Journal of the World Federation of Orthodontists 8 (2019) 18–23

Contents lists available at ScienceDirect

Journal of the World Federation of Orthodontists

journal homepage: www.jwfo.org

Research Article

# Rotational effects of Class II Division 1 treatment with the Herbst appliance and fixed appliances in growing subjects with different vertical patterns

Emily Deen [a], Michael G. Woods [b,*]

[a] Graduate Orthodontics, University of Melbourne, 549 Dandenong Road, Malvern, Victoria 3144, Australia
[b] Oral and Maxillofacial Surgery Unit, Royal Melbourne Hospital, 549 Dandenong Road, Malvern, Victoria 3144, Australia

ARTICLE INFO

*Article history:*
Received 6 December 2018
Received in revised form
15 January 2019
Accepted 18 January 2019
Available online 15 February 2019

*Keywords:*
Class II Division 1
Herbst and fixed appliances
Vertical facial rotations

ABSTRACT

*Aim:* This retrospective study was undertaken to assess the rotational effects of the Herbst appliance and fixed appliances in the treatment of Class II Division 1 subjects with different vertical facial patterns.
*Method:* Pretreatment, post-Herbst, and post-fixed appliance lateral cephalograms from 115 growing Class II Division 1 subjects were divided into three groups based on differences in the mandibular plane angle. Changes in dental and skeletal measurements were assessed within these vertical groups and in relation to pretreatment overbite, overjet, and stage of cervical maturity.
*Results:* During the overall treatment period, there were changes as expected in upper and lower incisor angulations, reductions in the incisal overjet, and increases in total mandibular length in all groups. A real increase in horizontal chin projection was, however, seen only in mesofacial and brachyfacial subjects. In general, rotational facial changes during treatment were minimal, so that dolichofacial patterns remained long and brachyfacial patterns remained short.
*Conclusion:* The results support previous reports that combined Herbst and fixed appliance treatment is likely to be associated with considerable Class II dental correction in many cases. Although there is likely to be a wide range of individual response to the use of the Herbst appliance, it is unlikely that such overall treatment will be associated with clinically significant forward mandibular rotation in dolichofacial subjects.


## 1. Introduction

The Herbst appliance is commonly used as a fixed Class II corrector in contemporary orthodontic practice. As with all forms of functional appliance, a greater chance of successful Class II correction has been associated with cases in which a favorable direction of growth is expected. As a result, the use of the Herbst appliance has often been restricted to those with average to decreased vertical facial dimensions, in whom increases in the vertical dimension would not be detrimental to facial appearance. In a number of previous studies examining the effect of this appliance on the vertical dimension, no predictable rotational response has been found for patients with extremes of vertical facial pattern [1–9]. In two recent studies, however, it was shown that during Herbst treatment, short faces generally remain short and long faces generally remain long [10,11].

Only a few previous studies have addressed Herbst treatment combined with a follow-up fixed appliance phase [12–14] and none have directly addressed rotational effects in subjects with different underlying vertical facial patterns. With this in mind, the present study was undertaken to confirm the generally accepted anteroposterior dental and skeletal changes occurring during overall Class II Division 1 treatment with the Herbst appliance and contemporary fixed appliances, and then to focus on the range of vertical and rotational effects.

## 2. Materials and methods

### 2.1. Sample

Approval for this study of patient records was first obtained from the Melbourne Dental School Human Ethics Advisory Group and Dental Health Services Victoria. All patients had been treated by one

Funding: This work was supported in part by a grant from the Australian Society of Orthodontists' Foundation for Research and Education.
Competing interests: Authors have completed and submitted the ICMJE Form for Disclosure of potential conflicts of interest. None declared.
Provenance and peer review: Non-commissioned and externally peer reviewed.
* Corresponding author: 549 Dandenong Road, Malvern, Victoria 3144, Australia.
*E-mail address:* michaelgwoods55@gmail.com (M.G. Woods).

