The Effects, Limitations, and Long-Term Dentofacial Adaptations to Treatment With the Herbst Appliance

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The purpose of this article is to summarize the existing scientific data with respect to the short- and long-term effects of the Herbst appliance on the occlusion and on the maxillo/mandibular complex. The article also discusses the treatment indications and possible treatment limitations. The Herbst method is most effective in the treatment of Class II malocclusions. Long-term stability seems to be dependent on a stable cuspal interdigitation. Marked mandibular morphological changes occur during therapy and sagittal condylar growth is increased. Posttreatment, most of the mandibular morphological changes revert and no long-term influence of Herbst treatment on mandibular growth can be verified. The appliance effect on the maxillary complex can be compared with that of a high-pull headgear. Without proper retention, however, this effect is of a temporary nature. Herbst treatment is especially indicated in the permanent dentition at or just after the pubertal peak of growth. Mixed dentition treatment is not recommended, as a stable cuspal interdigitation after therapy is difficult to achieve and relapses are prone to occur. In the nongrowing patient, the appliance should be used with great caution. (Semin Orthod 1997;3:232-243.)

At the International Dental Congress in Berlin in 1909, Emil Herbst presented a fixed bite jumping device for Class II treatment. The appliance keeps the mandible in a continuous anterior forced position (Fig 1) both on jaw closure as well as when the teeth are not in occlusion. As a result of this, mandibular jaw and muscle function is changed and the appliance can thus be looked on as a fixed functional appliance.

In 1934, Herbst presented a series of articles on his experiences with the appliance.[1] After 1934, however, very little was published on the subject until 1979 when Pancherz called attention to the possibilities of stimulating mandibular condylar growth by means of the Herbst appliance.[2] In subsequent articles, Pancherz et al analyzed the effects of the appliance on the occlusion, dentofacial complex, and masticatory system on a short- and long-term basis.[3-28] After 1979, interest in the Herbst appliance increased, especially in Europe and in the United States, and several clinical and scientific articles have been published on the subject.[29-61]

In clinical research analyzing the effects of dentofacial orthopedics, the Herbst appliance is a most suitable tool. In contrast to the removable functional appliances such as the activator,[62] Bionator,[63] or Fränkel appliance,[64] the fixed Herbst appliance has several advantages: (1) it works 24 hours a day, (2) no cooperation by the patient is required, and (3) active treatment time is short (approximately 6 to 8 months).

The purpose of this article is to give an overview of the Herbst appliance with respect to its short- and long-term effects on the occlusion,

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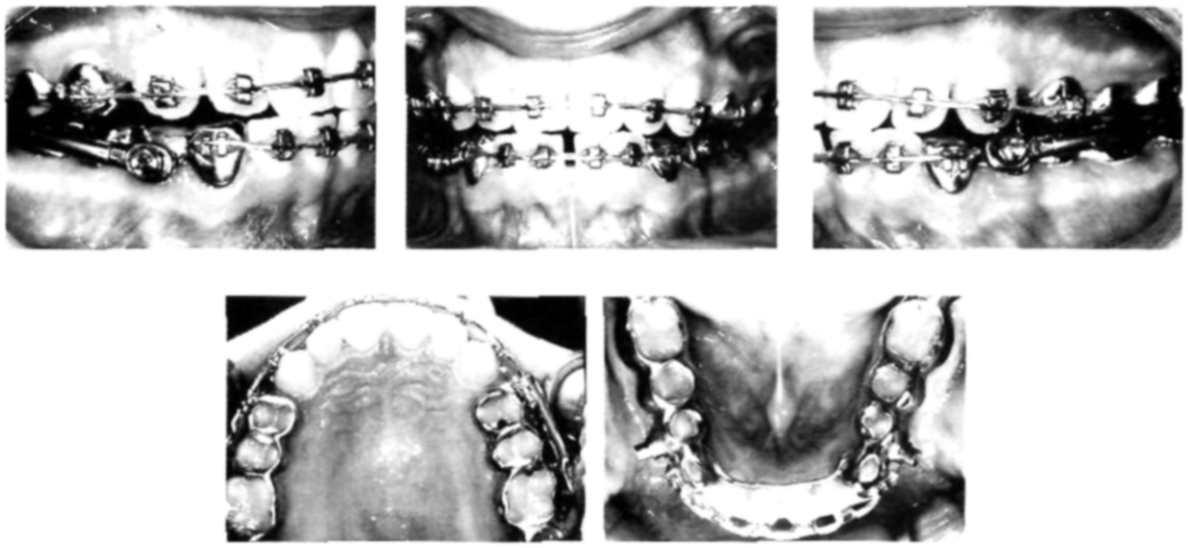

Figure 1. The cast splint Herbst appliance.

and on the maxillo/mandibular complex. The results presented are based on prospective studies using consecutively treated Class II malocclusions. Untreated subjects were used as controls. Finally the article discusses the treatment indications and possible treatment limitations.

