Effects of the Herbst appliance in growing orthodontic patients with different underlying vertical patterns

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Introduction: The present study involved an assessment of the effects of the Herbst appliance used for Class II correction in subjects with different vertical facial patterns.

Methods: Pre- and post-treatment lateral cephalograms of 91 growing Class II patients were divided into three vertical facial groups on the basis of mandibular plane angulation. All received a Herbst appliance and dental and skeletal changes were assessed in relation to pretreatment incisal overbite, overjet and the stage of cervical maturity.

Results: Herbst appliance treatment was accompanied by changes in the angulation of the upper and lower incisors, overjet reduction and an increase in mandibular length. In general, the rotational facial changes occurring during treatment were minimal, so that dolichofacial patterns remained long and brachyfacial patterns remained short.

Conclusion: Herbst appliance treatment can be expected to result in considerable Class II dental correction. It is unlikely, however, that its use will be associated with clinically significant forward rotation in dolichofacial subjects. Since dolichofacial patterns are likely to remain long-faced, even after considerable Class II dental correction, orthognathic surgery may still be a consideration if normal facial proportions, without excessive facial convexity and lip strain, are treatment aims.

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Introduction

The Herbst appliance is commonly used in contemporary practice for the correction of Class II malocclusions, with treatment achieving a combination of dental and skeletal changes. A significant proportion of the Class II correction has been shown to occur through the effect of the appliance on the dentition, as a forward movement of the lower teeth. In addition, the Herbst appliance has previously been reported to produce a considerable increase in mandibular length when compared with untreated controls. Harmonisation of the facial profile through forward movement of the bony chin is also commonly claimed.[1-8]

While the focus of most published work on Class II treatment with the Herbst appliance has been on the sagittal dimension, its effect on the vertical dimension has also been studied.[9-12] An observed effect of the stainless steel crown version of the Herbst appliance has been the tipping and intrusion of the maxillary molars.[11,13-15] As a result, it has been proposed that the appliance produces a forward autorotation of the mandible which enhances a Class II correction.[14,16] Forward autorotation following Herbst appliance treatment has been reported in a case study by Hägg[17] and in a larger sample by Burkhardt.[1] The result of these findings has created speculation that the Herbst appliance may be useful, not only in the correction of Class II malocclusions in mesofacial and brachyfacial subjects, but also in dolichofacial subjects with and without open bites.[6,18] While this is a promising concept, there have been no reports in the literature which have compared the potential selective forward or backward rotation of the mandible in dolichofacial
and brachyfacial subjects. The present study was therefore designed to assess the anteroposterior and vertical dental and skeletal changes occurring during Herbst appliance treatment in subjects with differing vertical facial patterns.

Materials and methods

Sample

The sample was sourced from the office of a specialist orthodontist and identified by item codes entered on the day of Herbst appliance insertion. All patients were initially included, with cases selected on the basis of a complete and acceptable set of hard copy lateral cephalograms. The sample consisted of 91 adolescent patients treated with a variant of the Herbst appliance for the correction of Class II malocclusions. The sample was divided on the basis of vertical facial pattern determined by the mandibular plane angulation (FMP). The sample therefore included 26 brachyfacial (FMP < 23°), 41 mesofacial (FMP 23–29°) and 24 dolichofacial (FMP > 29°) individuals. The baseline difference between these groups was determined to be statistically significant ($p = 0.00$). Pretreatment incisal overbite and overjet were recorded. The skeletal maturity of each patient was also assessed and recorded using the cervical maturational staging (CVMS) method as described by Baccetti et al.\textsuperscript{19} Skeletal maturity, rather than age or gender, was used as a basis for comparison in the present study for mandibular growth response. The average stage of maturity within the total treatment sample was CVMS 3 (entering the peak of mandibular growth). A retrospective study is dependent on the availability and accuracy of the records and so it is likely that there are additional patients who did not complete treatment. It is further possible that there may have been bias towards completed records in successful cases.

Pretreatment and post-Herbst appliance lateral cephalograms were measured to determine the dental and skeletal changes that occurred in the total sample and for each of the three vertical groups. The average duration of the Herbst appliance treatment was approximately nine months. The aim of Herbst treatment was to provide an over-corrected Class I molar relationship, if possible.

The inclusion criteria for the sample were bilateral Class II molar relationships, each greater than 4mm (inclusive of both division 1 and division 2 incisal variants). Division 1 was defined by an upper incisor angulation to the N-A line greater than, or equal to, 18 degrees. The sample was almost exclusively comprised of Class II division 1 subjects, with the exception of the brachyfacial group, which contained three Class II division 2 subjects.

