NS	NS	NS
Overbite (mm)	–2.00	1.82	0.000	–2.15	1.49	0.000	0.05	1.30	NS	0.000	0.000	NS

SD, standard deviation; NS, non-significant.

Mandibular changes

In the present study, when interjaw relations were evaluated, treatment effects were mainly produced by mandibular changes because maxillary base measurements were not affected by therapies with both appliances.

Although no significant difference was found among groups for corpus length measurement (Go-Gn), statistically significant greater increases were found for mandibular base, composite mandibular length, and effective mandibular length measurements in TB group compared with those in control. For these measurements, no difference was found between treatment groups. Schaefer *et al*. (2004) compared the treatment effects of TB and Herbst appliances and reported similar increases in condylion-gnathion measurements for both groups.

During active Herbst therapy, Pancherz (1982a) reported three times greater mandibular length increases in Herbst group than in control group. After 7–12 months of active treatment, increases of 1.3–3.4 mm in mandibular length (condylion-pogonion or condylion-gnathion) were reported in several studies (Pancherz, 1979; Pancherz, 1982a; Valant and Sinclair, 1989). In the present study, increase in effective mandibular length was found to be greater in control group (3.83 ± 2.62 mm). Hansen and Pancherz (1992) evaluated short- and long-term treatment effects of Herbst therapy. Six months after the termination of active functional appliance therapy (an average of 13 months after the initiation of treatment), they reported that the mandibular growth was 2.4 mm greater than the maxillary growth in the Herbst group; the growth was 1.6 mm in the control group. They concluded that the Herbst appliance changed the amount and direction of mandibular growth (Hansen and Pancherz, 1992). The difference in our group was 2.35 ± 2.13 mm in the Herbst group, 0.77 ± 1.80 mm in th control group, and the difference between groups was 1.57 ± 3.03 mm. Although the difference seems greater than that in the study of Hansen and Pancherz (1992), no statistically significant difference was found between groups.

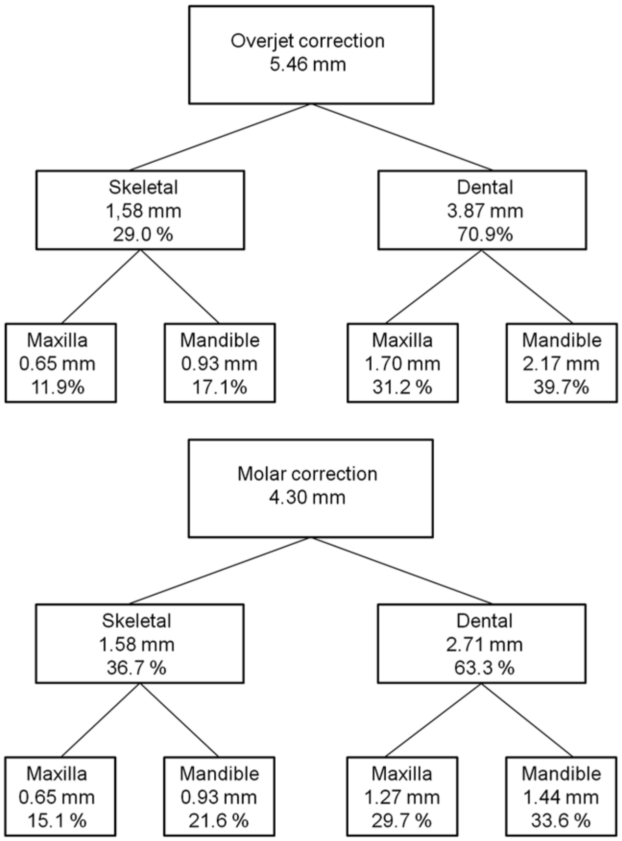

Figure 3 Diagram of maxillary and mandibular skeletal and dentoalveolar changes contributing to sagittal overjet and molar correction during Herbst therapy.

