CONTINUING EDUCATION ARTICLE

Treatment and posttreatment effects of acrylic splint Herbst appliance therapy

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This study evaluated the skeletal and dentoalveolar changes induced by acrylic splint Herbst therapy of Class II malocclusion. The treated group comprised 55 subjects with Class II malocclusion treated with the acrylic splint Herbst appliance followed by comprehensive edgewise therapy. The mean age at Time 1 (immediately before treatment) was 12 years and 10 months ± 1 year and 2 months. The mean age at Time 2 (immediately after debonding of the Herbst appliance) and Time 3 (posttreatment) was 13 years and 10 months ± 1 year and 2 months and 15 years and 2 months ± 1 year and 4 months, respectively. The two control groups were one group of 30 subjects with untreated Class II malocclusion and another group of 33 subjects with Class I occlusion. The three groups were homogeneous as to the stage of maturation of cervical vertebrae at all observation times. A modification of Pancherz's cephalometric analysis was applied to the lateral cephalograms of the three groups at Time 1, Time 2, and Time 3. Linear and angular measurements for mandibular dimensions, cranial base angulation, and vertical relationships were added to the original analysis. Differences for all the variables from Time 1 to Time 2 (active treatment effects), from Time 2 to Time 3 (posttreatment effects), and from Time 1 to Time 3 (overall treatment effects) were calculated for the treated group and contrasted to corresponding differences of both untreated groups by means of ANOVA ($P < .05$). The study showed that two thirds of the achieved occlusal correction was due to skeletal effects and only one third to dentoalveolar adaptations. Both skeletal and dentoalveolar effects were due mainly to changes in mandibular structures. A significant amount of relapse in molar relationship occurred during the posttreatment period, and this change could be ascribed to the mesial movement of the upper molars. (Am J Orthod Dentofacial Orthop 1999;115:429-38)

Among the various types of orthopedic and functional appliances, the Herbst appliance is known to be an effective device for correcting Class II malocclusion. The banded type of the Herbst appliance was developed by Emil Herbst in 1905 and was reintroduced by Pancherz in 1979.[1] This method of treatment has become increasingly popular during the last two decades because of good patient compliance. In 1988 McNamara and Howe[2] described the current design of the acrylic splint Herbst appliance, with occlusal coverage extending posteriorly from the canines to the first molars in the maxillary arch and full occlusal coverage in the mandibular arch. The maxillary splint is either removable or bonded, whereas the mandibular splint always is removable.

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The restraining effect on the growth of the maxillary skeleton after treatment with both banded and acrylic splint Herbst appliances has been reported to be of minor importance for the improvement in occlusal relationships.[1,3-8] In contrast, significant increases in the length of the mandible compared with untreated controls have been documented in previous Herbst studies. Increases in mandibular length ranged from 2.0 mm[4] to 2.2 mm[3] over a 6 month period for the banded appliance and from 2.7 mm[7] to 3.5 mm[8] in a 1 year treatment period for the acrylic splint appliance in comparison to control values. Remodeling of the temporomandibular joint (TMJ) has been described to occur both within the glenoid fossa and at the mandibular condyles, with new bone formation occurring on the roof of the fossa and on the posterior aspect of the condylar head.[9,10] Similar TMJ changes had been reported previously by Pancherz[1] and Wieslander[11] in some patients after Herbst treatment. On the other hand, Schiavoni et al[12] and Windmiller[8] found that mandibular condyle position was not affected by treatment.

Herbst appliances have a bite-opening effect. Although Pancherz[1,4] observed an increase in lower anterior facial height produced by the banded appli-

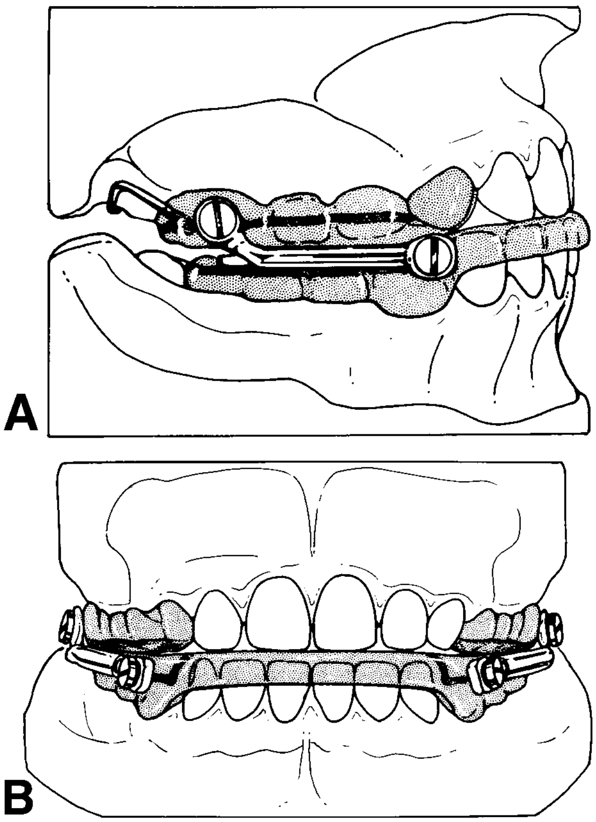

Fig 1. Acrylic splint Herbst appliance: **A**, lateral aspect; **B**, frontal aspect.

ance, studies of vertical skeletal changes induced by the acrylic splint appliance[7,8] also have shown a significant increase in ramus height.

