*Review Article*

# Immediate Skeletal and Dentoalveolar Effects of the Crown- or Banded Type Herbst Appliance on Class II division 1 Malocclusion

### *A Systematic Review*

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**ABSTRACT**

**Objective:** To evaluate the relative skeletal and dental changes produced by the crown- or banded-type Herbst appliance in growing Class II division 1 malocclusion cases.

**Materials and Methods:** Several electronic databases were searched with the help of a health sciences librarian, without language limitation. Abstracts that appeared to fulfill the initial selection criteria (Herbst use and clinical trial) were selected by consensus, and their original articles were then retrieved. Clinical trials were selected that used lateral cephalograms to assess immediate skeletal and dental changes from the use of either crown or banded Herbst appliances. Clinical trials that employed other simultaneous potentially growth-modifying appliances or surgery were excluded. A comparable untreated Class II division 1 malocclusion control group was required to factor out normal growth changes. References from the selected articles were also hand searched.

**Results:** Only three articles meet the selection criteria. Proclination and anterior movement of the lower incisors, overjet reduction, and improvement of first molar relationship thorough mesial movement of the first molars, reduction of ANB angle, and an increase in the mandibular plane angle were reported. There were mixed findings as to mandibular sagittal length and position and increases in lower face height, both anteriorly and posteriorly. No statistically significant changes were noted in the sagittal length or position of the skeletal maxilla.

**Conclusions:** Dental changes have more impact than skeletal changes in the correction of Class II division 1 malocclusions with the crown or banded Herbst appliance.

**KEY WORDS:** Functional appliances; Herbst; Systematic review

## INTRODUCTION

The term *functional appliance* refers to both removable and fixed appliances designed to alter the sagittal or vertical position of the maxilla or mandible.[1] The goal of these appliances is to encourage or possibly redirect growth in a favorable direction. Early animal studies[2,3] using functional appliance interventions showed increments in mandibular dimensions, but similar results have not been clearly demonstrated in human studies.

Currently, there is little doubt that measurable dental changes such as reduced overjet or molar correction occur in a favorable manner with the continuous use of functional appliances. However, the degree of skeletal versus dentoalveolar change that underlies these treatment effects is a source of debate.[4–8] Controversy continues to exist over the effectiveness of functional appliances in part because of the method of analysis employed by these published reviews. Ideally, the treatment effects of each appliance should be examined individually because each appliance has a theoretical different mechanism of action and application that will likely produce different movement based on the relative dental and skeletal changes. However, most reviews have analyzed several functional appliances simultaneously and may have obscured the real

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**Table 1.** Database Search and Results

| Database | Search Terms | Results | Abstracts Obtained | Selected for the Systematic Review | % of Total Selected Articles (3) Found by Database |
|---|---|---|---|---|---|
| PubMed (1966 to week 1 of March 2007) | (1) herbst; (2) orthod*; (3) #1 AND #2; (4) limit humans | 193 | 54 | 3 | 100 |
| Medline + In-Process and Nonindexed (up to March 12, 2007) | (1) herbst; (2) orthod$ (3) #1 AND #2; (4) limit humans | 193 | 54 | 3 | 100 |
| EMBASE (from 1988 to week 7 of 2007) | (1) herbst.mp; (2) orthod$.mp; (3) #1 AND #2 | 10 | 3 | 0 | 0 |
| All EBM reviews (Cochrane Database of Systematic Reviews, ACP Journal Club, DARE, CCTR; up to March 12, 2007) | (1) herbst; (2) orthod*; (3) #1 AND #2 | 22 | 14 | 2 | 67 |
| Web of Science (1945 to week 1 of March 2007) | (1) herbst AND orthod* | 56 | 10 | 0 | 0 |
| Scopus (up to March 12, 2007) | (1) herbst AND orthod*; (limit: Heath and Life Sciences) | 199 | 36 | 2 | 67 |
| Lilacs (up to March 12, 2007) | (1) herbst | 24 | 6 | 0 | 0 |
| Hand search | | | 0 | 0 | 0 |

effects of each individual functional appliance by combining all the effects.