Design of the Herbst Appliance

The Herbst appliance can be compared with an artificial joint working between the maxilla and mandible. A bilateral telescope mechanism attached to orthodontic bands (a design used until 1990) or to cast splints from cobalt cromium alloy (a design used after 1990) keeps the mandible in a protruded position. Originally when using the banded Herbst appliance, a partial anchorage system was used incorporating the premolars/molars in the maxilla and premolars/anterior teeth in the mandible into the anchorage.

In using the cast splint Herbst appliance, the anchorage is increased by incorporating most of the dental units (total anchorage): maxillary and mandibular splints cover the premolar/molar, and sometimes also the canine teeth and labial arch wires ligated to brackets on the front teeth are attached to the splints (Fig 1).

In comparison with the banded Herbst appliance, the cast splint appliance has several advantages: (1) it ensures a precise fit on the teeth, (2) it is strong, (3) it is hygenic, (4) it saves chair-side time and (5) it has few clinical problems such as broken bands.

Treatment and Posttreatment Effects of the Herbst Appliance

Sagittal Occlusion and Interjaw Relation

Treatment changes. In general, 6 to 8 months of Herbst treatment results in Class I or overcorrected Class I dental arch relationships. Overjet and Class II molar correction are a result of maxillary and mandibular skeletal and dental changes[2,6,10,12] (Fig 2):

- maxillary growth is inhibited
- mandibular growth is enhanced; during 6 months of treatment mandibular length is increased, on average, three times as much in Herbst cases than in untreated Class II control cases[6]
- maxillary teeth are moved posteriorly
- mandibular teeth are moved anteriorly (the incisors are proclined); independent of the anchorage system used, the mandibular incisor tooth movements are difficult to control.[13]

Early posttreatment changes. At the end of Herbst treatment when the appliance is removed, overcorrected sagittal dental arch relationships and an incomplete cuspal interdigitation are generally seen. The occlusion is in a state of instability and adaptive occlusal changes

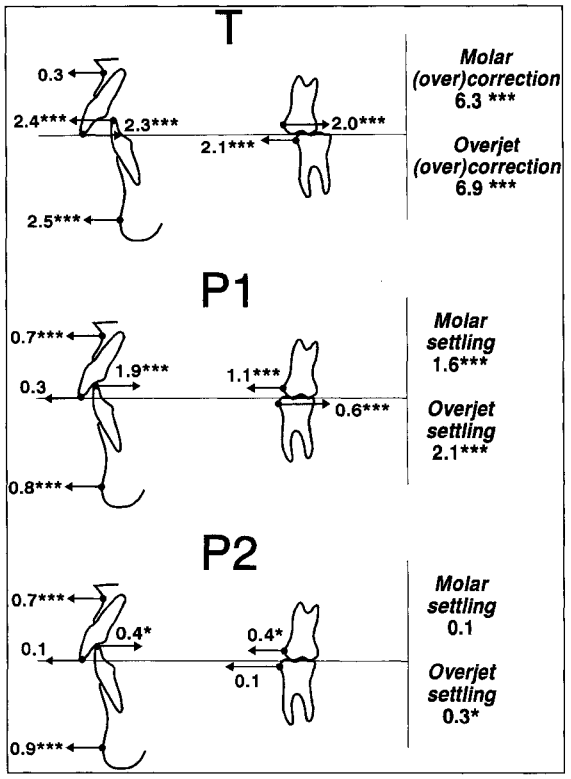

Figure 2. Treatment and early posttreatment effects of the Herbst appliance. Sagittal skeletal and dental changes (mm) contributing to alterations in molar and overjet relationships in 40 Class II Division 1 malocclusions. Registrations (mean values) during the treatment period (T) of 7 months, posttreatment period 1 (P1) of 6 months, and posttreatment period 2 (P2) of 6 months. * indicates statistical significance at the 5% level. *** indicates statistical significance at the 0.1% level.

tend to occur.[5,12] During the first year posttreatment period (Fig 2, P1 and P2), the occlusion settles into a Class I relationship. Approximately 30% of the overcorrected overjet and 25% of the overcorrected molar relationship recovered after occlusal settling. Approximately 90% of the posttreatment occlusal changes occur during the first 6 months posttreatment and are for the most part of dental origin: the upper teeth move anteriorly and the lower teeth move posteriorly (the mandibular incisors upright). An unfavorable relationship between maxillary and mandibular growth contributes only to a minor degree to the early posttreatment occlusal changes. When comparing the skeletal changes in Herbst patients with those in untreated controls, there seemed to be a minor relapse to previous maxillary and mandibular growth.[5,12]