2212-4438/$ – see front matter © 2019 World Federation of Orthodontists.
https://doi.org/10.1016/j.ejwf.2019.01.003

**Table 1**
Age, CVMS, and Duration of Herbst phase (months)

| | n | Age at Herbst commencement | | | | | CVMS at Herbst commencement | | | | | Duration of active Herbst phase | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif |
| Total sample | 115 | 143.68 | 22.56 | 96.00 | 186.00 | N.S. | 3.00 | 1.07 | 1.00 | 5.00 | N.S. | 8.67 | 0.93 | 7 | 13 | N.S. |
| Brachyfacial | 37 | 144.09 | 26.69 | 96.00 | 184.00 | N.S. | 3.18 | 1.40 | 1.00 | 5.00 | N.S. | 8.54 | 0.81 | 7 | 11 | N.S. |
| Mesofacial | 49 | 142.84 | 18.51 | 113.00 | 173.00 | N.S. | 3.11 | 1.05 | 1.00 | 5.00 | N.S. | 8.66 | 0.88 | 8 | 12 | N.S. |
| Dolichofacial | 29 | 144.73 | 26.55 | 99.00 | 186.00 | N.S. | 2.64 | 0.67 | 2.00 | 4.00 | N.S. | 8.79 | 1.14 | 8 | 13 | N.S. |

CVMS, cervical vertebrae maturational staging; Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation

specialist orthodontist, with a well-known interest in Herbst treatment. All available patients treated with Herbst/fixed appliances with complete sets of hard copy lateral cephalograms were included and the sample consisted of 115 adolescent Class II Division 1 patients. Once the number of available patients was known, the authors reflected on the appropriate sample sizes [14] that might ensure that the results of this retrospective assessment would be meaningful. It was decided that these samples were in fact large enough for the comparisons of the means and ranges being proposed. Skeletal maturity, rather than age or gender, was used as the basis for comparison in this study. The skeletal maturity of each patient was assessed using the cervical vertebrae maturational staging (CVMS) method, as described by Baccetti et al. [15]. Most patients were assessed as being in CVMS stage 3, approaching the peak of mandibular growth (Tables 1 and 2). At the completion of overall treatment, most patients were then classified as being 2 years or more past the maximum mandibular growth spurt, with an average CVMS of 5.6.

Treatment duration for the Herbst appliance phase averaged 9 months, followed then by an average 19-month fixed appliance phase. The Herbst appliance phase was commonly followed by a period of observation, with an average total treatment time then extending to more than 3.5 years (Tables 1 and 2). Inclusion criteria for this study were bilateral Class II molar relationships, each greater than 5 mm. All subjects were classified as Class II Division 1, defined from a preliminary clinical cephalometric analysis as when the upper incisal angulation was greater than, or equal to, 18 degrees to the nasion point A (N-A) line [15,16].

The stainless steel crown lower-cantilever version of the Herbst appliance used for the treatment of patients in this sample has previously been described [10,11]. During the detailing phase, all patients were treated with the same 0.022 × 0.028-inch slot preadjusted fixed appliances. As in most Class II cases, various elastics and adjunctive mechanics would have been used to help maintain the Herbst correction during the fixed appliance phase.

### 2.2. Cephalometric analysis

The total sample was first divided into three vertical groups based on the mandibular plane angle (FMP), measured in a preliminary standard clinical cephalometric analysis of each subject. The total sample then included 37 brachyfacial (FMP <23°), 49 mesofacial (FMP 23–29°) and 29 dolichofacial (FMP >29°) individuals. Simply reflecting the selection criteria, baseline differences in mandibular plane angle were determined to be statistically significant among these groups ($P = 0.00$). Pretreatment incisal overbite and overjet were also recorded. Pretreatment, post-Herbst, and post-fixed appliance cephalograms were used to provide measurements for the calculation of dental and skeletal changes in the total sample and in each of the three vertical facial groups.

All radiographs had been taken using the same calibrated cephalostat (enlargement factor 9.2%) and were traced by hand before digitization. The pterygomaxillary (PM) line through sphenoethmoidal was used to provide a consistent plane of reference for the evaluation of anteroposterior changes at pogonion [17–19]. All cephalograms were digitized using the Westcef analysis program (customised for the University of Melbourne by Mr Geoffrey West), which automatically orients the digitized image so that the pterygomaxillary line becomes vertical. Horizontal differences were then calculated relative to the X coordinates of this axis. Measurements were made by a single operator (E.D.) over several weeks and then separately assessed for reliability. Measurements were then entered directly into an Excel spreadsheet for further statistical analysis. Distances in millimeters were multiplied by a factor of 0.92 to correct for enlargement. Measurements for changes in effective horizontal mandibular expression (Pog' to Pog) were compared with those in untreated brachyfacial, mesofacial, and dolichofacial subjects, as presented previously [19].