TB treatment resulted in an additional 3.37 mm increase in effective mandibular length compared with that in the control group. After 12–16 months of treatment, increase of 1.46–4.75 mm in mandibular length was reported (Illing *et al*., 1998; Lund and Sandler, 1998; Mills and McCulloch, 1998; Toth and McNamara, 1999; Tumer and Gultan, 1999; Bacetti *et al*., 2000; O'Brien *et al*., 2003b) and in general, the increase was statistically significant compared with the control group (Mills and McCulloch, 1998; Toth and McNamara, 1999; Tumer and Gultan, 1999; Bacetti *et al*., 2000). Bacetti *et al*. (2000) reported an increase of 3.57 mm and O'Brien *et al*. (2003a) found 1.55 mm additional increase in composite mandibular length; in our study, the increase was 2.40 mm.

Schaefer *et al*. (2004) reported that TB therapy led to greater increase in the forward positioning of the mandible compared with Herbst therapy. We found similar results.

When overjet and molar correction percentages were evaluated (Figures 3 and 4), skeletal contribution seems to be approximately 50 per cent of dental contribution after Herbst treatment. On the other hand, TB appliance therapy results in greater skeletal changes for overjet and molar correction. When the skeletal discrepancy was evaluated, TB treatment resulted in greater improvement compared with the Herbst and control groups. Schaefer *et al*. (2004) reported 2 mm greater maxillomandibular changes in TB group than with the Herbst appliance.

Based on these above-mentioned findings, it may be concluded that greater sagittal skeletal changes may be achieved with TB treatment than with the Herbst appliance therapy.

Sagittal dental changes

No statistically significant difference was found for sagittal dental measurements between TB and control groups. Herbst treatment results in distalization of upper molars, retrusion of upper incisors, and protrusion of lower incisors. Distalization of upper dental arch may be related to the 'headgear effect' of Herbst appliance. Pancherz and Anehus-Pancherz (1993) reported as much as 4.5 mm maxillary molar distalization with Herbst treatment. Especially, lower incisor protrusion was more evident and was statistically significant in Herbst group compared with the TB and control groups. Pancherz (1997) reported backward movement of maxillary teeth and forward movement of mandibular teeth after Herbst appliance therapy. In addition, control of lower incisors was reported to be difficult regardless of the anchorage system used (Pancherz and Hansen, 1988). In the literature, 2–7.9 degree increases in lower incisor proclination were reported after TB appliance therapy (Illing *et al*., 1998; Lund and Sandler, 1998; Tumer and Gultan, 1999). Lund and Sandler (1998) and Tumer and Gultan (1999) found statistically significant lower incisor proclination compared with control group. In the present study, no difference in lower incisor position was found between control and TB groups; this finding may be related to the acrylic capping of lower incisors with the TB appliance. Mills and McCulloch (1998) and Toth and McNamara (1999) used modified TB appliances with a labial bow in order to control lower incisor protrusion, but the difference between treatment and control groups was reported to be statistically significant.

Vertical skeletal changes

Increases in lower anterior and posterior face heights are a consistent finding after TB therapy. Toth and Mcnamara (1999) reported 3.0 mm increase in anterior face height and 3.2 mm increase in posterior face height. Lund and Sandler (1998) found 2.6 mm increase in total anterior face height after TB therapy compared with control groups. Mills and McCulloch (1998) noted significant increases relative to controls; 3.8 mm in total anterior face height and 2.9 mm for posterior face heights.

Acrylic contouring during TB treatment should be taken into account when the increase in lower anterior face height is evaluated. In the current study, acrylic upper bite blocks were trimmed only in deep-bite patients, not in all subjects. For deep-bite patients, the vertical dimension may be increased. On the other hand, TB appliance may produce