The telescoping system of the Herbst appliances produces a posteriorly directed force on the upper posterior teeth and an anteriorly directed force on the lower anterior teeth. These forces produce distal tooth movements in the maxillary buccal segments and mesial tooth movements in the mandibular incisors, as reported previously.[1,4,5,7,8,13]

Studies with the banded Herbst appliance have shown, however, that the appliance has only a temporary impact on the existing skeletal growth pattern. During the posttreatment period of 7 years, several of the treatment changes tend to disappear. There seemed to be a catch-up growth in the maxilla,[6,14] and the increase in lower anterior facial height seen during treatment also tended to diminish with time.[4] Even though the rate of mandibular growth decreased to the level of untreated controls in the posttreatment period, Pancherz[14] and Wieslander[11] found that a greater mandibular length still existed 1 year after treatment in the Herbst groups. Posttreatment relapse is restricted mainly to the dentoalveolar area.[15,16] Long-term studies dealing with posttreatment changes after acrylic splint Herbst therapy at present are not available with the exception of the recent contribution by Lai and McNamara[13] who contrasted cephalometric data in treated group with normative values derived from the *University of Michigan Growth Study*. Overall increase in mandibular length after the posttreatment period (about 1 mm) was significant when compared with normative controls. Significant dentoalveolar rebound was seen during the posttreatment phase.

Before introducing the aim of the present study, a few method requirements that are of particular concern when investigating the effects of functional or orthopedic appliances on the craniofacial skeleton of growing subjects deserve to be stressed. Among these are the following:

1. The use of indicators of skeletal maturity. When dealing with growing subjects, the estimation of skeletal maturity in examined individuals at the time of treatment onset and discontinuation should be taken into account. A series of methods for the evaluation of skeletal maturity have been proposed, including the analysis of the hand-wrist radiographs and the curve of growth velocity in body height.[17-22] An alternative method is the evaluation of skeletal maturity on the basis of the developmental status of the cervical vertebrae. This approach has the advantage that the appraisal is performed on the same lateral cephalogram that is used for the cephalometric analysis, so that no additional radiographic exposure for the patient is needed. O'Reilly and Yanniello[23] have demonstrated that the developmental stages of the cervical vertebrae are highly correlated with changes in body height and that they can be used as an indicator of skeletal maturity in growing subjects. Moreover, Hellsing[24] found that the height and length of the cervical vertebrae could possibly represent an alternative method of assessing maturity, as increases in cervical dimensions during adolescence are highly correlated with statural height changes.
2. The availability of matched control groups for the statistical evaluation of treatment effects in treated groups. Control and treated groups have to be homogeneous as to race, gender distribution, age at different observation times, type of malocclusion and craniofacial pattern at the time of first observation, observation period, and stage of skeletal maturity.

Table I. Descriptive statistics for age and observation periods

	Mean age (y/mo) (±SD)			*Mean observation period (y/mo) (±SD)*		
	T1	*T2*	*T3*	*T1-T2*	*T2-T3*	*T1-T3*
Treated group (N = 55)	12 y 10 mo (±1 y 2 mo)	13 y 10 mo (±1 y 2 mo)	15 y 2 mo (±1 y 4 mo)	1 y (±6 mo)	1 y 4 mo (±6 mo)	2 y 4 mo (±9 mo)
Untreated Class II control group (N = 30)	13 y 1 mo (±1 y 2 mo)	14 y 2 mo (±1 y 2 mo)	15 y 3 mo (±1 y 2 mo)	1 y (±2 m)	1 y 1 mo (±4 mo)	2 y 1 mo (±4 mo)
Untreated Class I control group (N = 33)	12 y 11 mo (± 10 mo)	14 y 1 mo (±11 mo)	15 y 5 mo (±10 mo)	1 y 1 mo (±5 mo)	1 y 4 mo (±7 mo)	2 y 5 mo (±6 mo)

SD, Standard deviation.

3. Posttreatment changes have to be evaluated. The modifications that occur in the craniofacial structures after the discontinuation of active treatment regimen represent a fundamental component in the appraisal of the overall effect produced by the appliance. The posttreatment changes also should be contrasted to changes shown by controls with untreated malocclusions.

The aim of this work, therefore, is to evaluate the skeletal and dentoalveolar changes induced by acrylic splint Herbst therapy of Class II malocclusion, both during the phase of active treatment and during a posttreatment period. The study includes two matched control groups with untreated Class II and untreated Class I malocclusions, respectively, and the use of developmental staging of cervical vertebrae as an indicator of skeletal maturity.

SUBJECTS AND METHODS

Subjects

The treated group comprised 55 subjects (27 females and 28 males) with Class II malocclusions treated with the acrylic splint Herbst appliance (Fig 1). Mean ages of the treated group at Time 1 (T1, immediately before treatment), Time 2 (T2, immediately following Herbst appliance therapy), and Time 3 (T3, posttreatment observation including a phase of edgewise therapy) are reported in Table I. The mean durations of the T1-T2, T2-T3, and T1-T3 periods also are reported in Table I.