Both removable and fixed functional appliances have been used for decades, with various forms coming in and out of popularity. While removable appliances such as activators, bionators, and twin blocks are still widely used, fixed functional appliances have enjoyed a recent surge of use. Fixed functional appliances have the advantage of not relying on patient compliance because they are fixed in the mouth, thus always working, and they can be used concurrently with full fixed appliances. One significant disadvantage is that they are more prone to breakage[9] than their removable counterparts.

The most used and researched of these appliances is the Herbst appliance, reintroduced by Pancherz in the late 1970s. Three previous reviews analyzed exclusively Herbst treatment effects,[10–12] while a fourth review[13] reported Herbst effects individually while analyzing several other functional appliances. Of these four Herbst reviews, the oldest one[10] is not a systematic review and therefore is likely to be influenced by bias. The second review[13] had a limited search strategy that focused only on mandibular skeletal changes. The third review systematically analyzed only soft tissue changes.[11] The more recent review[12] analyzed only the skeletal and dental changes produced by the splint-type Herbst but not the banded or crown type. While the crown and banded versions are cemented into the mouth, the acrylic-splint version necessitates an interocclusal layer of acrylic and can also be used as either fully or partially removable.[14,15] Theoretically, an interocclusal layer of acrylic could help control vertical changes; therefore, a properly executed and comprehensive systematic review to analyze the dental and skeletal effects of the banded- or crown-type Herbst appliance exclusively is warranted. Such a comparison of actual changes in the anteroposterior and vertical dimensions between both Herbst-type designs could be distinguished if such differences actually exist.

This systematic review will attempt to answer the following question: In Class II malocclusion growing individuals, what are the maxillary and mandibular skeletal and relative dentoalveolar treatment effects produced by crown or banded Herbst compared to a Class II malocclusion nontreated control group?

## MATERIALS AND METHODS

Electronic databases were searched, and the selection and specific use of each search term with its respective truncation, if applicable, inside every database (Table 1) were made with the help of a senior librarian who specialized in health sciences database searches.

The following inclusion criteria were chosen to initially select potential articles from the published abstract results:

- Clinical trials
- Use of crown or banded Herbst appliance to correct Class II division 1 malocclusions
- Skeletal and/or dental changes evaluated through lateral cephalograms
- Nonsyndromic or medically compromised patients
- No surgical intervention

It was considered improbable that the abstracts would report enough information regarding control groups to factor out growth changes; thus, no attempts were made at this initial stage to identify studies with or without proper control groups.

The selection process was independently made by two of the researchers. Their selection results were compared to settle discrepancies through discussion, except for the Lilacs database, which was evaluated by only one of the researchers because of language limitations. If the abstract did not provide enough information to make a sound decision, the actual article was obtained. Any abstract that did not specifically mention the type of Herbst appliance used (acrylic-splint, crown or banded versions) was automatically included at this stage as well.

The same selection process was applied in the next selection stage including only full articles. Articles ultimately selected were chosen with the following additional inclusion criteria:

- A comparable nontreated Class II malocclusion control group was used.
- Cases must have been randomized or been consecutively started/treated.
- Measurements must have been taken soon after Herbst appliance removal.
- There was no concurrent use of any other orthodontic appliance during the evaluation period.

Reference lists of the selected articles were also hand searched for additional relevant publications that may have been missed in the database searches. In cases in which specific data were necessary for the discussion and were not specified in the article, efforts were made to contact the authors to obtain the required extra information.

## RESULTS

The details for the searches, as well as the number of abstracts selected from each database, can be seen in Table 1. Figure 1 presents a flow diagram of the selection process. After the final selection criteria were applied to the complete article, only 3 of the 51 articles were selected. Two of the three finally included articles came from the same sample, although they reported different measurements. The total number of patients under treatment combining the studies' samples was 52 active treated cases and 50 untreated control cases. Table 2 provides details on articles not selected for inclusion and the reason(s) for the exclusion in each case. A summary of the selected study characteristics can be found on Table 3

### Study Characteristics

The two Pancherz articles from 1982[16,17] involved the same groups of subjects, but each article reported different measurements. The subjects used were a consecutively treated prospective sample. The treatment group consisted of 21 subjects, while the untreated control group consisted of 20 subjects. The control group was followed on a parallel basis. One of the articles[16] stated that the mean age of the treatment group was 12 years 1 month, while the control group had a mean age of 11 years 2 months. The time between lateral cephalograms was 6 months for both groups. Posttreatment radiographs were taken upon appliance removal.

