A cephalometric and tomographic evaluation of Herbst treatment in the mixed dentition

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This study describes combined treatment and posttreatment effects for patients treated with the Herbst appliance in the mixed dentition followed by retention with a prefabricated positioner. The sample included 24 female and 16 male patients with Class II malocclusions. Posttreatment lateral cephalograms were taken an average of 17 months after Herbst removal, when the patients presented for phase II comprehensive orthodontics. The cumulative treatment and retention effects were compared with a sample of untreated Class II controls matched for age, sex, and mandibular plane angle. The overjet and molar relationship were corrected by 3.4 and 3.3 mm, respectively. A headgear effect of Herbst therapy was observed, as anterior maxillary displacement was reduced by 1.2 mm. Condylar growth was redirected to produce 2.0 mm greater posterior growth in the treatment group. These effects produced significantly greater decreases in SNA (0.8°) and ANB (1.4°), and a tendency toward an increase in SNB (0.5°) Mandibular orthopedic effects resulted in an increase in anterior facial height (1.6 mm) and inferior displacement of the chin. Minimal changes in the displacement of condylion in relation to stable cranial base structures suggest that glenoid fossa displacement does not contribute in a clinically significant way to Class II correction. Pretreatment, immediate posttreatment, and postretention corrected temporomandibular joint tomograms demonstrated a tendency for the condyle to be slightly forward (0.2 mm) at the end of treatment and then to fall back after treatment. Statistically significant joint space changes were limited to the posttreatment period. We conclude that Herbst treatment in the mixed dentition, in combination with retention, produces significant long-term improvements in dental and skeletal relationships as a result of dentoalveolar changes and orthopedic effects in both jaws. (Am J Orthod Dentofacial Orthop 1999;116:435-43)

The correction of Class II dental relationships can be achieved through dentoalveolar changes, orthopedic forces to inhibit maxillary growth and orthopedic forces to stimulate mandibular growth. The Herbst is a fixed-functional appliance, which is reported to combine these effects in order to achieve Class I dental relationships.[1-3] Its bilateral telescopic arms work as an artificial joint to force the mandible into continuous protrusion. The Herbst's increasing popularity stems, most likely, from the high degree of control it provides the clinician, as patient cooperation is not required.

Questions regarding appropriate treatment timing with the appliance remain largely unanswered. The majority of Herbst studies have evaluated individuals treated in the permanent dentition. Treatment timing has been addressed by comparing adolescents of varying levels of somatic maturation (prepeak, peak, and postpeak).[4,5] No long-term differences in Class II correction have been demonstrated,[5] yet it is suggested that the ideal time for treatment is in the permanent dentition, at or just after peak height velocity of growth.[4,5] It is believed, although not established, that the delay would minimize unfavorable growth after treatment and maximize interarch relationships that contribute to treatment stability.[6]

Few Herbst studies have evaluated treatment effects for patients in the mixed dentition,[7-9] The only long-term mixed dentition study[9] evaluated the Herbst in combination with headgear therapy for a relatively small sample of patients who were compared to poorly matched controls. Although dramatic treatment effects were reported, concerns were raised because of relapse despite long-term retention.

Changes in temporomandibular joint (TMJ) position are produced by the initial placement of the Herbst appliance. Several studies have evaluated the TMJ before and after treatment[1-3] to confirm that normal condyle/fossa relationships are restored at the end of Herbst treatment. Although their results suggest that significant joint space changes are rare, they are typi-

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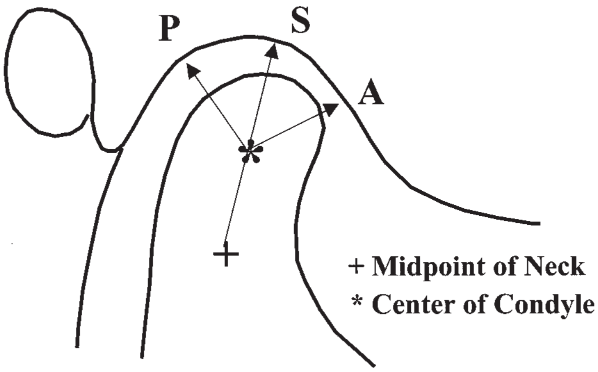

Fig 1. Posterior (*P*), superior (*S*), and anterior (*A*) joint spaces measured.

