ORIGINAL ARTICLE

Maxillary molar distalization or mandibular enhancement: A cephalometric comparison of comprehensive orthodontic treatment including the pendulum and the Herbst appliances

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Several methods of Class II treatment that do not rely on significant patient compliance have become popular during the last decade, including several versions of the Herbst appliance and the pendulum or Pendex molar-distalization appliances. Yet, these 2 general approaches theoretically have opposite treatment effects, one presumably enhancing mandibular growth, and the other moving the maxillary teeth posteriorly. This study examined the treatment effects produced by 2 types of the Herbst appliance (acrylic splint and stainless-steel crown) followed by fixed appliances, and the pendulum appliance followed by fixed appliances. For each of the 3 treatment groups, lateral cephalograms were analyzed before the start of treatment (T1) and after the second phase of treatment (T2). Patients were matched according to age and sex. The comprehensive treatment time for the pendulum group was 31.6 months, and the acrylic and crowned Herbst groups were treated for 29.5 months and 28.0 months, respectively. Overall from T1 to T2, there were no statistically significant differences in mandibular growth among the 3 groups. Skeletal changes accounted for a larger portion of molar correction in the Herbst treatment groups than in the pendulum group. Patients in the pendulum group had an increase in the mandibular plane angle. Conversely, the mandibular plane angle in patients treated with either Herbst appliance closed slightly from T1 to T2. At T2, the chin points (pogonion) of patients in both Herbst groups, however, were located slightly more anteriorly than were the chin points of the pendulum patients. It is likely that the slight downward and backward rotation of the mandible occurring during treatment in the pendulum patients accounted for much of this difference. The treatment effects produced by the 2 types of Herbst appliance were similar at T2, in spite of their differences in design. It is important not to generalize the findings of this comparison beyond the appliance systems evaluated. The 2 general approaches we evaluated involved a substantial dentoalveolar component in the treatment of Class II malocclusion. A comparison of a molar-distalizing appliance such as the pendulum with other types of functional appliances might yield differing results. (Am J Orthod Dentofacial Orthop 2003;123:108-16)

The correction of Class II malocclusion is one of the most common problems facing the orthodontist, with an estimated one-third of all orthodontic patients treated for this condition. It is well known, however, that Class II malocclusion is not a single diagnostic entity[1,2] but, rather, can result from various skeletal and dentoalveolar components.

Many strategies are available for Class II treatment, and most orthodontists tend to choose a treatment protocol based on what part of the craniofacial skeleton they believe the appliance will affect the most. For example, the Herbst appliance[3,4] commonly has been used to treat patients with mandibular skeletal retrusion, whereas the molar-distalizing pendulum appliance[5] typically is used in patients with maxillary dentoalveolar protrusion.

Perhaps more than any other type of functional appliance, whether fixed or removable, the treatment effects produced by the banded Herbst appliance have been well documented, especially by Pancherz and colleagues.[4,6-19] Other investigators have evaluated al-

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ternative designs, including the cast Herbst appliance by Wieslander[20,21] and the acrylic-splint Herbst appliance by McNamara et al,[22] Lai and McNamara,[23] and Franchi et al.[24] No published studies have appeared concerning the treatment effects of the stainless-steel crown[25-27] or the cantilever[28] Herbst designs. The short-term treatment effects of the pendulum appliance, which primarily affects the maxilla, also have been described.[29-31]

Although the long-term effects of the Herbst appliance used alone have been investigated,[32-36] there is only 1 published study evaluating the treatment effects of the Herbst appliance followed by a fixed-appliance phase of treatment.[23] Furthermore, the treatment effects after the removal of the pendulum appliance have not been evaluated.

Thus, considerable research has focused on the treatment of Class II malocclusions with the Herbst and the pendulum appliances. Presumably, knowing the treatment effects produced by different strategies to correct a Class II malocclusion is essential when considering what strategy to use to treat a Class II patient. Therefore, the idea of treating the "wrong jaw" has been an argument used by clinicians who support treatments aimed primarily at the maxilla or the mandible. Surprisingly, however, only very limited information is available regarding a direct comparison of a so-called mandibular-enhancing appliance such as the Herbst and a molar-distalizing appliance such as the pendulum. Thus, it is the purpose of this study to make a detailed comparison of the effects on Class II malocclusions of the Herbst appliance followed by fixed appliances, and the pendulum appliance followed by fixed appliances, to determine what morphological differences, if any, are apparent at the end of treatment.