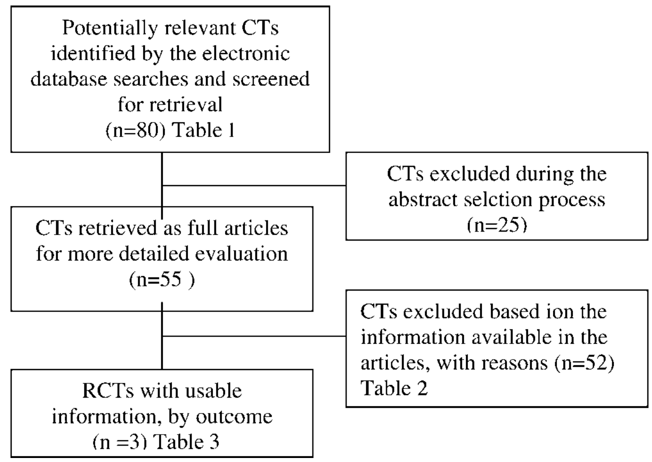


**Figure 1.** Flow diagram of the article selection.

The study by De Almeida et al[18] was published in 2005 and also presented consecutively treated prospective cases. It included only mixed dentition cases and thus, not surprisingly, had a young cohort (mean age of 9 years 8 months at the start of treatment in the Herbst group and 9 years 10 months for the control group). The mean treatment time was 12 months. Consecutive cases (40) were initially considered, and the final analysis excluded those cases in which appliances were removed prematurely because of breakage (eight cases) or poor positioning on radiographs (two cases). The untreated matched control group was drawn from files derived from the University of Sao Paulo (Bauru, Brazil) Growth Study. No intention-to-treat analysis was presented. Skeletal maturation was considered for the matching. Posttreatment radiographs were taken upon appliance removal—in some cases immediately and in other cases after 4 weeks.

All skeletal and dental measurement changes reported are the changes in the Herbst-treated groups relative to those changes observed in the untreated control groups (Table 4). Statistical significance of these differences at the $P < .05$ level is used for all measurements.

Because of the limited number of finally selected studies and the heterogeneity of their methodology, it was not considered valid to attempt to do a meta-analysis with the data.