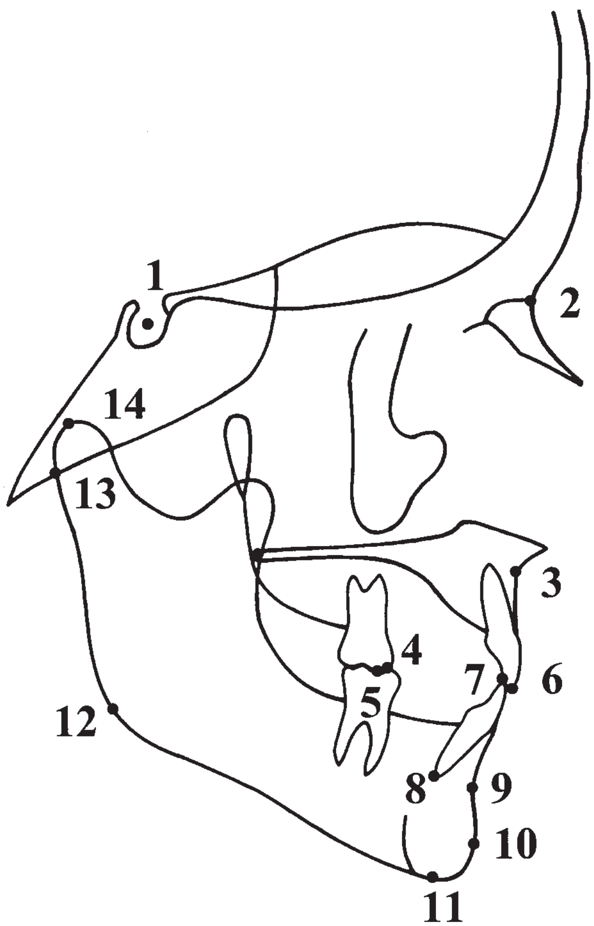

Fig 2. Cephalometric landmark digitized, including (*1*) sella, (*2*) nasion, (*3*) A point, (*4*) mesiobuccal cusp of maxillary first molar, (*5*) mesiobuccal cusp of mandibular first molar, (*6*) maxillary incisor tip, (*7*) mandibular incisor tip, (*8*) mandibular incisor apex, (*9*) B point, (*10*) pogonion, (*11*) menton, (*12*) gonion, (*13*) articulare, and (*14*) condylion.

cally based on small subsamples of the treated patients. More importantly, they have evaluated changes by means of transcranial radiographs, which have been shown to be inferior to the corrected tomograms in their ability to evaluate joint space changes.[10,11] In addition, studies of the long-term treatment effects on the condyle/fossa relationship[12] have not quantified joint changes.

Based on animal studies[12-15] that show the stimulation of new bone formation in the glenoid fossa by means of mandibular propulsion, we might expect Herbst therapy to produce anterior fossa displacement. However, the actual effects of Herbst treatment at the level of the glenoid fossa remain poorly understood. Although several authors have observed the formation of a double contour of the fossa radiographically,[3,7,16] a long-term anterior displacement of the glenoid fossa as a result of Herbst treatment has not been demonstrated.

The purpose of this study was to investigate the effects of mixed dentition Herbst therapy followed by retention for a large sample of patients. Effects of early Herbst treatment were evaluated when the patients returned for comprehensive orthodontic therapy (Phase II). Treatment changes were compared to a closely matched sample of untreated Class II individuals. Condyle/fossa relationship changes and glenoid fossa displacement were evaluated to better understand temporomandibular joint changes.

MATERIAL AND METHODS

Subjects

The treatment group consisted of consecutive cases treated by one clinician (R.M.) and selected based on the following criteria: (1) initiated Herbst therapy in the mixed dentition in patients between 7 and 10 years of age, (2) ANB $\geq 4°$, (3) molar relationship end-on or greater, (4) average compliance with retention appliance. Individuals without corrected TMJ tomograms were not excluded from the study, but an effort to obtain existing tomograms for all individuals was made. Approximately 3% of the patients were excluded because they could not tolerate the retention appliance; patients who wore the appliance even sporadically were included. A total of 24 females and 16 males meeting the selection criteria were identified.

Herbst treatment consisted of three phases. All patients underwent rapid maxillary expansion (RME) with a banded RME appliance, followed by Herbst therapy, and retention. A cantilever Herbst appliance design was used and included upper and lower stainless steel crowns, a mandibular lingual arch, and occlusal

Table I. Pretreatment (T1) comparison of Herbst treatment group versus untreated controls

	Herbst group		Controls		Group difference
Measurement	Mean	SD	Mean	SD	Mean
Age (years)	8.5	1.0	8.4	1.1	<0.1
Evaluation period	3.3	3.2	3.3	1.0	<0.1
Angular (°)					
MPA	35.6	4.6	36.8	3.7	–1.2
S-N-A	81.0	3.8	80.7	2.1	0.3
S-N-B	75.4	3.2	75.0	2.1	0.5
A-N-B	5.6	1.8	5.7	2.3	–0.2
N-A-Pg	10.9	4.9	11.1	4.8	–0.2
L1-MP	92.5	6.1	94.2	6.1	–1.8
Linear (mm)					
Co-Pg	92.5	3.7	91.1	4.7	1.4
Ar-Pg	87.1	3.3	86.5	4.0	
N-Me	99.7	5.2	95.5	4.6	4.2**
U6-L6	1.2	1.0	0.0	1.9	1.2**
OJ	5.5	1.9	3.7	1.7	1.8**
OB	4.1	2.4	3.5	2.4	0.6

*P < .05 level.
**P < .01 level.