PATIENTS AND METHODS

This is a retrospective study designed to evaluate cephalometrically the skeletal and dentoalveolar effects of Class II correction obtained by 3 two-phase treatment modalities. The first treatment group consisted of 30 patients treated with the stainless-steel crown Herbst appliance.[27] The outcome of these treatments was compared with that in 30 patients treated with the acrylic-splint Herbst appliance[37] and in 30 patients treated with rapid molar distalization with the pendulum appliance.[5] Comprehensive fixed-appliance therapy followed Phase I treatment in all 3 groups. The specific treatment protocols for the acrylic-splint and crown Herbst appliances and for the pendulum appliances evaluated in this study are described in detail elsewhere.[38]

Table I. Sample selection and exclusionary criteria: stainless-steel crown Herbst appliance

Sample selection		*n*
Parent sample		53
	Primary exclusionary criteria	
	1. Poor film quality/magnification problems	4
	2. Incomplete records	4
	Secondary exclusionary criteria	
	1. T1 age less than 10 years	3
	2. T1 to T2 interval greater than 48 months	4
	3. Not Class II malocclusion	8
Final sample		30

The stainless-steel crown Herbst appliance

Two designs of stainless-steel crown Herbst appliance were used in this study. The stainless-steel crown Herbst appliance,[38] consisting of crowned maxillary first molars and mandibular first premolars,[27,39] was used in 23 patients; the stainless-steel crown cantilever Herbst design[38] was used in 7 additional patients. Aside from the details of the Herbst design, the clinical protocol for the Herbst appliance did not vary substantially among practitioners. The maxillary and mandibular crowns always were cemented permanently, ensuring full-time wear of the appliance.

The stainless-steel crown Herbst sample was selected from an original group of 53 subjects from 4 private orthodontic practices. To be included in this treatment group, patients had to meet all of the following criteria: (1) a pretreatment Class II Division 1 malocclusion defined by at least an end-to-end molar relationship, (2) 2-phase treatment with Herbst therapy followed by preadjusted edgewise appliance treatment, (3) no permanent teeth extracted before or during treatment, and (4) good-quality radiographs with adequate landmark visualization taken before treatment began (T1) and immediately after removal of the preadjusted edgewise appliances (T2). Thirty of the 53 subjects met the inclusionary criteria (Table I). The sample consisted of 20 girls and 10 boys, whose average age was about 12 years (Table II).

The acrylic-splint Herbst appliance

Serial cephalometric records of Class II Division 1 subjects who underwent 2-phase treatment with an acrylic-splint Herbst appliance[37,40] immediately followed by preadjusted edgewise appliances also were analyzed. This acrylic-splint appliance had occlusal coverage from the canines to the first molars in the maxillary arch and full coverage in the mandibular arch. From a sample of 40 Class II Division 1 patients described previously by Lai and McNamara,[23] 30 pa-

Table II. Demographics of treatment times

	T1 (Age in Years)				T1-T2 (Years)	
Treatment group	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*
Pendulum						
Boys	12.4	0.5	11.6	12.9	2.7	0.6
Girls	12.3	0.9	10.8	13.8	2.6	0.5
Totals	12.3	0.8	10.8	13.8	2.6	0.5
Acrylic Herbst						
Boys	12.8	0.6	11.8	13.6	2.8	0.7
Girls	12.3	0.8	11.2	13.8	2.3	0.5
Totals	12.6	0.8	11.2	13.8	2.5	0.6
Crown Herbst						
Boys	12.0	0.8	10.7	13.8	2.4	0.4
Girls	12.3	1.0	10.4	14.1	2.3	0.4
Totals	12.2	1.0	10.4	14.1	2.3	0.4

tients were matched by age and sex to those in the stainless-steel crown Herbst sample. The final sample used in this study consisted of 20 girls and 10 boys, the same sex distribution as the crowned Herbst group. The average age at T1 and the mean treatment interval for the sample and its 2 subgroups are summarized in Table II.