**Table 2.** Articles Not Selected From the Initial Abstract Selection List and Reasons for Exclusion[a]

| Article | Reason Excluded |
|---|---|
| LaHaye[1] | Concurrent fixed appliances |
| Phan[2] | Inadequate control group |
| Bock[3] | Inadequate control group |
| VanLaecken[4] | Splint-type used |
| Ruf[5] | Concurrent fixed appliances |
| Alves[6] | Nonconsecutive Herbst sample |
| Berger[7] | Splint-type used; inadequate control group |
| do Rego[8] | Inadequate control group |
| Weschler[9] | Inadequate control group |
| Ruf[10] | Inadequate control group |
| Schaefer[11] | Inadequate control group |
| Ogeda[12] | Inadequate control group |
| Burkhardt[13] | Inadequate control group |
| Hagg[14] | Includes headgear; inadequate control group |
| O'Brien[15] | Inadequate control group |
| Hagg[16] | Headgear, Herbst used |
| Du[17] | Inadequate control group |
| Manfredi[18] | Inadequate control group |
| Cacciafesta[19] | Not a clinical trial of Herbst treatment |
| Hiyama[20] | Splint-type used; inadequate control group |
| Nelson[21] | Inadequate control group |
| Ursi[22] | Splint-type used |
| Ursi[23] | Splint-type used |
| Croft[24] | Included (mean) 17 mo of positioner retention in measurements |
| Ruf[25] | Inadequate control group |
| Franchi[26] | Splint-type used |
| Ruf[27] | Temporomandibular joint (TMJ) study; inadequate control group |
| Bowman[28] | Not a clinical trial |
| Lai[29] | Splint-type used |
| Xu[30] | Inadequate control group |
| Eberhard[31] | Class II division 2 Cases; inadequate control group |
| Ruf[32] | Inadequate control group |
| Ruf[33] | Inadequate control group |
| Sidhu[34] | Splint-type used |
| Hons[35] | Poster abstract |
| Tse[36] | Poster abstract |
| Pancherz[37] | Inadequate control group |
| Pancherz[38] | Nonrandom or nonconsecutive Herbst sample |
| Ursi[39] | Splint-type used |
| Kucukkeles[40] | Nonrandom or nonconsecutive Herbst sample |
| Hansen[41] | Inadequate control group |
| Schiavoni[42] | Inadequate control group |
| McNamara[43] | Splint-type used |
| Pancherz[44] | Inadequate control group |
| Pancherz[45] | TMJ study; inadequate control group |
| Pancherz[46] | Nonrandom or nonconsecutive Herbst sample |
| Pancherz[47] | Inadequate control group |
| Valant[48] | Half-splint type used |
| Pancherz[49] | Inadequate control group |
| Hagg[50] | Inadequate control group |
| Pancherz[51] | Inadequate control group |
| Pancherz[52] | Follow-up to 1979 study, same data |
| Pancherz[53] | Nonrandom or nonconsecutive Herbst sample |

[a] References appear in Appendix 1.

## DISCUSSION

Direct comparisons between studies were difficult on several levels: different landmarks/measurements reported, different group age ranges, and different treatment durations. This variability between the measurements used prevented the validity of adding a meta-analysis.

### Treatment Duration

The 12-month treatment time used by de Almeida et al[18] is longer than many other Herbst studies but still relatively common in the literature, especially when acrylic-splint Herbst appliances are used. This may have been influenced by the relatively young age of the treatment cohort (about 9 years at start of treatment).

### Skeletal Effects

Minimal effects were demonstrated on the maxilla, as only two of the seven maxillary sagittal variables measured showed statistically significant changes, whereas several significant (and nonsignificant) increases were seen in mandibular length as compared to the untreated controls. It appears that the magnitude of the mandibular change lies in the 2- to 3-mm range, depending on which measurement is considered. How much of this effect is an artifact of mandibular posturing has not been evaluated. Condylion was used several times to quantify mandibular length changes. Its use is questionable because of its low reliability.[19,20] None of the studies seemed to have used open-mouth cephalograms to help in the identification of condylion, as has been suggested before.[21] While the mandibular effects could be anticipated, the lack of a headgear effect on the maxilla is noteworthy. Previous studies involving various types of functional appliances have found both the presence and absence of this effect on the maxilla.

### Dentoalveolar Effects

Generally, maxillary incisors were retroclined, despite the fact that no appliances were used directly on them in any of the studies included in this review. These findings are similar to those seen elsewhere with Herbst appliances. This is no doubt influenced by the fact that all cases used in this review were Class II division 1 and thus were already quite proclined prior to treatment, which is not the case for all studies in the literature. Mandibular incisors showed a definite proclination, which is not surprising given the force vectors involved with Herbst treatment.

Maxillary first molar position showed small but statistically significant amounts of intrusion. The clinical

**Table 3.** Key Methodological Information From the Finally Selected Studies

| Study | Sample Size | Nontreated Sample | Selection | Measurement Error | Treatment Length ($\bar{x}$) |
|---|---|---|---|---|---|
| Pancherz[16,17] | 22 (3 F/19 M), 12.1 y ± SD 11 mo | 20 (3 F/17 M), 11.2 y ± SD 9 mo | Prospective, consecutive | Yes | 6 mo |
| de Almeida[18] | 30 (15 F/15 M), 8.2−11.0 y | 30 (15 F/15 M), 8.0−10.9 y | Prospective and consecutive, mixed dentition | Yes | 12 mo |

significance of this level of intrusion is questionable. It also was moved distally within the maxillary alveolus. This distal movement could account for the retroclination of the maxillary central incisors via transeptal fibers. Mandibular first molars showed an extrusive and anterior direction of movement. This could be accounted for by the relative intrusion of the opposing maxillary first molar, allowing for this small but significant amount of eruption.