The untreated Class II control group consisted of 30 subjects (15 females and 15 males) with untreated Class II malocclusions selected from the longitudinal records of the University of Michigan Elementary and Secondary School Growth Study. The untreated Class I control group included 33 subjects (16 females and 17 males) with untreated Class I malocclusions selected from the same study group. Mean ages at T1, T2, and T3, and mean observation periods for both control groups are given in Table I.

Cephalometric Analysis

Lateral cephalograms of the three groups at T1, T2, and T3 were standardized as to magnification factor and were analyzed by means of a digitizing tablet (Numonics, Lansdale, Pa) and digitizing software (Viewbox, ver. 1.9).[25] A modified Pancherz's cephalometric analysis[3] was applied. The following landmarks, reference points, and reference lines were used (Figs 2 and 3).

Landmarks: 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), gonial intersection (goi), gonion (go), articulare (ar), basion (ba).

Reference points: frontomaxillary nasal suture (FMN), T point (the most superior point of the anterior wall of sella turcica, at the junction with tuberculum sellae).[26] *FMN* and *T point* substitute *nasion* and *sella* of Pancherz's analysis[3] respectively. We introduced this modification to the original analysis of Pancherz to overcome problems in the stability of *nasion* and *sella* during growth. Along with growth, *sella* is displaced backward and downward after resorption of part of the floor and of the posterior wall of the sella turcica, whereas *nasion* may be displaced vertically and sagittally because of possible development and expansion of the frontal sinus.[26-32] According to Melsen,[29] the anatomic regions of *FMN* and *T point* do not undergo any remodeling after childhood.

Reference lines: T-FMN line, this line was used for orientation of all cephalograms; OL (occlusal line), a line through *is* and distobuccal cusp of the maxillary permanent first molar; OL_p (occlusal line perpendiculare), a line perpendicular to *OL* through *T point*.

Measuring lines: nasal line (nl), mandibular line (ml), condylar line (cl, a line through *co* and *go*), ramal line (rl).

Measuring Procedure

Measurements with the superimposition procedure (modified Pancherz's analysis) (Fig 2). The occlusal

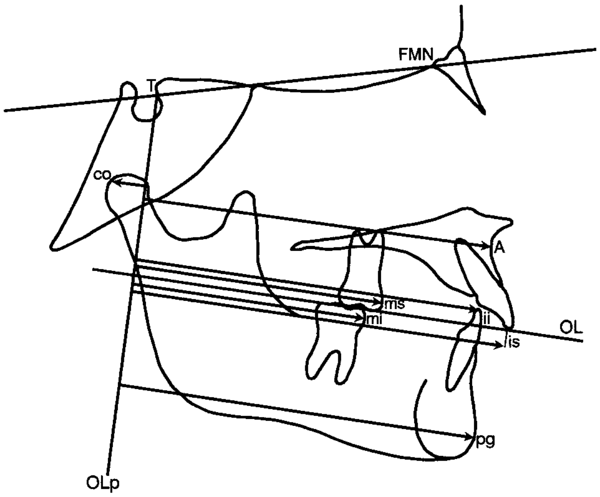

Fig 2. Modified Pancherz's analysis.

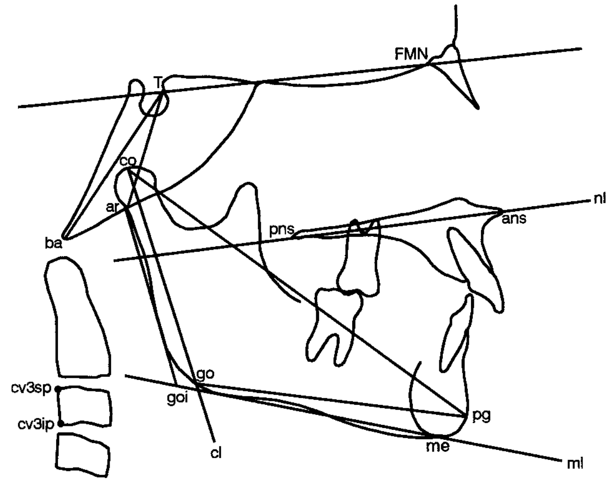

Fig 3. Additional cephalometric measurements.

line (OL) and the occlusal line perpendiculare (OL_p) from the cephalogram at T1 were used as a reference grid. The grid was transferred from the initial tracing to subsequent tracings at T2 and T3 by superimposing the tracings on the T-FMN line, with T point as the registration point. All linear measurements were performed parallel to OL and perpendicular to OL_p. The following variables were measured:

- is/OL_p minus ii/OL_p: Overjet.
- ms/OL_p minus mi/OL_p: molar relationship (a positive value indicates a distal relationship; a negative value indicates a mesial relationship).
- A point/OL_p: sagittal position of the maxillary base.
- pg/OL_p: sagittal position of the mandibular base.
- co/Ol_p: sagittal position of the condylar head.
- pg/OL_p + co/OL_p: composite mandibular length.
- is/OL_p minus A point/OL_p: sagittal position of the maxillary central incisor within the maxilla.
- ii/OL_p minus pg/OL_p: sagittal position of the mandibular central incisor within the mandible.
- ms/OL_p minus A point/OL_p: sagittal position of the maxillary permanent first molar within the maxilla.
- mi/OL_p minus pg/OL_p: sagittal position of the mandibular permanent first molar within the mandible.