The pendulum appliance

The study also evaluated the cephalometric records of Class II subjects who underwent 2-phase treatment with a pendulum appliance[5,38] immediately followed by preadjusted edgewise appliances. The orthodontists who contributed the original sample of 101 Class II patients treated with the pendulum or the Pendex appliance in the short-term study of Bussick and McNamara[36] were contacted again and asked whether they had the records of patients from the initial sample who had finished preadjusted edgewise appliance therapy; the 50 patients so identified comprised the parent sample in the pendulum group. This sample then was matched to the stainless-steel crown Herbst sample on the basis of sex and age at the start of treatment (Table II). The final sample used in this study consisted of 20 girls and 10 boys, the same sex ratio as the other 2 groups.

Cephalometric analysis

Lateral cephalograms of a given series were hand-traced at a single sitting in the same manner. Cephalograms were traced by 1 investigator (D.R.B.); landmark location was verified by a second (J.A.M.). Any disagreements were resolved by retracing the landmark or the structure to the satisfaction of both investigators.

A customized digitization regimen (Dentofacial Planner version 2.5, Toronto, Ontario, Canada) that included 78 landmarks and 4 fiducial markers was devised and used for the cephalometric evaluation. Testing the regimen and analysis for accuracy followed the development of this customized digitization protocol. This program allowed analysis of cephalometric data and superimposition among serial cephalograms according to the specific needs of this study.

Lateral cephalograms for each patient at T1 and T2 were digitized, and 50 variables were generated for each film. A cephalometric analysis containing measures chosen from the analyses of McNamara,[22,38,41,42] Ricketts[43] and Steiner[44] was performed on each cephalogram.

Regional superimpositions were accomplished by hand, and then the 78 landmarks and 4 fiducial markers were digitized with Dentofacial Planner. The cranial bases were superimposed along the basion-nasion line and registered at the most posterosuperior aspect of the pterygomaxillary fissure, with the contour of the skull immediately posterior to the foramen magnum used to check the accuracy of the cranial base superimposition as well. Movements of the maxilla and the mandible relative to the cranial base were assessed. The maxillae were superimposed along the palatal plane by registering on internal structures of the maxilla superior to the incisors and on the superior and inferior surfaces of the hard palate. The movement of the dentition in the maxilla was determined from this maxillary superimposition. The mandibles were superimposed posteriorly on the outline of the mandibular canal and the tooth germs (before initial root formation) and anteriorly on the internal structures of the symphysis and the anterior contour of the chin.[41,43]

Statistical analysis

Means and standard deviations were calculated for age, duration of treatment, and all cephalometric measures at T1 and T2 for the 3 groups. Data on the outcomes of phase I treatment are available from the authors on request. Additionally, mean differences and standard deviations were calculated for the changes between T1 and T2 and for each group. The data were analyzed with a social science statistical package (version 10.0, SPSS, Inc, Chicago Ill). Statistical significance was tested at $P < .05$, $P < .01$, and $P < .001$. The error of the method has been described previously by McNamara et al.[22]

An exploratory test (the Hotelling T^2 test) followed by 1-way analysis of variance (ANOVA) was used to test for significant differences between the means of the cephalometric measurements for the 3 groups at T1. The Tukey test was conducted to compare differences between treatment group means. Mean differences