### 2.3. Error study and the assessment of data

To evaluate tracing and measurement error, the cephalograms of 20 patients were retraced and measured 6 weeks later. From the results of the paired *t* test at the 95% level, the differences between the first and second measurements were determined to be insignificant. A one-way analysis of variance was used to determine significant differences in means for the total sample containing the three vertical groups. The IBM-SPSS, Version 24, package (IBM, Armonk, NY) was used for all statistical calculations. Further statistical testing of the three vertical facial types and their relationships with the pretreatment incisal overbite, incisal overjet, and CVMS was undertaken using a multivariate analysis of variance. Keeping in mind the focus of the assessment being on the range of likely rotational effects, rather than on complex statistical

**Table 2**
CVMS and Duration of fixed appliance phase (months)

| | n | CVMS at commencement of fixed appliance phase | | | | | Duration of fixed appliance phase | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif |
| Total sample | 115 | 4.34 | 1.04 | 2.00 | 6.00 | N.S. | 19.05 | 4.10 | 6.00 | 30.00 | N.S. |
| Brachyfacial | 37 | 4.73 | 0.90 | 3.00 | 6.00 | N.S. | 18.55 | 5.92 | 6.00 | 30.00 | N.S. |
| Mesofacial | 49 | 4.21 | 0.98 | 3.00 | 6.00 | N.S. | 19.11 | 3.45 | 13.00 | 26.00 | N.S. |
| Dolichofacial | 29 | 4.18 | 1.25 | 2.00 | 6.00 | N.S. | 19.45 | 3.21 | 14.00 | 24.00 | N.S. |

CVMS, cervical vertebrae maturational staging; Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation

**Table 3**
Changes in ANB angle (degrees)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 5.76 | 2.23 | 1.03 | 10.25 | N.S. | 4.33 | 1.87 | −0.38 | 7.66 | N.S. | 4.47 | 2.54 | −3.75 | 8.77 | N.S. | −1.29 | 2.29 | N.S. |
| Brachyfacial | 37 | 5.89 | 2.02 | 1.87 | 8.36 | N.S. | 4.37 | 1.98 | 1.10 | 7.62 | N.S. | 3.98 | 2.49 | −1.15 | 8.10 | N.S. | −1.91 | 2.63 | N.S. |
| Mesofacial | 49 | 5.20 | 2.39 | 1.03 | 9.26 | N.S. | 3.76 | 1.72 | −0.38 | 6.56 | N.S. | 4.21 | 2.73 | −3.75 | 8.48 | N.S. | −0.99 | 2.00 | N.S. |
| Dolichofacial | 29 | 6.60 | 2.04 | 2.35 | 10.25 | N.S. | 5.27 | 1.80 | 2.47 | 7.66 | N.S. | 5.40 | 2.17 | 2.50 | 8.77 | N.S. | −1.20 | 2.50 | N.S. |

ANB, A point, nasion, B point; Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation

interrelationships, it was considered to be most important to focus on the raw data within each group.

## 3. Results

Pretreatment, post-Herbst, and post-fixed appliance measurements, and changes in all measurements, are detailed in the tables. There was considerable individual variation for all measurements within each of the vertical pattern groups. There were reductions in mean ANB (A point, nasion, B point) angles within all groups during overall treatment, but all were still reflective of a mild Class II relationship (Table 3); reductions in mean incisal overjets during overall treatment, with greater reductions occurring during the Herbst phase (Table 4); anterior movements in mean lower incisor angulations, and at debond, the dolichofacial mean was significantly less than those for the other two vertical groups (Table 5); increases in mean mandibular lengths for all groups during overall treatment (Table 6); general increases in Pog' to Pog in all groups during overall treatment, with dolichofacial values generally being less than for the other groups, which reflects less horizontal expression of the chin in dolichofacial subjects (Table 7); similar changes in mean facial axes for all groups during overall treatment, at all stages, the means reflected the original vertical pattern groups (Table 8); and little change in the mean mandibular plane angles for all three groups. After overall treatment, the mean mandibular plane angles still reflected distinctly different brachyfacial and dolichofacial groups (Table 9).

For the total sample, significant correlations were found, as expected, between overall treatment changes in incisal overjet and the pretreatment overjet; and overall increases in mandibular length and pretreatment CVMS.