Late posttreatment changes. When examining patients treated with the Herbst appliance at the end of growth at least 5 years after treatment,[21,23,26] the following was found: a Class I dental arch relationship is maintained by a stable cuspal interdigitation of the upper and lower teeth, whereas a dental relapse tends to occur in cases with unstable occlusal conditions especially when combined with a persisting lip-tongue dysfunction habit.[21,26] In relation to normal growth records of subjects exhibiting an excellent occlusion (Bolton Standards),[23] it was found that on a long-term basis, the Herbst appliance improves the sagittal jaw base relationship, but does not normalize it. The sagittal dental arch relationship, on the other hand, is almost normalized. Thus the dental effects of the Herbst appliance, as part of the long-term treatment outcome, compensate for an unfavorable jaw base relationship. The long-term mechanism of Class II correction in Herbst-treated cases is shown in Figure 3.

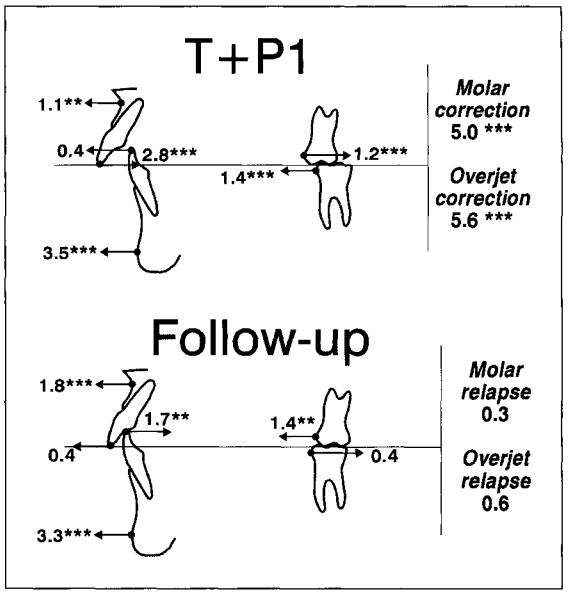

Figure 3. Long-term effects of the Herbst appliance. Sagittal skeletal and dental changes (mm) contributing to alterations in molar and overjet relationships in 32 Class II Division 1 malocclusions. Registrations (mean values) during the combined treatment period (T) of 7 months and first posttreatment (occlusal settling) period (P1) of 6 months as well as during the follow-up period (Follow-up) of 6.7 years after treatment. ** indicates statistical significance at the 1% level. *** indicates statistical significance at the 0.1% level.

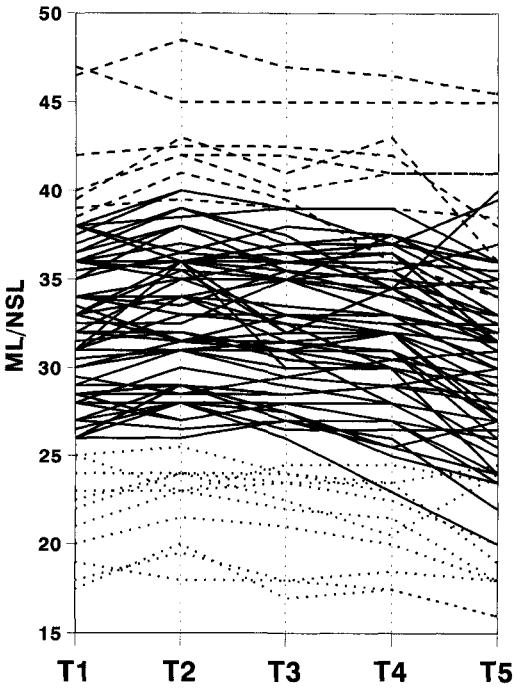

Figure 4. Individual changes (in degrees) of the mandibular plane angle ML/NSL at different observation intervals in 80 Class II Division 1 malocclusions treated with the Herbst appliance. T1: Before treatment. T2: Start of treatment when the appliance was placed. T3: After treatment when the appliance was removed. T4: 6 months after treatment when the occlusion had settled. T5: 5 years after treatment. Differentiation of subjects with hyperdivergent ("high-angle"), normodivergent and hypodivergent ("low-angle") vertical jaw base relationship. ----- Hyperdivergent, —— Normodivergent, ···· Hypodivergent.