## Comparison to Other Functional Appliance Reviews

Aelbers and Dermaut[5,22] reported the first significant reviews of the effects of not only functional appliances but also extraoral traction appliances. Chen et al,[8] until 1999, and Cozza et al,[13] until early 2005, studied mandibular skeletal measurements exclusively as an assessment of any functional appliance therapy. They searched only Medline. Shen et al[23] also analyzed only mandibular effects while trying to differentiate the effects between fixed and removal appliances. Collett[6] also focused on mandibular changes through functional appliance use. These last studies did not specify their search and selection methodology. The magnitude and controversy of the mandibular changes in these reviews were similar to the ones we reported. Other reviews tangentially touched on the functional appliances effects. Four reviews focused only on Bionator changes[24,25] and involved any Class II correction appliance.[7]

Four reviews were found that focused exclusively on Herbst appliance effects. The oldest one[10] was likely influenced by bias as it was not a systematic review. The second review[13] had a limited search strategy that focused only on mandibular skeletal changes. The third review systematically analyzed only soft tissue changes.[11] The more recent review[12] analyzed only the skeletal and dental changes produced by the splint-type Herbst but not the banded or crown type.

It is considered clinically important to compare the systematic results of bonded-type against banded-type Herbst appliances. Flores-Mir et al[12] reviewed acrylic-splint Herbst appliances, some of which can be partially removable. This systematic review included three studies in the final analysis and was updated to early 2006. Significant changes were found as the posterior facial height, lower anterior facial height, maxillary sagittal position, maxillary first molar position, and mandibular dimensions increased. They found mandibular incisors protruded and proclined while the mandibular molars protruded. Some differences, especially in the vertical skeletal dimensions, can be noted compared to the bonded-type and crown-type Herbst changes. The magnitude of the differences was small and associated with the interocclusal acrylic layer, and it is likely not clinically significant to consider one type more efficient. The decision of which Herbst type to be used is therefore more a clinical management decision, as skeletal and dental differences that are produced do not have a clinically significant impact.

## Limitations

It is of note that the studies included in this review involved a total of 52 Herbst-treated subjects. None of the studies included for analysis in this article were randomized control trials, which are generally accepted as the best possible trial design. Most of the mandibular length measurements relied on condylion, which is known to be difficult to determine cephalometrically.[19,20] In general, the methodological quality of the studies was poor.

Only one study[17] quantified changes at the condylar level. Only one measurement was used. Estimates of the amount and direction of condylar growth are considered key to correctly evaluate mandibular growth changes.[26,27] It has been suggested that not taking these factors into consideration significantly underestimates mandibular growth.[27,28]

Only two studies[16,17] used concurrent untreated Class II control samples, while the other study[18] used historical untreated Class II samples. Controversy regarding the use of historical control samples exists.[29]

Differences were noted in the after-treatment cephalometric timing. Two studies[16,17] exposed the radiographs immediately before Herbst appliance removal and one study[18] at different times between Herbst removal and 4 weeks. The justification for taking radiographs at different times in the latter study was to allow relapse. Is 4 weeks enough time to allow skeletal and