Table II. Cumulative treatment and posttreatment changes of Herbst group versus untreated controls

	Herbst group		Controls		Group difference
Measurement	Mean	SD	Mean	SD	Mean
Angular (°)					
MPA	0.2	1.7	–1.0	1.8	1.2
S-N-A	–0.9	1.4	–0.1	1.3	–0.8**
S-N-B	1.0	1.5	0.5	1.1	0.5
A-N-B	–1.9	1.2	–0.6	1.3	–1.4**
N-A-Pg	–4.0	2.8	–1.8	2.6	–2.2**
L1-MP	1.6	4.8	2.0	3.9	–0.5
Linear (mm)					
Co-Pg	7.5	3.6	6.7	2.8	0.8
Ar-Pg	6.5	2.6	5.8	2.4	0.7
N-Me	7.9	2.9	6.3	2.5	1.6**
U6-L6	–3.3	1.5	<0.1	1.4	–3.3**
OJ	–2.8	1.8	0.6	1.8	–3.4**
OB	–0.6	2.0	1.4	2.2	–2.0**

*P < .05 level.
**P < .01 level.

rests extending from the lower crown to the occlusal surface of the lower primary molars. After the active treatment, patients were given a prefabricated positioner appliance (the Occlusal Guide, Orthotain) designed to support the orthopedic correction and guide tooth eruption between the mixed and permanent dentitions. Patients were instructed to wear the positioner while studying, watching television, and sleeping.

The average age of the sample was 8.5 (± 1.0) years when treatment started, the Herbst was placed at 9.4 years of age and continued for a period of 11 months. The retention phase lasted at least 6 months, with a mean retention period of 17 months. Patients were reevaluated in the permanent dentition (11.8 ± 1.2 years) at the time they presented for phase II comprehensive orthodontic therapy.

A control group of untreated Class II individuals was drawn from longitudinal data collected by the Human Growth Research Center, University of the Montreal, Quebec, Canada. Each control subject was matched to a patient in the treatment group based on age, sex, and mandibular plane angle.

Method

Horizontally corrected TMJ tomograms taken in centric occlusion were available for 37 of the 40 individuals in the sample. A total of 97 sets of tomograms were evaluated (194 total joints) from 3 time points: pretreatment (T1), posttreatment (T2—just before Herbst removal), and postretention (T3—an average of 2.7 years posttreatment). A nearly identical number of tomograms were available for each time period. The tomograms were used to evaluate treatment, posttreatment, and overall long-term changes in condylar position within the glenoid fossa.

Each tomogram was traced and a joint space analysis was performed using a modification of the protractor overlay method described by Pullinger and Hollender.[10] Joint space was determined by tracing the surface of the condylar head and the inferior surface of the glenoid fossa and measuring the distance between those two surfaces along three planes (Fig 1). The first plane, measuring the superior joint space, represents the long axis of the condyle and was constructed by using the midpoint at the most narrow portion of the condylar neck and the concentric center of the condylar head. The other two planes, constructed at 45° angles to the first plane through the concentric center of the condylar head, were used to evaluate anterior and posterior joint spaces. All tracings were digitized, and the measurements were computed.

Pretreatment (T1) and postretention (T3) lateral cephalometric radiographs, taken in centric occlusion, were analyzed for all individuals. A total of 14 traditional landmarks were identified[17] and digitized (Fig 2). All radiographs were superimposed on stable cranial and cranial base structures, using techniques described

Table III. Sagittal (S) and vertical (V) displacement (mm) of skeletal and dental landmark: Cumulative treatment and posttreatment changes of Herbst group versus untreated controls