Table III. Comparison of starting forms

Cephalometric measures	Pendulum			Acrylic Herbst			Crown Herbst			Significance		
	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*P-A*	*P-C*	*A-C*
Maxillary skeletal												
Co-Pt A (mm)	30	88.7	4.8	30	91.4	5.3	30	92.9	4.5	NS	**	NS
SNA (°)	30	80.0	4.0	30	81.5	3.5	30	81.5	3.0	NS	NS	NS
Pt A to nasion perp (mm)	30	−1.0	3.5	30	0.2	2.5	30	0.3	3.5	NS	NS	NS
Mandibular skeletal												
Co-Gn (mm)	30	112.1	5.7	30	113.7	6.4	30	113.0	4.9	NS	NS	NS
SNB (°)	30	76.5	3.4	30	76.8	3.3	30	76.0	2.7	NS	NS	NS
Pg to nasion perp (mm)	30	−6.2	5.8	30	−6.3	4.9	30	−7.7	5.1	NS	NS	NS
Maxillary/mandibular												
Max/mand difference (mm)	30	23.4	2.7	30	22.2	3.3	30	20.1	3.8	NS	***	*
ANB (°)	30	3.5	2.1	30	4.7	1.3	30	5.5	1.8	*	***	NS
Vertical skeletal												
MPA (°)	30	24.5	4.2	30	22.8	5.1	30	23.5	4.8	NS	NS	NS
ANS to Me (mm)	30	64.3	4.3	30	65.0	5.5	30	65.9	3.8	NS	NS	NS
Interdental												
Overbite (mm)	30	4.5	2.1	30	4.4	1.7	30	5.8	1.7	NS	*	**
Overjet (mm)	30	4.8	1.4	30	7.3	1.6	30	7.0	2.1	***	***	NS
Interincisal angle (°)	30	134.4	9.8	30	122.6	8.2	30	125.2	8.3	***	***	NS
Molar relationship (mm)	30	−1.0	1.3	30	−1.0	1.4	30	−1.6	1.2	NS	NS	NS
Maxillary dentoalveolar												
U1 to Pt A vert (mm)	30	3.8	2.4	30	6.0	2.1	30	5.1	2.6	**	NS	NS
U1 to Frankfort (°)	30	109.0	7.6	30	115.7	7.0	30	112.7	7.7	**	NS	NS
U4 to Frankfort (°)	26	90.3	6.4	30	90.1	4.6	22	89.4	5.3	NS	NS	NS
U6 to Frankfort (°)	30	79.1	4.4	30	82.0	5.7	30	80.4	4.3	NS	NS	NS
Mandibular dentoalveolar												
L1 to Pt A Pg (mm)	30	0.2	2.3	30	0.8	1.6	30	0.3	2.1	NS	NS	NS
L1 to MPA (°)	30	92.1	6.4	30	98.9	6.2	30	98.4	5.5	***	***	NS
Soft tissue												
UL to E plane (mm)	30	−2.7	2.6	30	−1.6	2.3	30	−0.2	1.8	NS	***	NS
LL to E plane (mm)	30	−1.1	3.6	30	−0.3	2.3	30	0.6	2.4	NS	*	NS

$^{*}P < .05$; $^{**}P < .01$; $^{***}P < .001$; *NS*, not significant.
P-A, Pendulum and acrylic splint Herbst comparison; *P-C*, pendulum and stainless steel crown Herbst comparison; *A-C*, acrylic and crown Herbst comparison.

between treatment groups were compared using a 1-way ANOVA to analyze T2-to-T1 treatment changes between groups.

RESULTS

The crown Herbst group, the acrylic-splint Herbst group, and the pendulum group did not show any significant differences with the Hotelling T^2 test ($F = 1.42$; $P = .103$). The 3 groups generally were similar at T1, and there were no significant differences as to molar relationship, mandibular length, mandibular position, maxillary position, and vertical skeletal relationships (Table III). The crown Herbst group had a greater overbite of 1 mm and a smaller maxillomandibular differential[41] of 2 mm compared with the acrylic-splint Herbst group. Both Herbst treatment groups had increased overjet and mandibular incisor proclination compared with the pendulum group (Table III). Descriptive and inferential statistics for changes during overall treatment (T2-T1) are summarized in Table IV.

Skeletal measures

From T1 to T2, there was no significant difference in mandibular length increase among the 3 treatment groups; however, the pendulum group had the least amount of mandibular advancement as measured by the

Table IV. Comparison of change during comprehensive treatment (T1 to T2)