Vertical Occlusion and Interjaw Relation

In Class II malocclusions with a deep bite, the overbite is reduced by about 50% with Herbst therapy.[7] Overbite reduction is mainly accomplished by intrusion of the lower incisors and enhanced eruption of the lower molars.[7] It must be pointed out, however, that part of the vertical incisor changes result from proclination of the teeth. Because of the vertical dental changes, the occlusal plane tips downward.[7]

The Herbst appliance has a limited effect on the vertical maxillary and mandibular jaw relations, as expressed by the nasal plane angle (NL [nasal plane]/NSL [sella-nasion plane]) and mandibular plane angle (ML [mandibular plane]/NSL [sella-nasion plane]).[7] This is also true when comparing Herbst patients with "high" and "low" pretreatment mandibular plane angles[28] (Fig 4): in both groups the ML/NSL decreases continuously during, as well as after, Herbst therapy which could be interpreted as a result of normalized function[4] which permits normal growth and development.

Mandibular Complex

In the analysis of mandibular growth and morphological changes occurring during and after Herbst treatment,[16] mouth open lateral head films, in which the condylar head is not obscured by the petrous part of the temporal bone, were used. The measuring variables used are shown in Figure 5. For the assessment of remodeling

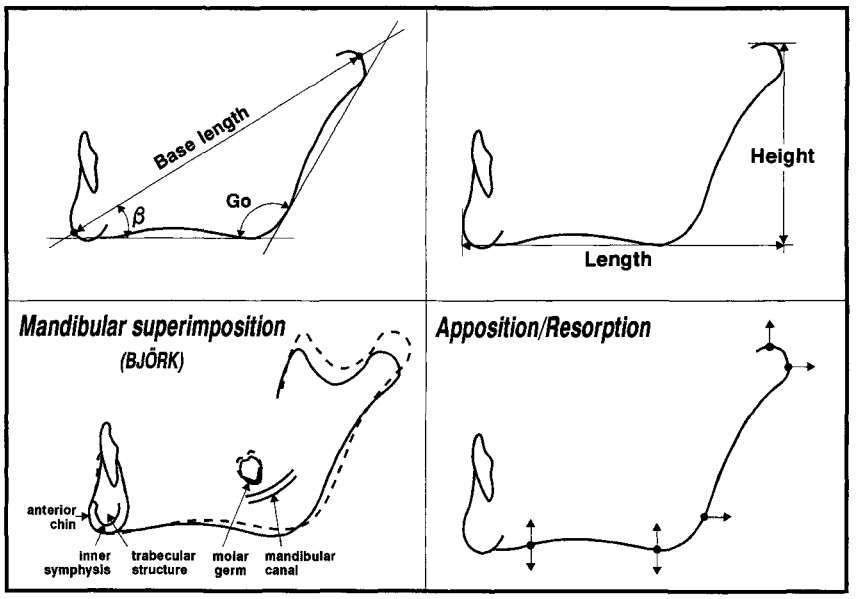

Figure 5. Angular and linear measurements for the assessment of mandibular morphological changes occurring during and after Herbst treatment (top row). Mandibular superimposition technique for the assessment of remodeling growth processes at the condyle and at the lower and posterior mandibular borders (bottom row).

growth processes at the lower and posterior mandibular borders, and to appraise sagittal and vertical condylar growth directions, the radiographs from different times of examination were superimposed on the natural mandibular reference structures used by Björk[66] (Fig 5).

In the evaluation, consecutively-treated male Herbst patients were compared with Class II control subjects.[16] The results of the comparisons are given in Figures 6 through 8.

Treatment changes. During 6 months of Herbst treatment, marked mandibular growth and morphological changes occurred (Fig 6):

- mandibular length increased more in the Herbst than in the control subjects
- the β-angle (angle formed by the intersection of condylion-gnathion line and the mandibular plane) closed in the Herbst subjects and opened in the control subjects
- the Go angle opened in the Herbst subjects and closed in the controls.

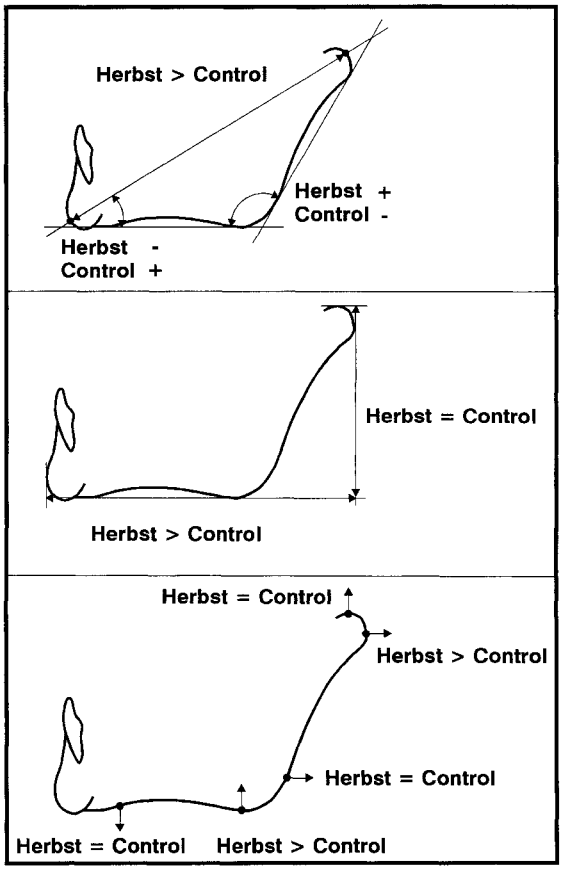

Figure 6. Mandibular morphological changes and bone remodeling processes (measurements as shown by lines and arrows in diagram) in 12 boys with Class II Division 1 malocclusions treated with the Herbst appliance. Registrations during the treatment period of 6 months. The comparison with Class II control subjects is given.