		Herbst group		*Controls*		*Group difference*
Landmarks		*Mean*	*SD*	*Mean*	*SD*	*Mean*
Skeletal						
Nasion	S	1.7	1.1	2.2	1.0	–0.5*
	V	0.0	1.3	0.1	0.8	–0.1
A point	S	0.6	1.4	1.8	1.7	–1.2**
	V	4.8	2.6	4.0	2.0	0.8
B point	S	2.3	2.4	1.8	1.9	0.5
	V	7.3	2.9	5.0	2.5	2.3**
Pogonion	S	2.3	2.7	2.5	2.3	–0.2
	V	7.7	3.1	6.3	2.8	1.4*
Menton	S	2.3	3.0	2.6	2.3	–0.2
	V	8.0	3.0	6.5	2.6	1.5
Condylion	S	–1.9	1.7	–1.8	1.5	–0.2
	V	1.3	2.3	1.1	1.3	0.2
Articulare	S	–1.7	1.3	–1.8	1.2	0.1
	V	2.4	1.4	2.3	1.2	0.1
Gonion	S	–1.7	2.2	–1.8	1.6	0.2
	V	5.7	2.7	5.0	2.2	0.7
Dental						
U6 tip	S	0.6	2.2	2.8	2.3	–2.2**
	V	5.8	2.2	5.2	1.7	0.6
L6 tip	S	3.7	2.2	3.0	2.0	0.6
	V	6.3	2.4	5.2	1.9	1.1*
U1 tip	S	0.8	2.2	3.2	2.8	–2.4**
	V	5.7	2.3	5.6	2.4	0.1
L1 tip	S	3.4	2.3	2.5	2.1	0.8
	V	6.2	2.5	4.2	2.3	2.1**
L1 apex	S	2.6	2.6	1.6	2.0	1.0
	V	6.2	2.8	4.8	1.9	1.4*

*$P < 0.05$ level
**$P < .01$ level.

by Björk and Skeiller,[18] to evaluate the horizontal and vertical changes of individual landmarks. Vertical changes in the position of each landmark were evaluated relative to a horizontal reference line constructed by registering on Sella and orienting along Sella-Nasion minus 7° (SN7). Horizontal changes were evaluated relative to a vertical reference line constructed perpendicular to SN7 through Sella. The reference lines were constructed on the T1 radiograph and transferred to the T3 radiograph after superimposition on the cranial-based structures. As described by Vargervik and Harvold,[19] condylion was used as a surrogate marker to evaluate the horizontal and vertical displacement of the glenoid fossa relative to stable cranial base structures. Tomograms were used to substantiate the validity of this measurement because it requires that joint space be essentially unchanged. Mandibular superimpositions[18] were performed for each patient to quantify the magnitude and direction of condylar growth. Total condylar growth and total glenoid fossa displacements were calculated as the hypotenuse of the horizontal and vertical changes.

Traditional linear and angular measures were also evaluated. The molar relationship (U6_L6) was defined as the horizontal distance between the upper and lower first molar mesial cusp tips; zero represents an end-on, cusp-to-cusp relationship. All linear measures were corrected for magnification.

Approximately 15% of the tracings from the cephalograms and tomograms were randomly selected and replicated to evaluate intra-examiner reliability. The average method error for the cephalometric variables was 0.5 mm with a range from 0.2 to 1.3 mm. Method errors for the joint tomograms produced an average of 0.3 mm with a range from 0.3 to 0.4 mm.

Table IV. Sagittal and vertical condylar growth (mm): Cumulative treatment and posttreatment changes of Herbst group versus untreated controls

	Herbst group		*Controls*		*Group difference*
Growth	*Mean*	*SD*	*Mean*	*SD*	*Mean*
Sagittal	–2.4	2.1	–0.4	2.9	–2.1
Vertical	7.9	3.8	7.6	2.7	0.3
Total	8.5	3.8	8.0	3.0	0.4

$P < .01$ level.

Table V. Sagittal and vertical glenoid fossa displacement (mm): Cumulative treatment and posttreatment changes of Herbst group versus untreated controls

	Herbst group		*Controls*		*Group difference*
Displacement	*Mean*	*SD*	*Mean*	*SD*	*Mean*
Sagittal	–1.9	1.7	–1.8	1.4	–0.2
Vertical	1.3	2.3	1.1	1.3	0.2
Total	3.3	1.7	2.6	1.2	0.7*

*$P < .05$ level.

The skewness and kurtosis statistics showed that the variables' distributions were normal. Means and standard deviations were used to describe central tendencies and dispersion. The treatment and control groups were statistically compared using *t* tests.

RESULTS

The treatment and control groups demonstrated few cephalometric differences before treatment (Table I). The angular skeletal measurements evaluating anteroposterior relationships differed by less than 0.5°. Linear skeletal measurements suggested that individuals in the treatment group were slightly larger, but the only significant difference was in anterior facial height. The control group presented on average with end-on molar relationships (molar = 0.0) and 3.7 mm of overjet, whereas the treatment group presented with greater than end-on class II relationships (molar = 1.2 mm) and 5.5 mm of overjet.