	Pendulum 31.6 months n = 30		*Acrylic Herbst 29.5 months n = 30*		*Crown Herbst 28.0 months n = 30*		*Significance*		
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P-A*	*P-C*	*A-C*
Maxillary skeletal									
Co-Pt A (mm)	2.7	1.8	1.9	2.4	2.1	1.7	NS	NS	NS
SNA (°)	−0.8	1.4	−0.6	1.0	−1.2	1.4	NS	NS	NS
Pt A to nasion perp (mm)	−0.9	1.3	−1.0	1.2	−0.9	1.4	NS	NS	NS
Mandibular skeletal									
Co-Gn (mm)	6.2	3.6	6.4	3.1	6.4	2.5	NS	NS	NS
SNB (°)	−0.5	1.1	0.9	1.1	0.2	1.0	***	*	*
Pog to nasion perp (mm)	−0.6	2.3	0.9	2.6	0.9	1.8	*	*	NS
Maxillary/mandibular									
Max/mand difference (mm)	3.6	3.0	4.4	3.0	4.3	1.8	NS	NS	NS
ANB (°)	−0.3	0.9	−1.6	1.2	−1.4	1.2	***	***	NS
Vertical skeletal									
MPA (°)	1.2	2.3	−0.4	1.8	−0.3	1.4	**	**	NS
ANS to Me (mm)	4.5	2.8	4.0	2.5	3.2	1.5	NS	NS	NS
Interdental									
Overbite (mm)	−1.6	1.8	−1.9	1.2	−3.5	1.7	NS	***	**
Overjet (mm)	−1.5	1.5	−4.0	2.5	−3.9	2.1	***	***	NS
Interincisal angle (°)	−8.0	8.5	0.0	8.6	−5.8	9.9	**	NS	*
Molar relationship (mm)	2.8	1.3	3.6	1.3	3.7	1.5	NS	*	NS
Maxillary dentoalveolar									
U1 to Pt A vert (mm)	0.1	1.9	−1.2	2.2	−0.9	1.8	*	NS	NS
U1 horizontal (mm)	0.1	1.9	−0.9	2.1	−0.9	1.5	NS	NS	NS
U1 vertical (mm)	1.0	1.3	1.4	1.8	0.2	1.5	NS	NS	*
U6 horizontal (mm)	−0.8	1.4	0.2	1.3	0.6	1.2	*	***	NS
U6 vertical (mm)	1.7	1.5	1.4	1.3	1.4	1.0	NS	NS	NS
U1 to Frankfort (°)	2.8	7.7	−3.2	8.8	1.0	7.6	*	NS	NS
U6 to Frankfort (°)	3.7	4.5	0.0	3.7	2.2	3.9	**	NS	NS
Mandibular dentoalveolar									
L1 horizontal (mm)	1.1	1.5	1.0	1.4	1.7	1.5	NS	NS	NS
L1 vertical (mm)	1.9	1.6	1.4	1.6	0.1	1.4	NS	***	**
L6 horizontal (mm)	1.4	1.2	1.4	0.9	2.6	1.0	NS	***	***
L6 vertical (mm)	2.8	1.4	2.8	1.6	1.9	1.2	NS	*	NS
L1 to MPA (°)	4.1	4.4	3.4	3.9	5.2	6.4	NS	NS	NS
Soft tissue									
UL to E plane (mm)	−2.1	1.7	−2.6	1.6	−2.8	1.4	NS	NS	NS
LL to E plane (mm)	−1.0	2.3	−1.0	1.3	−1.0	1.3	NS	NS	NS

*$P < .05$; **$P < .01$; ***$P < .001$; *NS*, not significant.
P-A, Pendulum and acrylic splint Herbst comparison; *P-C*, pendulum and stainless steel crown Herbst comparison; *A-C*, acrylic and crown Herbst comparison.

SNB angle and the projection of the chin (pogonion) relative to the nasion perpendicular (Table IV). In addition, after comprehensive treatment, a significant reduction in the ANB angle with respect to the pendulum treatment group ($P < .001$) was observed in both Herbst samples.

From T1 to T2, the pendulum group exhibited a slight opening of the mandibular plane angle (1.2°), whereas the mandibular plane angle of the patients treated with the Herbst appliance closed slightly (-0.4° in the acrylic-splint group, −0.3° in the crown Herbst group).

Dentoalveolar measures

The angulation of the maxillary incisors relative to the Frankfort horizontal increased 2.8° in the pendulum group and 1.0° in the crown Herbst group. In the acrylic Herbst group, the incisor position relative to Frankfort horizontal decreased 3.2°.

No significant differences in molar movement existed between the 2 Herbst groups from T1 to T2. The maxillary molars of the pendulum group were distalized slightly (0.8 mm), whereas the molars of the Herbst appliance treatment groups stayed in their original sagittal position or moved slightly mesially.

From T1 to T2, the mandibular incisors moved mesially and tipped anteriorly in all groups. The mandibular first molars moved mesially in all groups, although the mesial movement in the crowned Herbst group was slightly greater than that in the other 2 groups. There also was not a clinically significant difference in eruption among the 3 groups over the comprehensive treatment period.

Soft tissue changes

The changes in soft tissue profile from T1 to T2 were similar among the groups. Both the upper and lower lips showed a tendency toward retraction relative to the E plane in all groups.