The group differences for linear and angular changes were a result of the following growth processes (bottom of Fig 6):

- larger bone resorption at the posterior part of the lower corpus border in the Herbst than in the control subjects
- larger sagittal condylar growth in the Herbst than in the control subjects (vertical condylar growth was unaffected by treatment).

Posttreatment changes. When reexamining the Herbst patients at the end of growth (on the average 7 years after treatment), the treatment changes reverted to a great extent (Fig 7):

- less mandibular length increase in the Herbst than in the control subjects
- larger mandibular height increase in the Herbst than in the control subjects
- larger opening of the β-angle in the Herbst than in the control subjects
- larger closing of the Go angle in the Herbst than in the control subjects.

The following growth processes could explain the group differences for linear and angular changes (bottom of Fig 7):

- bone apposition at the posterior part of the lower corpus border in the Herbst subjects and bone resorption in the control subjects
- less sagittal condylar growth in the Herbst than in the control subjects.

Treatment and posttreatment changes. During the total observation period of 7½ years, only a minimal long-term influence of Herbst treatment on mandibular growth and morphology could be verified (Fig 8):

- larger mandibular height increase in the Herbst than in the control subjects
- larger opening of the β-angle in the Herbst than in the control subjects.

The following growth process could explain the group difference for linear and angular changes (bottom of Fig 8): bone apposition at the posterior part of the lower corpus border in the Herbst subjects and bone resorption in the control subjects.

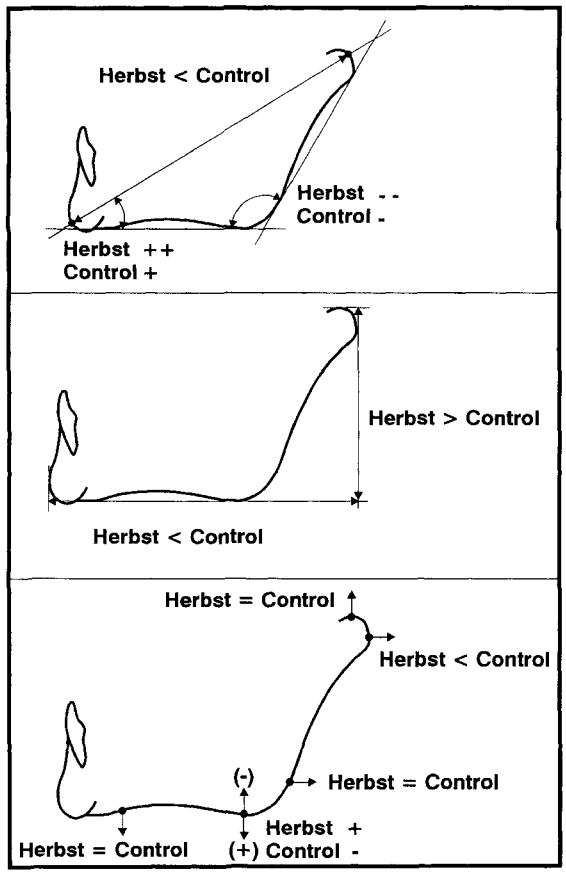

Figure 7. Mandibular morphological changes and bone remodeling processes in 12 boys with Class II, Division 1 malocclusions treated with the Herbst appliance. Registrations during the posttreatment period of 7 years. The comparison with Class II control subjects is given.

The remodeling growth processes at the posterior part of the lower mandibular corpus border during and after Herbst treatment can be explained by a continuous increase in masseter electromyographic (EMG) activity during these periods.[4,8] In an unpublished study, a moderate correlation ($r = 0.67$; $P < .05$) between the posttreatment increase in masseter EMG activity and bone apposition was found.

Maxillary Complex

The telescope mechanism of the Herbst appliance produces a posterior-upward directed force on the maxillary jaw base and dentition. Thus, the force system on the maxillary complex could be compared with that of a high-pull headgear.

In the analysis of the maxillary effects, 45 consecutively-treated Herbst patients were followed 5 to 10 years posttreatment.[24] The results of the evaluation are presented in Figures 9 through 11.