Mixed dentition Herbst therapy with retention resulted in significantly improved dental and skeletal relationships (Table II). At postretention, the molar relationship had improved by nearly 3.3 mm in the treatment group as compared to no change in the control group. Overjet and overbite worsened in the control group and improved in the treatment group. The net treatment effects for overjet and overbite were 3.4 mm and 2.0 mm, respectively. The lower incisor position of the Herbst group did not significantly change its relationship with the mandibular plane.

Although skeletal angular measurements of SNA, ANB, and NAPg were reduced in both groups, they were reduced significantly more in the treatment group. The treatment effect differences on the jaw base relationship was –1.4°, whereas maxillary protrusion and facial convexity were reduced by 0.8° and 2.2°, respectively. The SNB angle showed a slightly greater increase for the treatment group, but differences were not statistically significant. There was a significantly greater increase in total facial height in the treatment group. The mandibular plane did not show a treatment effect, although it tended to open slightly in the treatment group and close slightly in the control group.

Sagittal orthopedic treatment effects were observed for the upper face. Treatment reduced the anterior displacement of A point by 1.2 mm (Table III). The control group had 0.5 mm more anterior growth at nasion. In contrast, the mandibular landmarks showed no significant sagittal group differences. The anterior mandibular landmarks (B point, pogonion, and menton) showed significantly greater inferior displacement (2.3 mm, 1.4 mm, and 1.5 mm, respectively) in the treatment than control group. Gonion demonstrated a tendency toward greater vertical displacement in the treatment group, but the differences were not statistically significant. There were no treatment effects on articulare.

The dental landmarks (Table III) revealed significant treatment effects on the sagittal displacement of the upper molar and upper incisor. Treatment reduced the mesial movements of the upper molar by 2.2 mm and the upper incisor by 2.4 mm. Greater mesial movements of the lower dentition were observed for Herbst group, but differences were not significant. Significantly greater inferior displacement was observed after treatment for the lower molar (1.1 mm), the lower incisor tip (2.1 mm), and the lower incisor apex (1.4 mm).

The mandibular superimposition showed increased posterior, vertical, and total condylar growth in the treatment group (Table IV). However, only the 2.1 mm increase in posterior growth was statistically significant. These orthopedic effects increased mandibular length, measured at Co-Pg and Ar-Pg, by less than 1.0 mm.

Small group differences in glenoid fossa displacement (Table V) were observed. The fossa of the treatment group was displaced slightly more posteri-

Table VI. Anterior, superior, and posterior joint space changes (mm) with Herbst treatment

	Anterior		*Superior*		*Posterior*	
Joint spaces	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Distances						
Pretreatment (T1) N = 34	2.2	0.7	2.7	0.7	3.1	0.8
Posttreatment (T2) N = 31	2.0	0.6	2.8	0.7	3.2	0.9
Postretention (T3) N = 32	2.3	0.7	2.7	0.8	2.7	1.0
Changes						
Treatment (T1–T2) N = 28	–0.1	0.7	0.1	0.8	0.2	0.9
Posttreatment (T2–T3) N = 26	0.3*	0.6	–0.2	0.8	–0.7**	1.1
Overall (T1–T3) N = 29	0.0	0.6	–0.1	0.8	–0.4*	0.8

*$P < .05$ level.
**$P < .01$ level.

orly and inferiorly. The combined effects of greater posterior and vertical displacement produced a significant 0.7 mm treatment effect for total fossa displacement.

The joint space analysis demonstrated only small changes throughout the entire observation period (Table VI). While there was a slight tendency toward anterior repositioning of the condyle during Herbst treatment (0.1 to 0.2 mm), there were no significant treatment changes observed. During posttreatment the condyles repositioned posteriorly, with the anterior joint space increasing 0.3 mm and the posterior space decreasing 0.7 mm. As a result of the significant posttreatment changes, there was an overall (T1 to T3) decrease in the posterior joint space only; the anterior and superior spaces demonstrated no long-term treatment effects.

DISCUSSION

Concern has been raised regarding the merit of early Herbst treatment, due to the potential for relapse. Recovering tooth movements, less growth stimulation and unfavorable growth after treatment have been suggested as reasons for delaying treatment until later in somatic maturation.[4,6,20] These concerns are especially important in the mixed dentition because tooth exfoliation and flat plane occlusion may predispose the patient to relapse.[6]

The results of this study showed a significant Class II correction that was maintained throughout the transitional dental period. The molar relationship and overjet were each improved by nearly 3.3 to 3.4 mm. There were also significant orthopedic effects in both the maxilla and the mandible producing improvements in skeletal convexity and jaw base relationships.