DISCUSSION

This study compared the treatment effects achieved in 3 two-phase Class II treatment modalities. One method incorporated the pendulum appliance[5] intended to distalize the maxillary molars. The other 2 methods integrated the bite-jumping mechanism of Herbst[3] into 2 types of Herbst appliances. On the surface, both general approaches seemingly had differing effects on the skeletal and dentoalveolar structures of the craniofacial complex. The results of this study, however, showed that the differences between these approaches were modest at best. Similarly, the differences in treatment effects between the 2 types of Herbst appliances were less remarkable than expected.

No major differences between groups in measures of maxillary, mandibular, or vertical skeletal relationships existed before treatment (Table III). The homogeneity of the 3 samples analyzed here as to initial parameters of both maxillary and mandibular size and position reduces significantly the impact of susceptibility bias[45,46] when treatment assignment is based on diagnostic criteria (eg, not randomized) and causes patients treated 1 way to be different at the start of treatment from patients treated another way.[46]

The acrylic-splint and the stainless-steel crown Herbst groups underwent very similar changes from T1 to T2. Thus, the 2 groups of Herbst patients will be compared collectively with the pendulum patients in the following discussion.

Skeletal changes

The results of this study indicate that, although treatment with the Herbst appliance followed by fixed appliances is an effective way to increase mandibular length in correcting a Class II to a Class I relationship, either type of Herbst appliance followed by fixed appliances ultimately did not produce substantially more mandibular growth than was seen in patients treated with the pendulum appliance followed by fixed appliances.

On the basis of data not reported here extensively, the increases in mandibular length observed in both Herbst groups, however, occurred during the active Class II correction (ie, phase I). Lai and McNamara[23] found an accelerated mandibular growth rate during the first phase of treatment, followed by a diminished growth rate in the second phase (compared with untreated Class II controls). The analysis of the current data for both Herbst treatment groups agrees with those findings and also with the results of Franchi et al.[24] The patients in the acrylic and crown Herbst groups experienced greater mandibular growth (4.6 and 4.5 mm, respectively) during the first phase than during the second phase of treatment (1.8 and 2.3 mm, respectively), even though the second treatment interval was substantially longer than the first. Pancherz[47] stated that the major advantage of Herbst treatment in correcting a Class II malocclusion is that "you get the growth when you need it." Because the maxilla and the mandible grew forward essentially the same amount during phase II in both Herbst groups, occlusal interdigitation might have helped maintain the correction during the fixed-appliance phase.

The results of this study of Herbst therapy generally agree with the findings of previous investigations. For example, Pancherz and Fackel[14] compared craniofacial growth changes during Herbst treatment to changes before and after dentofacial orthopedics in 17 male patients treated with the Herbst appliance for an average of 7 months. The pretreatment and posttreatment periods in each patient averaged 31 months. When comparing the growth changes during Herbst treatment with those in the pretreatment control period, maxillary growth was inhibited and redirected, mandibular displacement was increased, anterior mandibular growth rotation was arrested, the sagittal intermaxillary jaw relationship was improved, and the skeletal profile was straightened. During the posttreatment period, many of the treatment changes reverted. Pancherz and Fackel[14] noted that "maxillary and mandibular growth seemed to strive to catch up with their earlier patterns," because the craniofacial growth pattern before treatment prevailed after treatment. Thus, dentofacial orthopedics using the Herbst appliance had only a temporary impact on the craniofacial growth pattern.

As for the vertical skeletal relationships, the pendulum group exhibited an increase in the inclination of the mandibular plane at the end of the 2-phase treatment (more than 1°). These data agree with previous findings in the short term by Bussick and McNamara.[36] The Herbst appliances left the vertical relationships practically unchanged.

Dentoalveolar changes

After treatment, the overjet in each of the 3 treatment groups was corrected to an almost ideal relationship. The amounts of mesial movement and proclination of the mandibular incisors were similar in the 3 groups.

Although molar distalization during active therapy was a common finding in each group, maxillary first molar distalization produced by the pendulum appliance (5.9 mm) was significantly greater than that produced by the acrylic Herbst appliance (1.2 mm) and the crown Herbst appliance (2.2 mm). The maxillary first molars in the pendulum treatment group underwent 10° of distal tipping, an amount statistically greater than in both Herbst groups. The results from this study regarding molar distalization and tipping in the pendulum subjects are similar to those seen in previous studies.[29-31,36]

During the fixed-appliance phase of treatment, there was considerable rebound in the position of the maxillary molars and premolars. After comprehensive treatment, the maxillary first molar was only 0.8 mm distal to its original position, and the first premolar had returned to the anteroposterior position in which it began. Although 87% of the molar distalization achieved during the first phase of treatment was lost during the second phase of treatment, the Class I molar relationship was maintained, and overjet was corrected.