The version of the Herbst appliance used consisted of stainless steel crowns fitted to the upper and lower first permanent molars. A cantilevered arm extended forward from the lower first molar to the level of the lower first premolar. A closely-adapted 0.040 inch stainless steel lingual arch connected the left and right lower molars and, in some cases, incorporated an occlusal rest on the lower first premolar or second deciduous molar. A Hyrax expansion screw was incorporated, where necessary, to expand the maxillary arch to accommodate the potential advanced position of the lower arch. Where the incisal relationship did not permit the required advancement, as in the Class II division 2 subjects, activated palatal finger-springs were incorporated into the design to procline the upper incisors.

Cephalometric analysis

All radiographs had been taken using the same calibrated cephalostat (enlargement factor 9.2%) and were traced by hand before digitisation. The pterygomaxillary (PM) line through sphenoethmoidale was used to provide a consistent plane of reference for the evaluation of antero-posterior changes at pogonion. This method has been previously described.\textsuperscript{20-23} The cephalometric measurements analysed in the present study are listed in Table I. Cephalograms were digitised using the Westcef analysis program, which automatically orients the digitised image so that the pterygomaxillary (PM) line is vertically aligned. Horizontal differences were calculated relative to the X coordinates of this axis. Measurements were made by one operator (E.D.) and repeated to assess reliability. Measurements were 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.

Error study and the assessment of data

In order to evaluate tracing and measurement error, the cephalograms of 14 patients were traced six weeks apart. 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 (Table II). A one-way analysis of variance (ANOVA) was used to determine significant differences in the means for the total sample and the three vertical groups. Further statistical testing of the treatment changes in the three vertical facial groups and their relationships with the pretreatment incisal overbite, incisal overjet and CVMS was performed using a multi-variate analysis of variance. For interest only, the rates of change in Pog’ to Pog and mandibular length were compared with previously-reported rates of change in 96 untreated dolichofacial, mesofacial and brachyfacial growing subjects from the same population and source.

Results
There was considerable individual variation for all measurements, taken before and after Herbst treatment, in all three vertical groups.

The pretreatment and post-Herbst appliance measurements and changes in their values for the ANB angle are presented in Table IV. It is evident that the average ANB angle for the dolichofacial group was significantly greater, before and after the Herbst appliance phase. Following the Herbst treatment, there was a comparable average reduction in the ANB angle for all groups. However, all group means still reflected mild Class II relationships.

The data related to incisal overjet are presented in Table V. A reduction in overjet occurred in all vertical groups, without obvious inter-group differences identified. The data for the angulation of the upper incisors to A-Pog are presented in Table VI. The pretreatment and post-Herbst appliance angulations were, on average, less for those in the brachyfacial group. This possibly reflected the inclusion of three Class II division 2 individuals (prior to proclination) in this group. The average angulation was reduced in all vertical groups during the Herbst appliance phase, without inter-group differences detected.

The data related to mandibular length are presented in Table VIII. No significant differences were found in the pretreatment and post-Herbst appliance averages of the three vertical groups, although there was wide individual variation. Over the average

| Measurement                          | Definition                                                                 |
|--------------------------------------|---------------------------------------------------------------------------|
| Facial axis (°)                      | Postero-inferior angle formed by the intersection of the BaN and Pt-Gn lines |
| Mandibular plane angle (°)           | Angle formed by the intersection of Frankfort horizontal and the gonion–gnathion line |
| ANB (°)                              | Angle formed by the intersection of the NA and NB lines                   |
| Upper incisor angulation to A-Pog (°) | Angle formed by the intersection of the long axis of the upper incisor and the A-Pog line |
| Lower incisor angulation to mandibular plane (°) | Angle between the lower incisor and the gonion–gnathion line |
| Pog’-Pog (mm)                        | Perpendicular distance from pogonion to the PM reference line             |
| Co-Gn (mm)                           | Absolute distance from condylion to gnathion                              |

Table I. Cephalometric measurements used in this study.