## 4. Discussion

### 4.1. Limitations

To control the limitations of this study of clinical records, efforts were made to gather as homogeneous a Class II Division 1 sample as possible, treated by one clinician with very similar versions of the Herbst appliance. As with any retrospective study, this sample was dependant on the availability and accuracy of the records. It is difficult to account for those patients who did not complete treatment. It is possible that it may have been more likely for complete records to have been taken after successful treatment. The chosen sample was divided into significantly different vertical groups based on the mandibular plane angle. During cephalometric analysis, all efforts were made to eliminate error in landmark location and measurement [20]. Although some might consider it important to undertake all clinical studies on a prospective basis, including a discrete contemporary control group, the control group was not considered to be absolutely necessary in this case, because the main focus was simply to assess whether or not it is likely for mandibles to undergo sufficient rotation for there to be a major change in the description of the vertical pattern after this type of treatment.

### 4.2. Class II dentoalveolar correction: ANB

The current results would support those of previous studies, in that Herbst appliance treatment, followed by a phase of fixed appliances, may be an efficient method of Class II dentoalveolar correction in many cases. In this sample, on average, molars were corrected to at least a Class I relationship with ideal incisal overbite and overjet at the end of overall treatment. However, despite the overall improvement in ANB angulation in all vertical groups, most would still be considered Class II at the end of treatment, when compared with accepted cephalometric norms for Class I subjects. Close examination of the results shows that most of the reduction in ANB angulation occurred in all groups during the Herbst appliance phase, while, on average, the ANB angulation seemed to increase a little during the fixed appliance phase. Because equivalent increases in mandibular length were found in all groups, this apparent reversal of the Class II correction in some cases may well be attributed to a combination of the extrusive effects of fixed appliances and some continued vertical facial development or rebound, especially in the dolichofacial group.

### 4.3. Changes in lower incisor angulation

Changes in lower incisor angulation found in this study are similar to those that have been described previously [2,4,12]. The changes largely occurred during the Herbst appliance phase, with an average proclination of 4.5 degrees. On average, there was only minimal further proclination of the lower incisors during the fixed

**Table 4**
Changes in incisal overjet (mm)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 8.77 | 3.46 | 4.84 | 14.00 | N.S. | 3.38 | 2.07 | 0.00 | 9.00 | N.S. | 2.17 | 1.09 | 0.00 | 6.00 | N.S. | −5.12 | 3.55 | N.S. |
| Brachyfacial | 37 | 9.44 | 3.88 | 5.24 | 12.20 | N.S. | 2.41 | 1.53 | 0.00 | 5.00 | N.S. | 1.91 | 0.94 | 0.00 | 3.00 | N.S. | −3.73 | 4.15 | N.S. |
| Mesofacial | 49 | 8.79 | 2.75 | 5.82 | 13.88 | N.S. | 3.74 | 2.35 | 1.00 | 9.00 | N.S. | 2.32 | 1.34 | 1.00 | 6.00 | N.S. | −5.47 | 3.26 | N.S. |
| Dolichofacial | 29 | 8.09 | 2.19 | 4.84 | 14.00 | N.S. | 3.73 | 1.85 | 2.00 | 7.00 | N.S. | 2.18 | 0.75 | 1.00 | 4.00 | N.S. | −5.91 | 3.33 | N.S. |

Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation

**Table 5**
Changes in lower incisor angulation to mandibular plane (degrees)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 97.88 | 7.02 | 84.03 | 113.05 | N.S. | 102.37 | 7.38 | 89.01 | 115.18 | N.S. | 102.81 | 6.72 | 89.24 | 118.27 | [a] | 4.93 | 7.62 | N.S. |
| Brachyfacial | 37 | 97.90 | 6.77 | 85.07 | 106.77 | N.S. | 104.73 | 7.97 | 90.79 | 115.18 | N.S. | 106.64 | 6.57 | 100.67 | 118.27 | N.S. | 8.75 | 5.63 | N.S. |
| Mesofacial | 49 | 98.84 | 8.04 | 84.03 | 113.05 | N.S. | 102.45 | 6.50 | 91.85 | 112.20 | N.S. | 103.56 | 4.62 | 96.86 | 113.43 | N.S. | 4.72 | 9.13 | N.S. |
| Dolichofacial | 29 | 96.20 | 5.48 | 89.42 | 106.93 | N.S. | 99.89 | 8.09 | 89.01 | 114.13 | N.S. | 97.67 | 7.27 | 89.24 | 111.17 | [b] | 1.47 | 4.59 | N.S. |

Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation; Signif, analysis of variance, significant differences in means.
[a] $P \leq 0.05$.
[b] $P \leq 0.05$, significant difference in vertical pattern subgroup.