Maintenance of the Class I molar relationship and improvement in overjet in adolescent patients can be explained by a favorable growth pattern (skeletal changes) and dentoalveolar compensation (intercuspation and Class II mechanics).[48] Lande[49] found that the mandible outgrows the maxilla and becomes more prognathic relative to the cranial base during normal growth. Johnston[50] has shown that 9 of 10 Class II patients have a favorable growth pattern in which the mandible outgrows the maxilla. After the Class I molar relationship is established during the first phase of treatment, the mandible outgrows the maxilla in most patients. Thus, the maxillary first molars must move anteriorly to the same extent that the mandibular first molars move anteriorly. If the mandibular first molars were held in a constant position relative to the mandible (ie, they did not undergo mesial dental movement in the mandible), then one would expect the maxillary first molars to move anteriorly (relative to the maxilla) by exactly the amount that the mandible outgrows the maxilla. If the maxillary first molars do not compensate, a Class III molar relationship would result. Because of dentoalveolar compensation and the practice of overcorrecting the molar relationship during the first phase of treatment, it is not surprising that only 0.8 mm of the original 5.9 mm remained at the end of comprehensive treatment in a growing patient.

In the pendulum group, by T2, the mandibular molars had extruded 2.8 mm and moved anteriorly 1.4 mm. Interestingly, the vertical position of the mandibular molars in all 3 groups had extruded by a clinically similar amount. Mesial movement of the mandibular molars in the acrylic Herbst and pendulum groups was identical; however, the mandibular molars in the crowned Herbst group had moved mesially to a greater extent (1.2 mm).

Clinical significance

One should not generalize the findings of this comparison to appliance systems other than those evaluated. The 2 general approaches to Class II treatment (Herbst and pendulum) involve a substantial dentoalveolar component. This study showed that the skeletal and dentoalveolar treatment effects of the acrylic-splint Herbst appliance and the stainless-steel crown Herbst appliance achieve Class II correction by about 50% skeletal and 50% dental changes. All 3 groups achieved a complete correction of the initial discrepancy in molar relationship.

The pendulum appliance, principally a dentoalveolar treatment appliance, achieves Class II correction largely by tooth movement rather than by growth alteration. Even with a similar amount of mandibular lengthening (slightly more than 6 mm in 2.5 years), the pendulum group did not show the improvements in the sagittal position of the chin that were observed in the 2 Herbst groups.

A comparison of a molar-distalizing appliance such as the pendulum with other types of functional appliances might yield differing results. Unfortunately, data—especially long-term data—on other functional appliance systems are scarce. Falck,[51] cited also by Fränkel and Fränkel,[52] presented data on 2 groups of

Class II subjects observed at ages 7 and 15 years. One group was treated with an FR-II appliance of Fränkel according to his usual protocol. The second group received no treatment. At the second observation, there was no difference in the increase in midfacial length between the 2 groups; however, mandibular length increased by over 5 mm in the Fränkel group compared with the untreated controls. Mills and McCulloch[53] also have reported increases in mandibular length in follow-up studies of Twin-block treatment in young adolescents. The data from both studies indicate that long-term increases in mandibular length might be possible with appliances that produce more skeletal and fewer dentoalveolar treatment effects.

CONCLUSIONS

This study examined the treatment effects of the stainless-steel Herbst appliance followed by fixed appliances, the acrylic-splint Herbst appliance followed by fixed appliances, and the pendulum appliance followed by fixed appliances.

There were no statistically significant differences in mandibular growth among the 3 treatment groups. The Herbst patients, however, had slightly greater mandibular projection than did the pendulum patients, who had an increase in the mandibular plane angle during the first phase of treatment that was still evident at T2. Conversely, the mandibular plane angle in patients treated with either Herbst appliance did not open from T1 to T2.

The stainless-steel crown Herbst appliance and the acrylic-splint Herbst appliance produced similar changes in horizontal and vertical skeletal position. The acrylic-splint Herbst appliance did not demonstrate a bite-block effect when compared with the stainless-steel crown Herbst appliance. After comprehensive treatment, the mandibular dentition in patients treated with the crown Herbst underwent significantly more anterior tooth movement than in the other 2 groups.

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