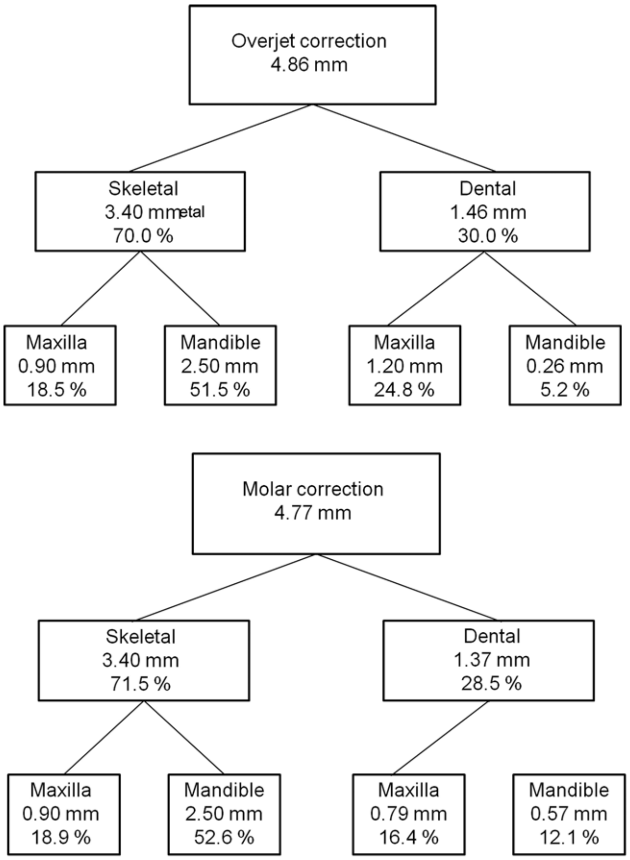

Figure 4 Diagram of maxillary and mandibular skeletal and dentoalveolar changes contributing to sagittal overjet and molar correction during twin block therapy.

a 'posterior bite-block effect', if not trimmed (Toth and McNamara, 1999). Thus, TB therapy may inhibit vertical development in some subjects and enhance lower molar eruption in others. The results of our study should be interpreted with caution.

Pancherz (1982b) reported 1.8 mm increase in lower anterior face height with banded Herbst design. Increases in lower anterior face height and concomitant increase in posterior face height prevent the change in mandibular plane angle (Ruf and Pancherz, 1996).

In the current study, TB therapy resulted in greater elongation of ramus (3.37 mm additional elongation), which was statistically significant compared with the control group. Schaefer *et al*. (2004) reported statistically significant greater elongation of mandibular ramus in TB group than in Herbst group. Mills and McCulloch (1998) reported 2.9 mm additional increase in ramus height compared with control group. They determined that overall mandibular length increase resulted from ramus height increase. Only one-third of the increase was due to the increase in mandibular body length (gonion to gnathion). In the current study, no difference was found for corpus length among the three groups. Thus, the effective mandibular length increase may be the result of ramus height increase in TB group.

Vertical dental changes

In control group, upper incisor eruption was less than that observed in Herbst group. The impeded eruption in the control group may be attributed to the position of the lower lip. If a lip trap had been continued in untreated subjects, this would have increased the inclination of incisors. And the proclination may camouflage vertical eruption of upper incisors.

In the TB group, lower incisor intrusion was found despite the eruption in other groups. The possible explanation for this finding may be the acrylic capping over lower incisors.

When the skeletal and dental contributions to overjet and molar correction percentages were evaluated, two-thirds of overall treatment effects of TB therapy could be attributed to skeletal changes. On the other hand, two-thirds of overall treatment effects were mainly dentoalveolar after Herbst appliance therapy. Within the limitations of this clinical prospective study, the choice of appliance for skeletal mandibular retrognathy patients may be the TB appliance. Herbst appliance may be especially useful in skeletal Class II patients with maxillary dentoalveolar protrusion and mandibular dentoalveolar retrusion.

Conclusion

- Therapies with both appliances resulted in correction of Class II relationship, reduction of overjet, and improvement in skeletal discrepancy. The only statistically significant differences between treatment groups were recorded for mandibular incisor position and skeletal discrepancy. After treatment, incisor protrusion was higher in the Herbst group and skeletal discrepancy improvement was greater in the TB group.
- Compared with the control group, Herbst therapy did not result in a statistically significant improvement in sagittal discrepancy.
- TB appliance therapy resulted in greater skeletal changes than Herbst therapy.
- Correction of Class II malocclusion with Herbst therapy could be a combination of dental and skeletal changes.

Funding

Erciyes University, Scientific Research Projects Unit (SBT-07-36).

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