Treatment changes. During 7 months of Herbst treatment, the following changes occurred (Fig 9):

- the occlusal plane tipped downward anteriorly in 82% of the cases with a maximum value of 7.5 degrees
- the upper molars were moved distally in 96% of the cases with a maximum value of 4.5 mm
- the upper molars were intruded in 69% of the cases with a maximum of 3.5 mm.

When analyzing the treatment effects on the molar position with respect to different maxil-

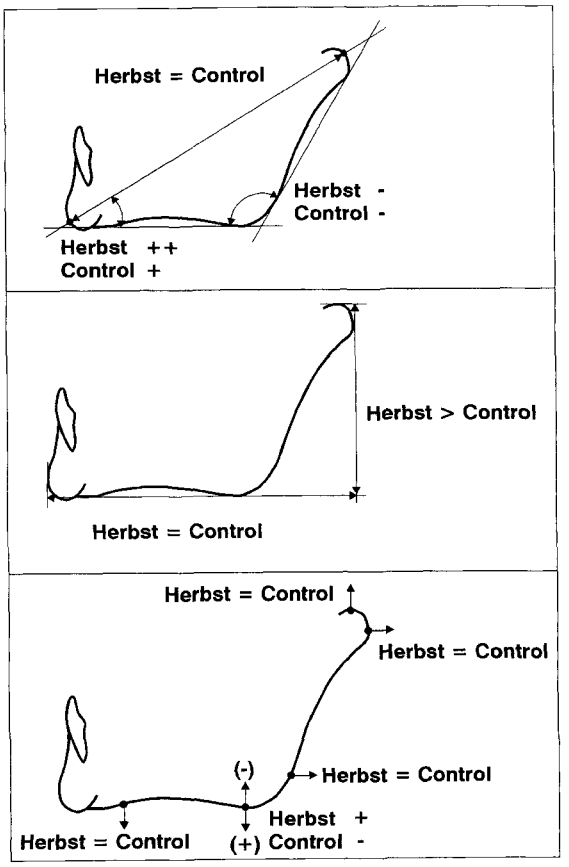

Figure 8. Mandibular morphological changes and bone remodeling processes in 12 boys with Class II, Division 1 malocclusions treated with the Herbst appliance. Registrations during the treatment and posttreatment periods of 7½ years. The comparison with Class II control subjects is given.

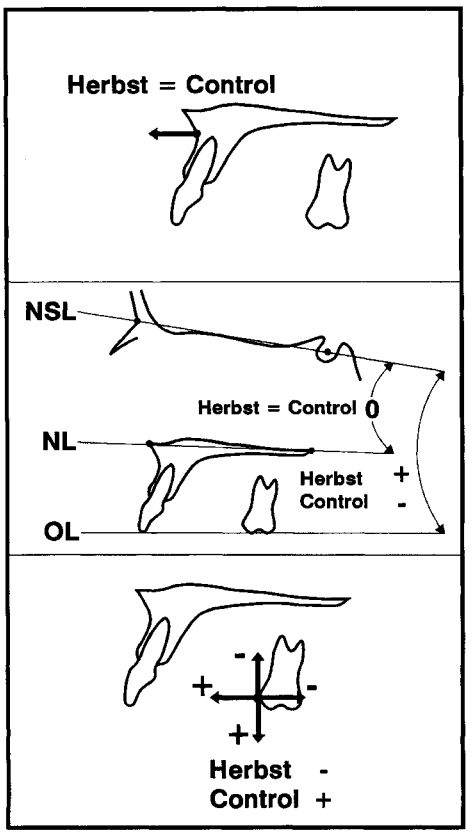

Figure 9. The effect of the Herbst appliance on the maxillary complex in 45 Class II Division 1 malocclusions. Registrations during the treatment period of 7 months. The comparison with Class II control subjects is given.

lary anchorage systems, no differences were found between partial and total anchorage.

Posttreatment changes. During the posttreatment period of an average of 6½ years, a relapse occurred in the Herbst subjects with respect to the following variables (Fig 10):

- the occlusal plane tipped upward anteriorly
- the upper molars moved mesially
- the upper molars extruded.

It must be emphasized that most of the posttreatment changes occurred during the first 6 months after Herbst therapy. Retention (upper plate, activator) performed in 29 of the 45 cases prevented the early posttreatment molar relapse, to some extent. On a long-term basis, however, no differences were found between retention and no-retention subjects.

Treatment and posttreatment changes. For the total observation period of an average of 7 years, no differences were found when comparing the Herbst patients with control subjects. Thus, on a long-term basis, Herbst treatment seemed not to affect the maxillary complex. The skeletal and dental changes seen were a result of normal growth and development (Fig 11):

- anterior jaw growth
- upward tipping of the occlusal plane anteriorly
- mesial movements of the molars
- extrusion of the molars.