Comparison of these results to existing literature is difficult because of the extended posttreatment observation period of this study. Studies that do not allow for posttreatment dental and skeletal recovery invariably show greater treatment results.[21] Samples evaluated at least 6 months out of treatment are more appropriate for comparison because 90% of relapse reportedly occurs during the first 6 months.[22] On that basis, the treatment effects observed in this sample compare very favorably to those previously described for older patients.[5] Depending on the level of somatic maturation, Hansen et al[5] reported that Herbst therapy reduced the SNA by 0.5° or less, ANB was reduced between 1.2° and 1.6° and SNB increased between 1.0° and 1.4°. Our sample of mixed dentition patients achieved decreases in SNA and ANB of 0.9° and 1.9°, respectively; the increase (1.0°) observed for SNB was not significantly more than observed for controls. Our results suggest that the magnitude of the skeletal changes achieved by early Herbst treatment with retention must either have been greater than those previously reported and then partially relapsed or that they were similar and did not relapse. These results do not support the notion that unfavorable growth will reassert itself to a greater extent when patients are treated at a younger age and then maintained with adequate retention.

Although the skeletal treatment effects were comparable to existing reports, dental effects were of slightly lesser magnitude. Individuals treated during different levels of somatic maturation have shown no statistical differences in improvements of sagittal dental relationships.[5] Hansen et al[5] observed 4.1 mm to 5.1 mm of sagittal dental correction for patients treated at prepeak, peak, and postpeak, while we observed somewhat less, 3.3 mm to 3.4 mm. This may be partially because our sample presented with a less severe sagittal malocclusion than theirs did. Nevertheless, these differences in overjet and molar correction are possibly an indication of greater dental relapse in mixed dentition patients. Although relapse remains a concern, clinically significant improvements in dental relationships can be expected with early Herbst therapy and retention.

The maxillary orthopedic effect of early treatment in this sample produced a 1.2 mm restraint on the sagittal displacement of A point. A significant headgear effect on the maxilla was also evident in Wieslander's[7] early treatment study. He observed 1.5 mm of posterior translation of A point at the end of treatment and an additional 0.8 mm after active retention. Long-term maxillary orthopedic effects reported for older patients have been of lesser magnitude and often produce only temporary effects[23] suggesting that maxillary growth modifications in younger patients may be more adaptable and less susceptible to relapse.

As previously reported,[23,24] there was a distal driving effect on the upper dentition provided by treatment, This produced a maxillary dental effect similar in magnitude to the orthopedic effect (~1.2 mm), which together inhibited mesial translation of the maxillary dentition by over 2 mm. There was also a tendency in the treatment group for anterior movement of the mandibular dentitions, which probably contributed to the improvements in molar relation and overjet. Importantly, the mandibular dental movement did not produce a significant "flaring" effect on the lower incisor, although the incisor was translated anteriorly approximately 1 mm. This is in agreement with other studies that have found that incisor flaring tends to relapse after treatment[22] and occurs less in younger individuals.[25]

Mandibular orthopedic effects resulted in a redirection, rather than an augmentation, of condylar growth. Although overall condylar growth showed no group differences, there was 2.1 mm greater posterior condylar growth in the treatment group than the control group. Pancherz[4] has reported similar sagittal condylar growth effects, (1.5 mm greater sagittal growth than controls), in an older sample of prepeak individuals. Pancherz and Hägg[4,26] have also observed somewhat greater sagittal condylar effects in peak growth patients, reportedly from 3.3 to 3.6 mm, but without adequate controls it is impossible to quantify the actual treatment effects. The similarity of our condylar orthopedic effects to previously published reports supports the notion that treatment effects of sagittal condylar growth are age independent.[4]

The condylar growth redirection produced a tendency for increased mandibular length, but the mandible was not displaced anteriorly. The anterior mandible was displaced inferiorly, resulting in a 1.6 mm greater increase in anterior facial height of the patient group. The skeletal vertical excess observed was similar to the 1.8 mm increase in lower facial height reported by Pancherz.[27] McNamara[28] described how facial height increases could produce an effective mandibular retrusion. This explains why increased chin projection was not seen despite the mandibular orthopedic effects. As previously shown,[24,29] this study found no statistical change in the mandibular plane angle.

Other authors have observed small increases in mandibular projection as a result of Herbst therapy. Wieslander[9] noted a tendency toward 1.5 mm of increased B point projection after headgear-Herbst therapy and extended activator retention. Hansen, Pancherz, and Hägg[5] showed 2.9 mm of anterior chin projection in older prepeak individuals 6 months after treatment. Although they did not present control data, 2.9 mm represents a greater change than our observed anterior displacement of B point, which was 2.3 mm in the treatment group and 1.8 mm in the control group. Interestingly, there was a notable tendency in the study by Hansen et al[5] toward greater chin projection in the older peak (3.8 mm) and postpeak (4.5 mm) groups, but changes were not compared to control data. The results of this study, however, suggest that patients treated with the Herbst appliance in the mixed dentition will not have long-term improvements in chin projection. Better results may be achieved in patients treated later in development, but the underlying biological mechanism for any such difference remains unclear.