Additional measurements for cranial base angulation, mandibular dimensions, and skeletal vertical relationships (Fig 3). The following measurements were obtained on all cephalograms at T1, T2, and T3, independently from the superimposition reference system:

- Linear measurements: co-pg, co-go, go-pg.
- Angular measurements: FMN-T-ba, FMN-T-ar, cl-ml, ar-goi-me, nl/T-FMN line, ml/T- FMN line, nl-ml.

Assessment of Skeletal Maturity

The three groups were homogeneous at T1, T2, and T3 as to the maturation of cervical vertebrae. The mean maturation stage for all the groups at T1 was between stage 3 and stage 4 according to the classification of O'Reilly and Yanniello,[23] ie, around the peak growth velocity. Further, the posterior height of the body of the third cervical vertebra was measured on the cephalograms of all subjects (the distance from cv3sp, the most superoposterior point on the body of the third cervical vertebra, to cv3ip, the most inferoposterior point on the body of the same vertebra) (Fig 3). This measurement was chosen because, according to Hellsing,[24] it shows the highest correlation with statural height. No significant difference for this variable among the three groups was assessed at T1, T2, and T3.

Statistical Analysis

The three groups were matched as to mean age at T1, T2, and T3, skeletal maturation stage at T1, T2, and T3, mean observation periods, and gender distribution. The treated group and the untreated group with Class II malocclusion were matched as to mean craniofacial pattern at T1 (no significant difference was found between starting forms in the two groups). Differences for all the variables from T1 to T2 (treatment effects), from T2 to T3 (posttreatment effects), and from T1 to T3 (total effects) were calculated in treated groups and contrasted directly to corresponding differences in both untreated groups by means of ANOVA ($P < .05$). Post-hoc between-group multiple comparisons were performed by means of Bonferroni's correction. All statistical procedures were performed using SPSS for Windows (Release 6.1.3).

Table II. Changes T2-T1 in the three examined groups

Variable Modified Pancherz's analysis (mm)	*Treated group (n = 55)*		*Untreated Class II group (n = 30)*		*Untreated Class I group (n = 33)*		*Comparison of treated/ untreated*	*Comparison of treated/ untreated*	*Group difference of treated/untreated Class II (treatment*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Class II**	*Class I**	*effect)*
Overjet (is/OL_p minus ii/OL_p)	–4.11	2.05	+0.49	0.92	–0.29	1.15	S	S	–4.6
Molar relation (ms/OL_p minus mi/OL_p)	–5.31	2.15	+0.07	0.71	–0.01	0.91	S	S	–5.38
Maxillary base (A point/OL_p)	+0.58	2.46	+0.84	1.00	+0.38	1.59	NS	NS	–0.26
Mandibular base (pg/OL_p)	+3.1	3.43	+0.55	1.71	+0.81	3.46	S	S	+2.55
Condylar head (co/OL_p)	+0.58	1.57	+0.27	1.37	+0.68	1.82	NS	NS	+0.31
Composite mandibular length (pg/OL_p + co/OL_p)	+3.68	2.84	+0.81	2.01	+1.49	2.77	S	S	+2.87
Maxillary incisor (is/OL_p minus A point/OL_p)	–0.26	1.93	–0.18	1.39	–0.43	1.41	NS	NS	–0.08
Mandibular incisor (ii/OL_p minus pg/OL_p)	+1.34	1.31	–0.38	1.15	–0.57	1.46	S	S	+1.72
Maxillary molar (ms/OL_p minus ss/OL_p)	–1.36	1.43	+0.35	1.48	+0.65	1.47	S	S	–1.71
Mandibular molar (mi/OL_p minus pg/OL_p)	+1.44	1.25	+0.57	1.15	+0.22	1.55	S	S	+0.87
Other Variables									
FMN-T point-ba (degrees)	+0.02	3.3	+0.13	1.58	+0.05	1.50	NS	NS	–0.11
FMN-T point-ar (degrees)	–0.19	2.61	+0.37	2.11	+0.22	1.45	NS	NS	–0.56
co-pg (mm)	+4.78	4.02	+2.12	1.99	+2.48	1.74	S	S	+2.66
co-go (mm)	+3.25	2.4	+2.01	1.94	+1.92	1.85	S	S	+1.24
go-pg (mm)	+1.93	2.75	+0.83	1.33	+1.30	2.22	NS	NS	+1.10
cl-ml (degrees)	+0.55	2.32	–0.66	1.94	–0.57	1.86	S	S	+1.21
ar-goi-me (degrees)	+0.05	2.75	–0.91	1.66	–0.7	2.03	NS	NS	+0.96
nl/FMN-T line (degrees)	+0.32	2.58	+0.49	1.34	+0.59	1.59	NS	NS	–0.17
ml/FMN-T line (degrees)	–0.34	2.59	+0.05	1.44	–0.35	1.26	NS	NS	–0.39
nl-ml (degrees)	–0.66	2.03	–0.43	1.39	–0.94	1.39	NS	NS	–0.23

*ANOVA with post–hoc multiple range test.
S, significant; NS, not significant.

Method Error

Thirty randomly selected cephalograms were retraced to calculate method errors for all the variables, as described by Dahlberg.[33] Systematic error was determined by calculating the coefficients of reliability for all the variables, as suggested by Houston.[34] Method errors ranged from 0.10 mm to 0.68 mm, corresponding to coefficients of reliability from 0.981 to 0.997.