**Table 6**
Changes in mandibular length (Co-Gn) (mm)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 112.58 | 5.97 | 101.14 | 127.22 | N.S. | 116.61 | 6.21 | 102.79 | 129.74 | N.S. | 119.26 | 6.58 | 106.29 | 131.06 | N.S. | 6.68 | 5.79 | N.S. |
| Brachyfacial | 37 | 114.82 | 6.58 | 105.52 | 123.44 | N.S. | 119.94 | 6.03 | 110.35 | 127.06 | N.S. | 119.87 | 6.54 | 109.45 | 128.35 | N.S. | 5.05 | 5.44 | N.S. |
| Mesofacial | 49 | 113.08 | 5.53 | 101.14 | 127.22 | N.S. | 116.43 | 6.51 | 102.79 | 129.74 | N.S. | 119.84 | 6.04 | 106.62 | 129.57 | N.S. | 6.76 | 6.17 | N.S. |
| Dolichofacial | 29 | 109.49 | 5.27 | 102.10 | 119.79 | N.S. | 113.58 | 4.39 | 108.14 | 123.53 | N.S. | 117.66 | 7.80 | 106.29 | 131.06 | N.S. | 8.17 | 5.54 | N.S. |

Co-Gn, condylion-gnathion; Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation

appliance phase. A significant association was found between the vertical facial pattern and the amount of lower incisor proclination occurring during treatment, with less proclination occurring in the dolichofacial group. This is consistent with the results of previous studies that have highlighted such a relationship between proclination and vertical facial type, with the orofacial musculature in brachyfacial patients seeming to be more tolerant of proclined lower incisors than that in dolichofacial patients, and the lower incisors perhaps remaining more upright on basal bone as any further clockwise mandibular rotation occurs [21–24].

### 4.4. Changes in mandibular length

Average increases in mandibular length (Co-Gn [condylion-gnathion]) found during the Herbst appliance phase in this study were consistent with those previously reported and greater than might have been expected in untreated cases over the same approximately 9-month period [25–29]. It must be remembered, however, that such increases in mandibular length do not necessarily lead to increases in horizontal chin projection, especially in dolichofacial subjects. In such cases, increases in mandibular length may be expressed more vertically without significant increases in chin prominence.

The fact that there seemed to be less overall horizontal chin projection in the dolichofacial subgroup at each stage is important. This would support the conclusions of previous authors [13,14] that it is unlikely for a dolichofacial, retrognathic mandible to grow, or rotate forward significantly, with the use of any functional appliance. In these cases, it is also unlikely that significant extra mandibular growth, beyond that which would normally be expected, will accompany combined Class II correction with the Herbst appliance and fixed appliances.

### 4.5. Facial axis and mandibular plane angle changes: rotations

It is interesting to note that only small average changes were found for both facial axis and mandibular plane angles during the Herbst appliance phase, with the rotational changes seen in response to treatment being similar to those previously reported [4,30,31]. During the fixed appliance phase, a slight average decrease in the facial axis angulation occurred. Similarly, small opening rotations were seen in the mandibular plane angle. Once again, although there was considerable individual variation, there was no real evidence of clinically significant forward rotational changes occurring in dolichofacial patients, to the extent that their individual vertical pattern descriptions might be changed.

It has been reported previously that any opening rotation during the fixed appliance phase is likely to be the result of molar extrusion exceeding the amount of posterior facial growth. Even small opening rotations may complicate management of an anteroposterior discrepancy by accentuating the Class II profile and increasing both the incisal overjet and the amount of dentoalveolar compensation required to achieve a detailed occlusion [30–32].