It is important to consider possible vertical maxillary effects produced by the RME and Herbst therapy. Although there is a tendency for backward rotation immediately after RME therapy,[30,31] the effect is temporary and long-term normal vertical growth should be expected.[32] Our treatment group, however, showed a slight increase in vertical maxillary skeletal and dental development 2 years posttreatment. Although the Herbst has been reported to produce a high-pull headgear effect,[23,24] any such effect produced on our treatment group was temporary and must have been overcompensated for during the posttreatment period.

Several authors[33,34] have suggested that forward posturing of the mandible after treatment exaggerates the actual orthopedic effects. Our large sample of tomograms showed that there were no significant joint space changes at the end of treatment. The small changes observed were during the posttreatment period. There was a tendency for the condyle to be positioned slightly forward in the fossa at the end of treatment (~0.2 mm) and then to fall back (~0.3 mm) during the retention period. Our results were similar to those reported for the Frankel appliance.[35] A previous long-term tomographic evaluation of Herbst patients[12] also concluded that condylar position was unaffected by treatment, but pretreatment and immediate posttreatment tomograms were not available. The small changes observed in joint space suggest that treatment effects can not be attributed to a forward mandibular posture and that condylar repositioning does not contribute substantially to relapse. The long-term significant change in posterior joint space suggests that Herbst treatment may have resulted in a lasting morphologic change of the condyle and/or the glenoid fossa.

The glenoid fossa demonstrated slightly greater inferior and posterior displacement in the treatment than the control group. Although we might have expected greater vertical displacement, greater posterior displacement of the fossa was not anticipated. It is possible that, because of the long-term change in posterior joint space, the condyle exaggerated the posterior position of the fossa. However, Windmiller[36] also observed greater inferior and posterior positioning of the condyle after Herbst therapy. Regardless, the results do not support the notion that constant mandibular propulsion encourages an anterior displacement of the glenoid fossa in human beings. It appears unlikely that treatment-induced fossa displacement plays any clinically significant role in Class II correction.

CONCLUSIONS

Treatment timing decisions remain a critical part of orthodontic planning and need to be addressed on an individual basis. The advantages and disadvantages of mixed-dentition treatment should be carefully considered before initiating therapy. This project suggests that early treatment with the Herbst appliance with retention results in improved skeletal and dental relationships and is a viable treatment option. Traditional measures of jaw base relationships appear to be improved equally well in young patients as in older patients. Mixed dentition Herbst therapy with retention produced:

1. A significant Class II correction that was maintained throughout the transitional dental period.
2. A significant restraining effect on maxillary sagittal development.
3. A significant redirection of condylar growth.
4. No significant lower incisor flaring.
5. Significant vertical mandibular development, with no greater sagittal mandibular projection.
6. No significant changes in joint space during treatment. A significant posttreatment decrease in posterior joint space was observed.
7. Only minor changes in the displacement of the glenoid fossa that were unlikely to contribute to Class II correction.