RESULTS

Treatment Effects (Table II and Fig 4)

The active treatment phase with the acrylic splint Herbst appliance produced an overjet correction of 4.6 mm and a correction in molar relation of 5.38 mm when compared with growth changes in the untreated Class II group. The skeletal contribution to overjet correction was predominant (61%). Both skeletal and dentoalveolar components of overjet correction were due mainly to mandibular changes. Mandibular base measurement showed significantly greater increments in the treated group when compared with both Class II and Class I controls. Mandibular incisors were proclined significantly by treatment (Table II), whereas the position of the maxillary incisors was not affected significantly.

Skeletal and dentoalveolar contributions to molar correction were almost equivalent. Increments in mandibular base measurement accounted for the majority of the skeletal change, whereas dental changes were due primarily to distal movement of the maxillary molars. The changes in the position of both maxillary and

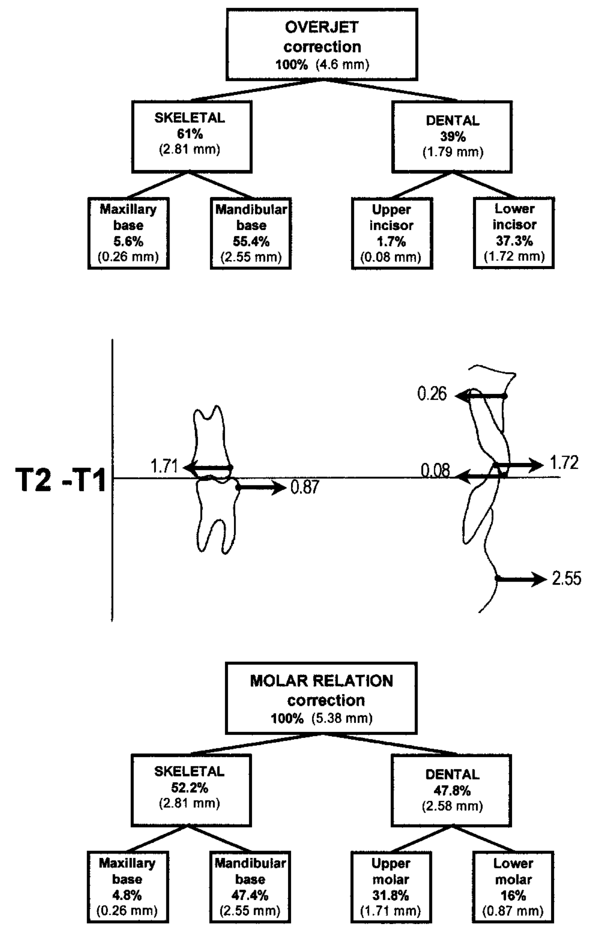

Fig 4. Diagram of maxillary and mandibular skeletal and dentoalveolar changes contributing to sagittal overjet correction and molar correction during active treatment period. (See the column "treatment effect" in Table II.)

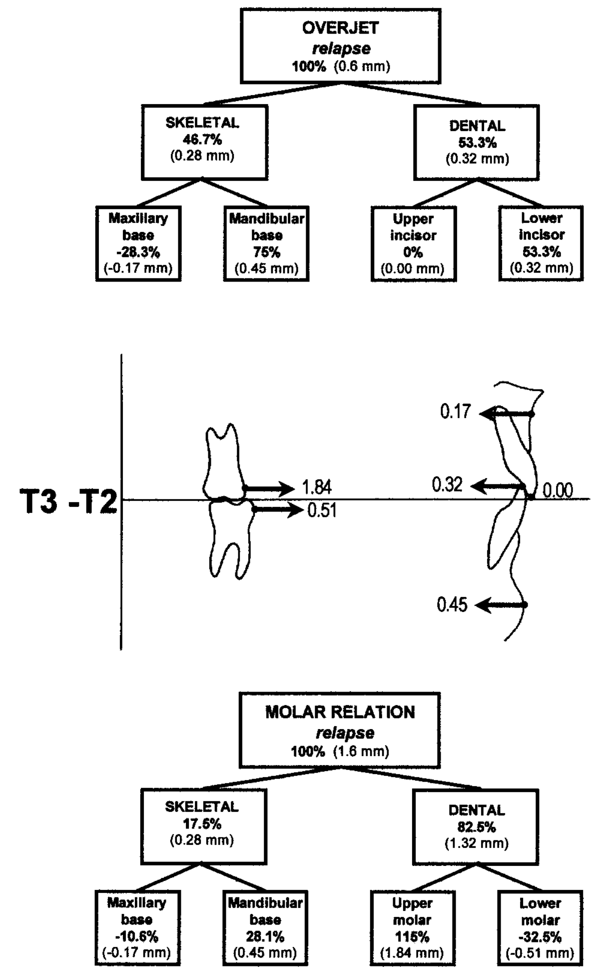

Fig 5. Diagram of maxillary and mandibular skeletal and dental changes contributing to relapse in overjet and molar relation during posttreatment period. (See the column "posttreatment effect" in Table III.)

mandibular molars, however, were significant when compared with both Class II and Class I control groups.

Active treatment also induced significantly greater increments in total mandibular length (co-pg), in the height of the mandibular ramus (co-go), and in the inclination of the condylar line in relation to the mandibular line (cl-ml) when compared with both control groups. No significant differences among the three groups were found as to cranial base angulation and vertical skeletal relationships.