Regardless of the underlying vertical pattern, it would be of interest to examine whether vertical and rotational changes occurring during treatment somehow revert toward the original pattern in the long-term [22,32–34]. It must be pointed out again that there was a wide range of individual variation for all study

**Table 7**
Changes in Pog' to Pog (mm)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 53.03 | 6.13 | 40.62 | 64.32 | N.S. | 55.52 | 7.29 | 39.39 | 69.48 | N.S. | 56.49 | 7.71 | 39.11 | 69.79 | N.S. | 3.46 | 5.96 | N.S. |
| Brachyfacial | 37 | 54.18 | 6.21 | 47.25 | 64.32 | N.S. | 57.13 | 8.29 | 44.76 | 69.48 | N.S. | 57.92 | 7.32 | 45.99 | 69.79 | N.S. | 3.73 | 6.81 | N.S. |
| Mesofacial | 49 | 53.85 | 5.91 | 45.15 | 63.56 | N.S. | 56.46 | 5.17 | 46.19 | 67.88 | N.S. | 58.43 | 5.97 | 43.19 | 69.51 | N.S. | 4.58 | 5.55 | N.S. |
| Dolichofacial | 29 | 50.47 | 6.25 | 40.62 | 60.34 | N.S. | 52.27 | 8.92 | 39.39 | 68.27 | N.S. | 51.71 | 9.25 | 39.11 | 65.45 | N.S. | 1.24 | 5.69 | N.S. |

Max, maximum value; Min, minimum value; N.S., not significant; Pog, pogonion; SD, standard deviation

**Table 8**
Changes in facial axis angle (degrees)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 88.21 | 4.85 | 78.23 | 100.16 | [a] | 88.18 | 4.83 | 74.91 | 102.85 | [a] | 87.01 | 5.10 | 75.55 | 101.74 | [a] | −1.20 | 3.10 | N.S. |
| Brachyfacial | 37 | 92.02 | 3.84 | 86.18 | 100.16 | [b] | 90.28 | 4.83 | 84.91 | 102.85 | [b] | 89.82 | 4.85 | 83.71 | 101.74 | [b] | −2.20 | 2.10 | N.S. |
| Mesofacial | 49 | 89.28 | 3.14 | 84.78 | 97.48 | [b] | 90.05 | 2.56 | 86.76 | 97.35 | [b] | 88.10 | 3.59 | 83.09 | 98.08 | [b] | −1.18 | 2.57 | N.S. |
| Dolichofacial | 29 | 82.56 | 2.85 | 78.23 | 88.33 | [b] | 82.87 | 3.97 | 74.91 | 89.03 | [b] | 82.31 | 4.70 | 75.55 | 89.74 | [b] | −0.24 | 4.47 | N.S. |

Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation; Signif, analysis of variance, significant differences in means.
[a] $P \leq 0.05$.
[b] $P \leq 0.05$, significant difference in vertical pattern subgroup.

**Table 9**
Changes in mandibular plane angle (degrees)

| | n | Pretreatment | | | | | After Herbst | | | | | After fixed appliances | | | | | Overall change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 115 | 25.77 | 5.70 | 12.29 | 38.60 | [a] | 25.91 | 6.06 | 12.44 | 40.16 | [a] | 26.43 | 6.16 | 12.11 | 41.44 | [a] | 0.66 | 3.53 | N.S. |
| Brachyfacial | 37 | 19.40 | 2.93 | 12.29 | 22.88 | [b] | 20.85 | 4.14 | 12.44 | 29.05 | [b] | 21.43 | 4.59 | 12.11 | 27.13 | [b] | 2.03 | 2.50 | N.S. |
| Mesofacial | 49 | 25.29 | 2.16 | 23.35 | 28.87 | [b] | 24.42 | 2.76 | 18.17 | 30.46 | [b] | 25.74 | 2.78 | 21.29 | 31.03 | [b] | 0.46 | 2.99 | N.S. |
| Dolichofacial | 29 | 32.97 | 3.18 | 29.87 | 38.60 | [b] | 33.55 | 4.43 | 27.21 | 40.16 | [b] | 32.61 | 6.82 | 21.24 | 41.44 | [b] | −0.35 | 4.92 | N.S. |

Max, maximum value; Min, minimum value; N.S., not significant; SD, standard deviation; Signif, analysis of variance, significant differences in means.
[a] $P \leq 0.05$.
[b] $P \leq 0.05$, significant difference in vertical pattern subgroup.

measurements. This may be partly explained by the fact that Class II malocclusions can occur in such a wide range of dental, skeletal, and muscular configurations.