Treatment Indications

The Herbst appliance is most effective in the treatment of skeletal Class II malocclusions.[6,10] This is true for both Class II, Division 1 and Class II, Division 2 cases. Basically, the same prerequisite conditions for successful treatment apply for

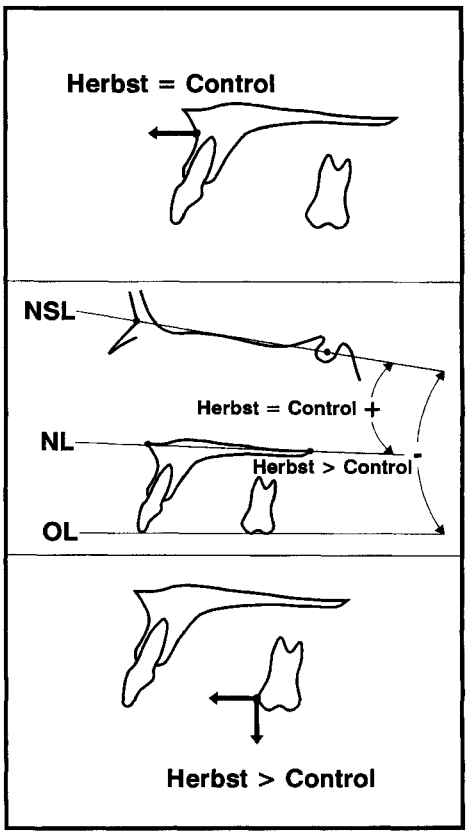

Figure 10. The effect of the Herbst appliance on the maxillary complex in 45 Class II Division 1 malocclusions. Registrations during the posttreatment period of 6½ years. The comparison with Class I and Class II control subjects is given.

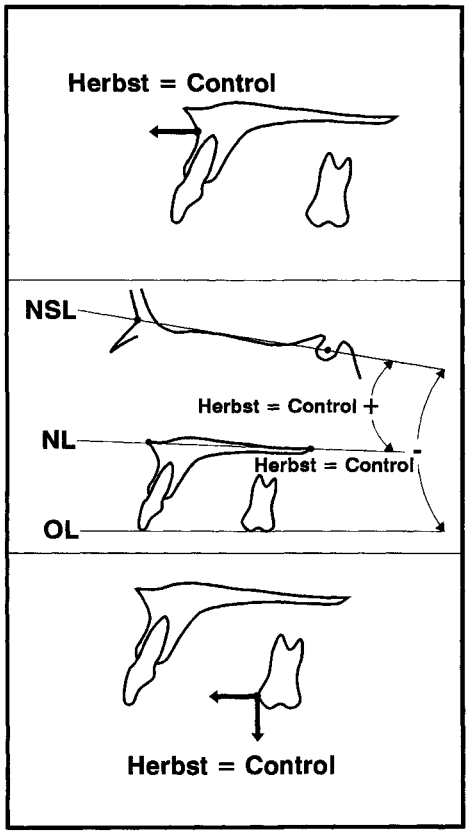

Figure 11. The effect of the Herbst appliance on the maxillary complex in 45 Class II Division 1 malocclusions. Registrations during the treatment and posttreatment periods of 7 years. The comparison with Class I and Class II control subjects is given.

the Herbst appliance as for removable functional appliances (activator, bionator, Fränkel appliance): the maxillary and mandibular dental arches should be in good alignment before the functional appliance therapy. Unlike removable functional appliances, the Herbst appliance can be used successfully in the following subject groups: (1) postadolescent patients, (2) uncooperative patients, and (3) mouth breathers.

Treatment Timing

The Herbst appliance is especially indicated in the permanent dentition and at or just after the pubertal peak of growth[11] corresponding to the skeletal maturity stages of MP3 FG-H using the hand radiographic assessment.[15] Treatment during this period will, on average, result in a large effect on mandibular condylar growth, whereas the undesired effect on the mandibular dentition (proclination of the incisors) will be small.[11]

Furthermore, "late" Herbst treatment in the permanent dentition has the advantage of promoting a good cuspal interdigitation of the teeth after therapy which is a factor of utmost importance for the prevention of a dental as well as a skeletal posttreatment relapse.[6,10,12,21,26,53] Teeth locked in a stable Class I intercuspidation will transfer maxillary growth forces to the mandible or vice versa and could thus act as a restricting or stimulating factor on mandibular and maxillary growth. This means that a functional stable occlusion after Herbst therapy (or any orthodontic therapy) could be of greater importance of a lasting treatment result than an unfavorable posttreatment growth pattern.