Posttreatment Effects (Table III and Fig 5)

In the posttreatment period, a certain amount of "relapse" in overjet (0.6 mm) and molar relationship (1.6 mm) was recorded in the treated group when compared with Class II controls. The rebound in overjet, however, was not significant when compared with the control groups. Significant relapse in molar relationship during the posttreatment period has to be ascribed mainly to dental changes and more specifically in a significant rebound in the position of the upper molars when compared with Class II controls.

As for the changes in the measurements for cranial base angulation, mandibular dimensions, and vertical skeletal relationships, no significant differences were found among the three groups at the end of the posttreatment period. A tendency to "relapse" in total mandibular length increments (co-pg) was assessed in the treated group (0.43 mm), however, when compared with untreated Class II subjects.

Total Effects (Table IV and Fig 6)

The overall effects of acrylic splint Herbst therapy from the beginning of treatment to the end of the post-

Table III. Changes T3-T2 in the three examined groups

Variable Modified Pancherz's analysis (mm)	*Treated group (n = 55)*		*Untreated Class II group (n = 30)*		*Untreated Class I group (n = 33)*		*Comparison of treated/ untreated*	*Comparison of treated/ untreated*	*Group difference of treated/untreated Class II (posttreatment*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Class II**	*Class I**	*effect)*
Overjet (is/OL_p minus ii/OL_p)	–0.03	1.67	–0.63	1.32	–0.31	0.92	NS	NS	+0.6
Molar relation (ms/OL_p minus mi/OL_p) +1.6	2.17	–0.00	1.14	+0.01	0.71	S	S	+1.60	
Maxillary base (A point/OL_p)	+0.55	1.89	+0.72	1.49	+0.34	2.04	NS	NS	–0.17
Mandibular base (pg/OL_p)	+1.08	2.96	+1.53	2.17	+0.83	3.54	NS	NS	–0.45
Condylar head (co/OL_p)	+0.17	1.31	+0.14	1.74	+0.49	2.04	NS	NS	+0.03
Composite mandibular length (pg/OL_p + co/OL_p) +1.26	2.71	+1.66	2.8	+1.33	4.88	NS	NS	–0.40	
Maxillary incisor (is/OL_p minus A point/OL_p)	–0.36	1.91	–0.37	1.40	–0.00	1.40	NS	NS	+0.01
Mandibular incisor (ii/OL_p minus pg/OL_p)	–0.87	1.5	–0.55	1.13	–0.18	1.55	NS	NS	–0.32
Maxillary molar (ms/OL_p minus ss/OL_p)	+1.6	1.55	–0.24	2.04	0.76	1.48	S	NS	+1.84
Mandibular molar (mi/OL_p minus pg/OL_p)	-0.53	1.46	-1.04	2.46	0.25	1.29	NS	NS	0.51
Other Variables									
FMN–T point–ba(degrees)	–0.06	1.66	+0.14	1.68	+0.21	1.33	NS	NS	–0.2
FMN–T point–ar (degrees)	+0.07	2.00	–0.06	1.94	+0.34	1.27	NS	NS	+0.13
co–pg (mm)	+1.61	2.63	+2.04	2.13	+2.59	2.33	NS	NS	–0.43
co–go (mm)	+1.03	1.82	+0.91	1.74	+2.00	1.93	NS	NS	+0.12
go–pg (mm)	+1.54	2.19	+1.73	2.5	+1.53	2.23	NS	NS	–0.19
cl–ml (degrees)	–1.1	1.71	–0.69	2.09	–1.07	2.02	NS	NS	–0.41
ar–goi–me (degrees)	–1.19	1.84	–0.35	2.18	–1.24	1.83	NS	NS	–0.84
nl/FMN–T line (degrees)	–0.16	1.56	+0.01	1.43	+0.05	1.41	NS	NS	–0.17
ml/FMN–T line (degrees)	–0.38	1.85	–0.43	1.80	–0.69	1.40	NS	NS	+0.05
nl–ml (degrees)	–0.22	1.74	–0.44	1.54	–0.74	1.66	NS	NS	+0.22

*ANOVA with post–hoc multiple range test.
S, significant; NS, not significant.

treatment period comprised an overjet correction of 3.99 mm and a correction in molar relationship of 3.78 mm. About two thirds of overjet correction can be attributed to skeletal changes, mainly as a result of significant mandibular advancement. No significant differences in the position of the maxillary base could be found at the end of the observation period. Dentoalveolar changes contributing to overjet correction have to be assigned primarily to significant proclination of the mandibular incisors when compared with both control groups. Two thirds of the correction in molar relationship was skeletal in nature as a consequence of the significant increments in mandibular base position. Significant mesial movement of the mandibular molars accounted for the dentoalveolar component in molar correction. No part of the correction in molar relationship was attributable to the changes in the position of the maxillary molars.

Overall skeletal changes induced by acrylic splint Herbst therapy included significantly greater increments in total mandibular length (co-pg) and in mandibular ramus height (co-go) in the treated group when compared with untreated Class II controls. Interestingly, the absolute values for the changes in these variables exceeded those of untreated Class I subjects. No significant differences were found in cranial base angulation, vertical skeletal relationships, and in the inclination of the condylar line in relationship to the mandibular line.