### 4.6. Clinical relevance

Based on the findings of this study, claims that the vertical facial pattern or direction of facial growth of an individual can be reliably altered with combined Herbst and fixed appliance treatment could not be supported. In planning long-term treatment for a young patient with Class II Division 1, it should not be expected that a significant underlying vertical pattern, whether long- or short-faced, can be changed in the long-term. This does not mean that fine occlusal results and considerable positive facial change cannot be achieved in many patients. It does mean, however, that, when confronted with a significant dolichofacial or brachyfacial pattern, there should be an expectation that, short of orthognathic surgery, the face will always be long or short, no matter what treatment devices are used. It does seem then that, if it is desired that the projected eventual mature face is to fall within normal vertical skeletal limits, without excessive hard and soft tissue convexity and lip strain, consideration may still have to be given to eventual routine orthognathic surgical correction [35–37].

## 5. Conclusions

Taking into account the limitations outlined previously, the following conclusions may be drawn:

1. Combined treatment with the Herbst appliance and fixed appliances in rapidly growing subjects is likely to result in reduction of the ANB angle and correction of Class II molar and Division 1 incisal relationships in many cases. Most of any ANB angle change is likely to occur during the Herbst phase.
2. Such treatment is likely to be accompanied by significant changes in lower incisor angulation.
3. It is likely to be accompanied by significant increases in absolute mandibular length, with greater increases in length more likely to be found in subjects with greater CVMS expectations of future growth.
4. It is likely to be accompanied by significant increases in horizontal chin projection, with greater projection more likely to occur in subjects with more brachyfacial patterns.
5. It is likely to be accompanied by only small changes in mandibular plane and facial axis angles. In fact, a reasonable expectation would be that brachyfacial faces will remain short and dolichofacial faces will remain long. There is little likelihood that there will be clinically significant forward autorotation in dolichofacial subjects.
6. Considerable individual variation is likely to be seen with all these changes.

## Acknowledgments

The authors thank Dr Paul Buchholz for providing all case records used in this study and Mr Geoffrey West for providing and modifying his Westcef analysis program. The authors also thank Professor Ian Gordon, Department of Mathematics and Statistics, University of Melbourne, for his help with the statistical management of the data. This work was supported in part by a grant from the Australian Society of Orthodontists' Foundation for Research and Education.

## References

[1] Lai M. Molar distalization with the Herbst appliance. Semin Orthod 2000;6:119–28.
[2] McNamara J, Howe R, Dischinger T. A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion. Am J Orthod Dentofacial Orthop 1990;98:134–44.
[3] Pancherz H. Vertical dentofacial changes during Herbst appliance treatment. A cephalometric investigation. Swed Dent J Suppl 1982;15:189–96.
[4] Pancherz H. The Herbst appliance: its biologic effects and clinical use. Am J Orthod 1985;87:1–20.
[5] Pancherz H, Anehus-Pancherz M. The headgear effect of the Herbst appliance: a cephalometric long-term study. Am J Orthod Dentofacial Orthop 1993;103:510–20.
[6] Pancherz H, Michailidou C. Temporomandibular joint growth changes in hyperdivergent and hypodivergent Herbst subjects. A long-term roentgenographic cephalometric study. Am J Orthod Dentofacial Orthop 2004;126:153–61.
[7] Ruf S, Pancherz H. The effect of Herbst appliance treatment on the mandibular plane angle: a cephalometric roentgenographic study. Am J Orthod Dentofacial Orthop 1996;110:225–9.
[8] Schiavoni R, Grenga V, Macri V. Treatment of Class II high angle malocclusions with the Herbst appliance: a cephalometric investigation. Am J Orthod Dentofacial Orthop 1992;102:393–409.