"Early" treatment in the decidious or mixed dentition is not recommended, as a stable cuspal interdigitation after Herbst therapy is difficult to achieve, and retention time has to be extended until all permanent teeth have erupted into stable occlusion. In case of insufficient retention, relapse is prone to occur[21,26,53] (Fig 12). Furthermore, "early" treatment can be discouraging in the long run because severe Class II discrepan-

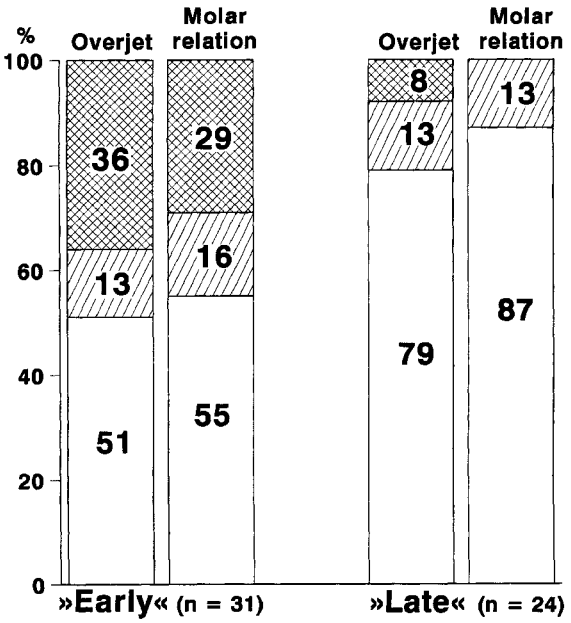

Figure 12. Long-term effects of Herbst therapy in 31 subjects treated "early" (mixed dentition; before the pubertal peak of growth) and in 24 subjects treated "late" (permanent dentition; after the pubertal peak of growth). Distribution of the patients with respect to relapse and stability 5 to 10 years after Herbst therapy according to overjet and sagittal molar relationships. ▨ Relapse, ▨ Insignificant Relapse, □ Stable


A
B
C

cies seem to strive constantly to reassert themselves. This assumption is supported by the long-term Herbst studies showing that the existing skeletofacial growth pattern is only temporarily affected by therapy.[14,16,19]

Multiphase Treatment

As a rule, a Class II malocclusion cannot be treated to a perfect end result with the Herbst appliance exclusively. Most cases will require a subsequent (sometimes also an initial) dental alignment treatment phase with a multibracket appliance. Therefore, in contemporary dentofacial orthopedics, the Herbst appliance should be looked on as part of a multiphase treatment approach.

Treatment of Class II, Division 1 Malocclusions

Generally a two-step treatment approach is used (Fig 13A and B):

Step 1. Orthopedic phase. The sagittal jaw base relationship is normalized and the Class II malocclusion is treated to a Class I malocclusion by means of the Herbst appliance.

Step 2. Orthodontic phase. Tooth irregularities and arch discrepancy problems are dealt with using a multibracket appliance (with or without the extraction of teeth).

Figure 13. The Herbst appliance as part of a multiphase treatment procedure. (A) Nonextraction treatment of a severe Class II Division 1 malocclusion. This postadolescent 14-year-old girl was previously treated unsuccessfully with removable functional appliances for 4½ years. Treatment time with the Herbst appliance was 6 months and with the multibracket appliance 11 months. Note the overcorrected sagittal dental arch relationships during the Herbst treatment phase. (B) Extraction treatment of a Class II Division 1 malocclusion with a high mandibular plane angle (ML/NSL = 40 degrees) and mandibular crowding. This adolescent 13-year-old boy was treated with the Herbst appliance for 8 months and with the multibracket appliance (in combination with extractions of the four first premolars) for 13 months. (C) Nonextraction treatment of a Class II Division 2 malocclusion. This postadolescent 15-year-old boy was treated with the Herbst appliance (after proclination of the maxillary incisors with a fixed appliance) for 7 months and with a multibracket appliance for 14 months.

Treatment of Class II, Division 2 Malocclusions

A three-step treatment approach is often required (Fig 13C):

Step 1. Orthodontic phase. Alignment (proclination) of the maxillary front teeth is performed with a maxillary multibracket appliance.

Step 2. Orthopedic phase. The Class II malocclusion is treated to a Class I malocclusion by means of the Herbst appliance.

Step 3. Orthodontic phase. Tooth irregularities and arch discrepancy problems are dealt with by means of multibracket appliance (extraction of teeth should be avoided).

Treatment Limitations

In nongrowing patients, the appliance should be used with great caution. In these older subjects, skeletal alterations will be minimal and the treatment effects will be confined to the dentoalveolar area. Furthermore, there is an increasing risk for the development of a dual bite[67] with dysfunction symptoms from the TMJ as a possible consequence.[68] However, recent MRI studies indicate that by keeping the mandible in a continuous protruded position a recapture of an anteriorly displaced disc is possible.[69]

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