DISCUSSION

The present study analyzed treatment and posttreatment effects of acrylic splint Herbst therapy of Class II malocclusion. Matched Class II and Class I untreated groups were used for the estimation of changes in skeletal and dentoalveolar relationships induced by therapy. Developmental staging in cervical vertebrae maturation as observed in the lateral cephalograms was applied as an indicator of skeletal maturity.[23]

Table IV. Changes T3–T1 in the three examined groups

Variable Modified Pancherz's analysis (mm)	*Treated group (n = 55)*		*Untreated Class II group (n = 30)*		*Untreated Class I group (n = 33)*		*Comparison of treated/ untreated*	*Comparison of treated/ untreated*	*Group difference of treated/untreated Class II (posttreatment*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Class II**	*Class I**	*effect)*
Overjet (is/OL_p minus ii/OL_p)	–4.13	1.8	–0.14	1.43	–0.61	1.29	S	S	–3.99
Molar relation (ms/OL_p minus mi/OL_p)	–3.71	1.66	+0.07	1.03	+0.00	0.8	S	S	–3.78
Maxillary base (A point/OL_p)	+1.14	2.27	+1.56	1.71	+0.71	2.67	NS	NS	–0.42
Mandibular base (pg/OL_p)	+4.18	3.54	+2.07	2.42	+1.64	5.19	S	S	+2.11
Condylar head (co/OL_p)	+0.76	1.37	+0.41	1.51	+1.18	2.22	NS	NS	+0.35
Composite mandibular length (pg/OL_p + co/OL_p)	+4.94	3.86	+2.48	2.7	+2.82	5.19	S	NS	+2.46
Maxillary incisor (is/OLp minus A point/OLp)	–0.62	2.57	–0.55	1.98	–0.43	1.74	NS	NS	–0.07
Mandibular incisor (ii/OL_p minus pg/ OL_p)	+0.47	1.91	–0.93	1.5	–0.75	2.00	S	S	+1.40
Maxillary molar (ms/OL_p minus ss/ OL_p)	+0.24	1.63	+0.11	2.67	+1.41	1.83	NS	S	+0.13
Mandibular molar (mi/OL_p minus pg/ OL_p)	+0.91	1.43	–0.47	2.54	+.47	2.11	S	NS	+1.38
Other Variables									
FMN–T point–ba (degrees)	–0.03	1.84	+0.27	1.82	+0.26	1.78	NS	NS	–0.3
FMN–T point–ar (degrees)	–0.12	2.22	+0.31	1.92	+0.56	1.83	NS	NS	–0.43
co–pg (mm)	+6.39	3.51	+4.16	2.72	+5.07	2.82	S	NS	+2.23
co–go (mm)	+4.28	2.14	+2.93	1.58	+3.92	2.26	S	NS	+1.35
go–pg (mm)	+3.47	2.57	+2.56	2.46	+2.83	2.47	NS	NS	+0.91
cl–ml (degrees)	–0.65	1.91	–1.35	2.15	–1.65	2.16	NS	NS	+0.7
ar–goi–me (degrees)	–1.14	2.22	–1.25	1.92	–1.93	2.54	NS	NS	+0.11
nl/FMN–T line (degrees)	+0.15	1.90	+0.50	1.59	+0.64	2.08	NS	NS	–0.35
ml/FMN–T line (degrees)	–0.73	2.17	–0.38	1.67	–1.04	1.52	NS	NS	–0.35
nl–ml (degrees)	–0.88	1.94	–0.88	1.84	–1.69	1.81	NS	NS	–0.00

*ANOVA with post–hoc multiple range test.
S, Significant; NS, not significant.

Acrylic splint Herbst therapy is able to induce significant skeletal and dentoalveolar changes in subjects with Class II malocclusion during the period of active treatment (approximately 1 year) when compared with both Class II and Class I controls. Significant favorable effects in treated Class II subjects were represented by modifications in both skeletal and dentoalveolar components of mandibular structures. Mesial movement of the mandibular dental arch was associated with a significant mandibular advancement and with significantly greater increments in mandibular dimensions. In particular, total mandibular length and ramus height exhibited significant increases. These data confirm previous observations by McNamara et al,[7] Windmiller,[8] and Lai and McNamara[13] on acrylic splint Herbst therapy. The presence of the acrylic splints probably is responsible for the increased vertical growth of the mandibular ramus. Herbst therapy also induced a more posterior direction of condylar growth, a biological mechanism that is known to contribute to mandibular lengthening.[35,36]

A greater skeletal contribution to the correction of both overjet and molar relation in subjects treated with acrylic splint Herbst appliance is evident when compared with the results reported by Pancherz for a 6 month period of active treatment with the banded Herbst appliance. The lesser amount of dentoalveolar changes as a result of acrylic splint Herbst therapy is due to the smaller effect on the maxillary dentition. These data, combined with the minimal treatment effects on maxillary skeletal structures, confirm the limited restraining effect of this type of Herbst appliance on maxillary dentoskeletal structures. As a matter of fact, the only significant change in the maxillary region was attributable to distal movement of the maxillary molars.