[9] Wieslander L. Intensive treatment of severe Class II malocclusions with a headgear-Herbst appliance in the early mixed dentition. Am J Orthod 1984;86:1–13.
[10] Deen E, Woods MG. Effects of the Herbst appliance in growing orthodontic patients with different underlying vertical patterns. Aust Orthod J 2015;31:59–68.
[11] Turnock C, Woods MG. The Herbst appliance and the Activator: influence of the vertical facial pattern. Aust Orthod J 2016;32:23–31.
[12] Burkhardt DR, McNamara Jr JA, Baccetti T. Maxillary molar distalization or mandibular enhancement: a cephalometric comparison of comprehensive orthodontic treatment including the pendulum and the Herbst appliances. Am J Orthod Dentofacial Orthop 2003;123:108–16.
[13] Schaefer AT, McNamara JA, Franchi L, Baccetti T. A cephalometric comparison of treatment with the Twin-block and stainless steel crown Herbst appliances followed by fixed appliance therapy. Am J Orthod Dentofacial Orthop 2004;126:7–15.
[14] Pandis N, Polychronopoulou A, Eliades T. Sample size estimation: an overview with application to orthodontic clinical trial design. Am J Orthod Dentofacial Orthop 2011;140:e141–6.
[15] Baccetti T, Franchi L, McNamara Jr JA. An improved version of the Cervical Vertebral Maturation (CVM) method for the assessment of mandibular growth. Angle Orthod 2002;72:316–23.
[16] von Bremen J, Pancherz H. Efficiency of early and late Class II Division 1 treatment. Am J Orthod Dentofacial Orthop 2002;121:31–7.
[17] Nanda RS, Ghosh J. Longitudinal growth changes in the sagittal relationship of maxilla and mandible. Am J Orthod Dentofacial Orthop 1995;107:79–90.
[18] Shearn BN, Woods MG. An occlusal and cephalometric analysis of lower first and second premolar extraction effects. Am J Orthod Dentofacial Orthop 2000;117:351–61.
[19] Woods MG. Sagittal mandibular changes with overbite correction in subjects with different mandibular growth directions: Late mixed-dentition treatment effects. Am J Orthod Dentofacial Orthop 2008;133:388–94.
[20] Vincent AM, West VC. Cephalometric landmark identification error. Aust Orthod J 1987;10:98–104.
[21] Bishara SE, Jakobsen JR. Longitudinal changes in three normal facial types. Am J Orthod 1985;88:466–502.
[22] Ricketts RM. The influence of orthodontic treatment on facial growth and development. Angle Orthod 1960;30:103–33.
[23] Schudy FF. The rotation of the mandible resulting from growth: it's implications in orthodontic treatment. Angle Orthod 1965;35:36–50.
[24] Tweed CH. The diagnostic facial triangle in the control of treatment objectives. Am J Orthod 1969;55:651–7.
[25] DeVincenzo JP. Changes in mandibular length before, during, and after successful orthopedic correction of Class II malocclusions, using a functional appliance. Am J Orthod Dentofacial Orthop 1991;99:241–57.
[26] Pancherz H, Hägg U. Dentofacial orthopedics in relation to somatic maturation. An analysis of 70 consecutive cases treated with the Herbst appliance. Am J Orthod 1985;88:273–87.
[27] Malmgren O, Omblus J, Hägg U, Pancherz H. Treatment with an orthopedic appliance system in relation to treatment intensity and growth periods. A study of initial effects. Am J Orthod Dentofacial Orthop 1987;91:143–51.
[28] Riolo ML. An Atlas of craniofacial growth: cephalometric standards from the University School Growth Study, the University of Michigan. Ann Arbor: Center for Human Growth and Development, University of Michigan; 1974.
[29] Creekmore TD. Inhibition or stimulation of the vertical growth of the facial complex, its significance to treatment. Angle Orthod 1967;37:285–97.
[30] Deberardinis M, Stretesky T, Sinha P, Nanda RS. Evaluation of the vertical holding appliance in treatment of high-angle patients. Am J Orthod Dentofacial Orthop 2000;117:700–5.
[31] Isaacson RJ, Zapfel RJ, Worms FW, Bevis RR, Speidel TM. Some effects of mandibular growth on the dental occlusion and profile. Angle Orthod 1977;47:97–106.
[32] Schudy FF. Vertical growth versus anteroposterior growth as related to function and treatment. Angle Orthod 1964;34:75–93.
[33] Baccetti T, Antonini A, Franchi L, Tonti M, Tollaro I. Glenoid fossa position in different facial types: a cephalometric study. Br J Orthod 1997;24:55–9.
[34] Woods MG. The mandibular muscles in contemporary orthodontic practice: a review. Aust Dent J 2017;62:78–85.
[35] Bell WH, Creekmore TD, Alexander RG. Surgical correction of the long face syndrome. Am J Orthod 1977;71:40–67.
[36] Woods MG, Swift JQ, Markowitz NR. Clinical implications of advances in orthognathic surgery. J Clin Orthod 1989;23:420–9.
[37] Woods MG, Wiesenfeld D. A practical approach to presurgical orthodontic preparation. J Clin Orthod 1998;32:350–8.