**Table 4.** Findings of Selected Articles[a]

| Measurement | de Almeida et al[18] | Pancherz[16,17] |
|---|---|---|
| Herbst, n | 30 | 22 |
| Control, n | 30 | 20 |
| **Mx skeletal sagittal** | | |
| SNA, ° | −0.4 | |
| A − FHp, mm | −0.7 | |
| Co − A, mm | −0.5 | |
| ANS − FHp, mm | −0.8 | |
| OLp − A, mm | | −0.4 |
| **Mx angulation** | | |
| NSL/NL, ° | 0.2 | 0.6 |
| Mx occ plane (to SN), ° | | **1.2** |
| **U1 angulation** | | |
| U1 − NA, ° | **−5.7** | |
| **U1 vertical** | | |
| Mx incisor height (U1-NL), mm | | 0 |
| **U1 sagittal** | | |
| U1 − NA, mm | **−1.5** | |
| Olp − U1 minus Olp-A, mm | | −0.5 |
| **U6 vertical** | | |
| Mx molar height (U6-NL), mm | **−0.4** | **−1.0** |
| **U6 sagittal** | | |
| Olp − ms minus Olp-A, mm | | **−2.8** |
| **Md skeletal sagittal** | | |
| SNB, ° | **0.6** | |
| Co − Gn, mm | **1.6** | |
| B − FHp, mm | 0.4 | |
| Pg − FHp, mm | 0.2 | |
| OLp − Pg, mm | | **2.5** |
| OLp − Pg + OLp − Co, mm | | **2.2** |
| **Md angulations** | | |
| NSL/ML, ° | 0.4 | 0.2 |
| Md occ plane (to SN), ° | | **5.1** |
| **L1 angulation** | | |
| IMPA, ° | **4** | |
| L1-NB, ° | **5.4** | |
| **L1 vertical** | | |
| Md incisor height (L1 − ML), mm | | **−1.8** |
| **L1 sagittal** | | |
| L1 − NB, mm | **1.0** | |
| OLp − L1 minus OLp − Pg, mm | | **1.8** |
| **L6 vertical** | | |
| Md molar height (L6 − ML), mm | **0.7** | **1.3** |
| **L6 sagittal** | | |
| OLp − L6 minus OLp − Pg, mm | | **1.0** |
| **Mx-Md relationship skeletal** | | |
| ANB, ° | **−1.0** | |
| **Interincisor relationships** | | |
| OJ, mm | | |
| OB, mm | | **−3.2** |
| **Intermolar relationship** | | |
| U6/L6, mm | | |
| Condyle sagittal | | |
| OLp − Co, mm | | |
| **Other** | | |
| ANS − Gn (LFH), mm | | **1.8** |
| ANS − Me (LFH), mm | 0.7 | |
| Ar − Go, mm | **1.4** | |
| S − Go, mm | 0.7 | |

[a] Bold indicates changes that are significant at the $P = .05$ level or lower. FHp indicates a line perpendicular to the Frankfort horizontal running through sella; Lp, a line perpendicular to the maxillary occlusal plane (defined as the line connecting the most prominent upper incisor tip and the maxillary first molar distobuccal cusp); NL, a line connecting ANS and PNS; NSL, a line connecting nasion and sella, same as "SN"; Mx occ plane, a line connecting the maxillary central incisor tip and the maxillary first molar mesiobuccal cusp tip; Md occ plane, a line connecting the mandibular central incisor tip and the mandibular first molar mesiobuccal cusp tip; NA, a line connecting nasion and point A; NB, a line connecting nasion and point B; U1, the incisal tip of the most prominent maxillary central incisor, same as "is" for the Pancherz analysis; L1, the incisal tip of the most prominent mandibular central incisor, same as "ii" for the Pancherz analysis; U6s, the mesial contact point of the maxillary permanent first molar, same as "ms" for the Pancherz analysis; L6, the mesial contact point of the mandibular permanent first molar, same as "mi" for the Pancherz analysis; ML, the line connecting gnathion and gonion; and IMPA, the angle formed by the intersection of the line connecting the tip and apex of the mandibular central incisor and the ML.

dental relapse? It is hoped that the recent trials published on headgear and removable appliances will evoke more trials with fixed functional appliances.

The present systematic review evaluated immediate changes only, and it is thus difficult to judge the results here as conclusive, as dental relapse and/or mandibular growth rate deceleration could occur, lessening the positive changes seen. No identified studies reported long-term results.

## CONCLUSIONS

- Controversy was identified for the mandibular sagittal skeletal effects; depending on the measurement used, significant and nonsignificant changes were shown.
- There were minimal maxillary skeletal effects.
- There was proclination/anterior movement of the lower incisors.
- There was retroclination/posterior movement of the upper incisors.
- Overjet and overbite were reduced; molar relationships were improved in the direction of Class I.

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## APPENDIX 1

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