REFERENCES

1. Pancherz H. Treatment of Class II malocclusions by jumping the bite with the Herbst appliance: a cephalometric investigation. Am J Orthod 1979;76:423-42.
2. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment: a cephalometric investigation. Am J Orthod 1982;82:104-13.
3. Pancherz H. The Herbst appliance: its biologic effects and clinical use. Am J Orthod 1985;87:1-20.
4. Pancherz H. Dentofacial orthopedics in relation to somatic maturation, an analysis of 70 consecutive cases treated with the Herbst appliance. Am J Orthod 1985; 88:273-87.
5. Hansen K, Pancherz H, Hägg U. Long-term effects of the Herbst appliance in relation to the treatment growth period: a cephalometric study. Eur J Orthod 1991; 13:471-81.
6. Pancherz H. The nature of Class II relapse after Herbst appliance treatment: a cephalometric long-term investigation. Am J Orthod Dentofacial Orthop 1991;100:220-33.
7. Wieslander L. Intensive treatment of severe Class II malocclusions with a headgear-Herbst appliance in the early mixed dentition. Am J Orthod 1984;86:1-13.
8. Kucukkeles N, Arun T. Bio-thermal Herbst application during the mixed dentition period. J Clin Ped Dent 1994;18:253-8.
9. Wieslander L. Long-term effect of treatment with the headgear-Herbst appliance in the early mixed dentition: stability or relapse? Am J Orthod Dentofacial Orthop 1993;104:319-29.
10. Pullinger A, Hollender L. Assessment of mandibular condyle position: a comparison of transcranial radiographs and linear tomograms. Oral Surg Oral Med Oral Pathol 1985;60:329-34.
11. Knoernschild KL, Aquilino SA, Ruprecht A. Transcranial radiography and linear tomography: a comparative study. J Prosthet Dent 1991;76:593-611.
12. Woodside DG, Metaxas A, Altuna G. The influence of functional appliance therapy on glenoid fossa remodeling. Am J Orthod Dentofacial Orthop 1987;92:181-98.
13. McNamara JA, Carlson DS. Quantitative analysis of temporomandibular joint adaptations to protrusive function. Am J Orthod 1979;76:593-611.
14. McNamara JA, Hinton RJ, Hoffman DL. Histologic analysis of temporomandibular joint adaptation to protrusive function in young adult rhesus monkeys (Macaca mulatta). Am J Orthod 1982;82:288-98.
15. Hinton RJ, McNamara JA. Temporal bone adaptations in response to protrusive function in juvenile and young adult rhesus monkeys (Mucaca mulatta). Eur J Orthod 1984;6:155-74.
16. Paulsen HU, Karle A, Bakke M, Herskind A. CT-scanning and radiographic analysis of temporomandibular joints and cephalometric analysis in a case of Herbst treatment in late puberty. Eur J Orthod 1995;17:165-75.
17. Riolo ML, Moyers, RE, McNamara JA Jr, Hunter WS. An atlas of craniofacial growth series. Ann Arbor, University of Michigan, Center for Human Growth and and Development, 1974. 14-8.
18. Björk A, Skieller V. Normal and abnormal growth of the mandible: a synthesis of longitudinal cephalometric implant studies over a period of 25 years. Eur J Orthod 1983;5:1-46.
19. Vargervik K, Harvold EP. Response to activator treatment in Class II malocclusions. Am J Orthod 1985;88:242-51.
20. Pancherz H, Fackel U. The skeletofacial growth pattern pre- and postdentofacial orthopaedics: a long-term study of Class II malocclusions treated with the Herbst appliance. Eur J Orthod 1990;12:209-18.
21. DeVincenzo JP. Changes in mandibular length before, during, and after successful orthodontic correction of Class II malocclusions, using a functional appliance. Am J Orthod Dentofacial Orthop 1991;99:241-57.
22. Pancherz H, Hansen K. Occlusal changes during and after Herbst treatment: a cephalometric investigation. Eur J Orthod 1986;8:215-28.
23. Pancherz H, Anehus-Pancherz M. The headgear effect of the Herbst appliance: a cephalometric long-term study. Am J Orthod Dentofacial Orthop 1993;103:510-20.

24. Valant J, Sinclair P. Treatment effects of the Herbst appliance. Am J Orthod Dentofacial Orthop 1989;95:138-47.
25. Konik M, Pancherz H, Hansen K. The mechanism of Class II correction in late Herbst treatment. Am J Orthod Dentofacial Orthop 1997;112:87-91.
26. Pancherz H, Hägg U. Dentofacial orthopaedics in relation to chronological age, growth period and skeletal development: an analysis of 72 male patients with Class II Division 1 malocclusion treated with the Herbst appliance. Eur J Orthod 1988;10:169-76.
27. Pancherz H. Vertical dentofacial changes during Herbst appliance treatment: a cephalometric investigation. Swed Dent J Suppl 1982;15:189-96.
28. McNamara JA Jr. A method of cephalometric evaluation. Am J Orthod 1984;86:449-69.
29. Ruf S, Pancherz H. The effect of Herbst appliance treatment on the mandibular plane angle: a cephalometric roentgenographic study. Am J Orthod Dentofacial Orthop 1996;110:225-9.
30. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41-66.
31. Silva OG, Boas MCV, Capelozza L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1991;100:171-81.
32. Velazquez P, Benito E, Bravo LA. Rapid maxillary expansion: a study of the long-term effects. Am J Orthod Dentofacial Orthop 1996;109:361-7.
33. Gianelly AA, Brosnan P, Martignoni M, Bernstein L. Angle Orthod 1983;53:131-42.
34. Creekmore TD, Radney LJ. Frankel appliance therapy: orthopedic or orthodontic? Am J Orthod 1983;83:89-108.
35. Hamilton SD, Sinclair PM, Hamilton RH. A cephalometric, tomographic, and dental cast evaluation of Frankel therapy. Am J Orthod Dentofacial Orthop 1987;92:427-34.
36. Windmiller EC. The acrylic-splint Herbst appliance: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1993;104:73-84.