It is interesting to note that although the banded Herbst appliance has been shown to increase vertical relationships, no modifications in the inclinations of the palatal line and of the mandibular line in relation to the cranial base was noted in the present study. As already stated by Windmiller,[8] the lack of change in vertical relationships may be explained by the bite-block effect of the acrylic appliance in association with the consequent increases in mandibular ramus height. No change in the sagittal position of the condyle occurred in the active treatment period, confirming previous findings both with the acrylic splint[8] and the banded[12] appliances.

To our knowledge, cephalometric studies that evaluate posttreatment changes after Herbst therapy with a matched untreated group of subjects with Class II malocclusion have not been published previously. Lai and McNamara[13] recently compared cephalometric data of a Herbst-treated group with sex and age matched normative values from the *University of Michigan Growth Study.* In the present study, posttreatment modifications after acrylic splint Herbst therapy consisted of some relapse both in overjet and in molar relation. The relapse in molar relation (1.6 mm) was due mostly to dentoalveolar adaptations. In particular, the maxillary molars showed 1.84 mm of mesial movement. This rebound in upper molar position exceeded the total amount of relapse in molar relation, being partially compensated by a favorable posttreatment mesial movement of mandibular molars as well. Posttreatment changes in molar relation also may be interpreted as incomplete maintenance (–1.59 mm) of the Class I occlusion achieved during active treatment (5.38 mm of correction in molar relation). Posttreatment mesial movement of the upper molars after banded Herbst therapy when compared with an ideal occlusion control group had been described previously by Pancherz and Anehus-Pancherz.[6]

No significant posttreatment change was assessed for cranial base angulation, mandibular dimensions, and vertical relationships. It should be noted, however, that during the posttreatment period a net loss of 0.43 mm in the increments in total mandibular length (co-pg) was registered in the treated group when compared with untreated Class II controls.

Overall treatment effects of both active treatment results and posttreatment changes were represented by an overjet correction of about 4 mm and by a correction in molar relation of about 3.8 mm. More than half of the total observed changes in both measurements had to be ascribed to significant mandibular advancement, which was associated with a significant increase in total mandibular length and in ramus height. Mesial movement of the mandibular dentition represented the only significant dental change, and this movement con-

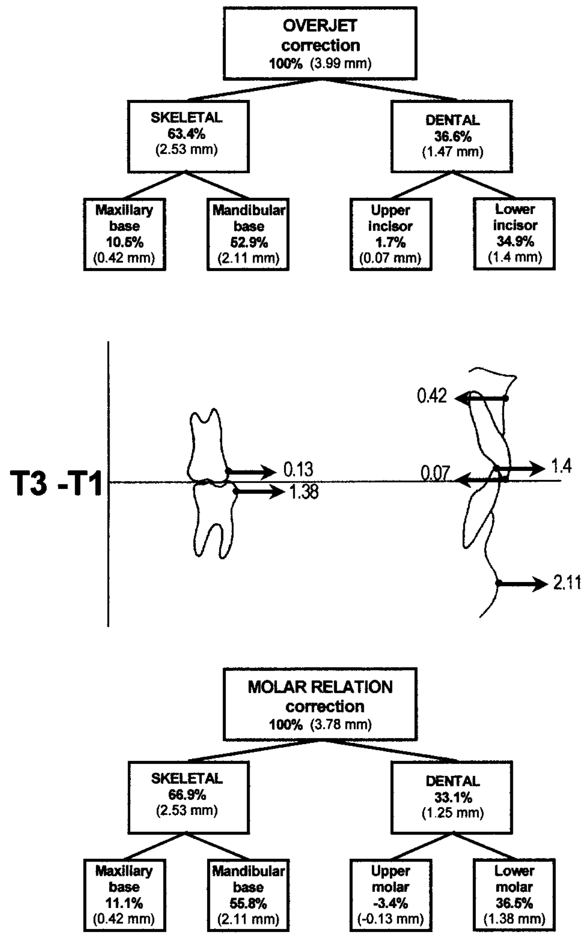

Fig 6. Diagram of maxillary and mandibular skeletal and dental changes contributing to sagittal overjet correction and molar correction during overall treatment period. (See the column "total treatment effect" in Table IV.)

tributed substantially to the correction of both overjet and molar relation. The question can be asked, "How much of this change is due to remodeling of the articular fossa?" Perhaps more precise assessment of this area will be possible with CAT-SCAN technique.[10] The contribution of the dentoskeletal modifications in the maxilla to the overall changes in treated group was scarce. In particular, the sagittal position of the maxillary incisors and molars remained virtually unchanged at the end of the observation period. The evaluation of the inclination of the condylar line relative to the mandibular line in the overall observation period did not reveal any of the significant changes that had been assessed during the active treatment period. It therefore is confirmed that the change to a more backward direction of condylar growth in treated Class II subjects is a transient biologic mechanism accounting for mandibular lengthening.[36] A mean increment in total mandibular length of 2.23 mm, however, was gained in the treated group when compared with untreated Class II controls after 28 months (including both the treatment and posttreatment periods).

CONCLUSIONS

A splint Herbst therapy is an effective treatment for the correction of Class II malocclusion. Treatment effects are mostly skeletal in nature and are due to changes in mandibular sagittal position and in mandibular dimensions (total mandibular length and ramus height). An important component in molar relationship and overjet correction is the mesial movement of the mandibular dental arch. The amount of relapse during posttreatment period is ascribed mainly to mesial movement of the maxillary molars.

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