| Variable                        | Mean  | SD    | p     | Limits of agreement |
|---------------------------------|-------|-------|-------|---------------------|
| Facial axis angle (°)           | 0.29  | 0.99  | 0.30  | Low -1.70 High 2.27 |
| Mandibular plane angle (°)      | -0.65 | 1.36  | 0.10  | Low -3.37 High 2.07 |
| ANB (°)                         | -0.41 | 1.52  | 0.33  | Low -3.46 High 2.64 |
| Upper incisor to A-Pog (°)      | -0.05 | 1.39  | 0.89  | Low -2.82 High 2.72 |
| Lower incisor to mandibular plane | -0.31 | 1.73  | 0.52  | Low -3.78 High 3.16 |
| Pog’-Pog (mm)                   | 0.74  | 3.12  | 0.39  | Low -5.51 High 6.98 |
| Mandibular length (mm)          | -0.26 | 0.81  | 0.26  | Low -1.87 High 1.36 |

Table II. Error of landmark location and cephalometric measurement.
### Table III. Age at commencement and duration of Herbst treatment (months).

|                          | Chronological age at Herbst commencement | CVM stage at Herbst commencement | Duration of active Herbst treatment |
|--------------------------|-----------------------------------------|----------------------------------|-------------------------------------|
|                          | N  | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Signif |
| Total sample             | 91 | 142.00| 21.10| 96.00| 186.00| NS     | 2.99  | 1.14| 1    | 5    | NS     | 8.66  | 0.93| NS     |
| Brachyfacial             | 26 | 142.65| 22.81| 96.00| 184.00| NS     | 2.69  | 1.26| 1    | 5    | NS     | 8.54  | 0.81| NS     |
| Mesofacial               | 41 | 142.51| 18.83| 113.00| 180.00| NS     | 3.12  | 1.14| 1    | 5    | NS     | 8.66  | 0.88| NS     |
| Dolichofacial            | 24 | 140.42| 23.57| 99.00| 186.00| NS     | 3.08  | 0.97| 1    | 5    | NS     | 8.79  | 1.14| NS     |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

### Table IV. ANB angle (degrees).

|                          | Pretreatment | After Herbst | Change during Herbst treatment |
|--------------------------|--------------|--------------|--------------------------------|
|                          | N  | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Signif |
| Total sample             | 91 | 5.85  | 2.16| 1.03 | 11.67 | *     | 4.30  | 2.03| 0.22 | 11.67 | *     | 1.55  | 1.70| NS     |
| Brachyfacial             | 26 | 5.25  | 1.77| 1.87 | 8.36  | NS    | 3.85  | 2.06| 0.27 | 6.31  | NS    | 1.40  | 1.71| NS     |
| Mesofacial               | 41 | 5.50  | 2.18| 1.03 | 9.26  | NS    | 3.95  | 1.80| 0.22 | 7.11  | NS    | 1.55  | 1.78| NS     |
| Dolichofacial            | 24 | 7.10  | 2.09| 2.35 | 11.67 | **    | 5.37  | 2.08| 2.16 | 11.67 | **    | 1.73  | 1.60| NS     |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = $p \leq 0.05$

** = $p \leq 0.05$, significant difference in vertical pattern subgroup

### Table V. Incisal overjet (mm).

|                          | Pretreatment | After Herbst | Change during Herbst treatment |
|--------------------------|--------------|--------------|--------------------------------|
|                          | N  | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Signif |
| Total sample             | 91 | 7.63  | 3.34| 0.00 | 14.00| NS     | 3.23  | 3.34| 0.00 | 11.00| NS     | 4.40  | 3.24| NS     |
| Brachyfacial             | 26 | 7.23  | 3.67| 0.00 | 13.00| NS     | 3.37  | 3.67| 0.00 | 11.00| NS     | 3.87  | 3.17| NS     |
| Mesofacial               | 41 | 7.46  | 3.27| 0.00 | 14.00| NS     | 2.98  | 3.27| 0.00 | 9.00  | NS     | 4.49  | 3.16| NS     |
| Dolichofacial            | 24 | 8.33  | 3.10| 1.00 | 14.00| NS     | 3.50  | 3.10| 0.00 | 10.00| NS     | 4.83  | 3.50| NS     |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

### Table VI. Upper incisor to APog (degrees).

|                          | Pretreatment | After Herbst | Change during Herbst treatment |
|--------------------------|--------------|--------------|--------------------------------|
|                          | N  | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Min  | Max  | Signif | Mean  | SD  | Signif |
| Total sample             | 91 | 33.30 | 9.12 | 52.70| 2.96  | *      | 29.33 | 3.34| 0.00 | 11.00| *      | 3.97  | 6.32| NS     |
| Brachyfacial             | 26 | 29.10 | 10.68| 47.13| 2.96  | **     | 24.15 | 7.42| 0.00 | 11.00| **     | 3.96  | 7.20| NS     |
| Mesofacial               | 41 | 34.10 | 8.92 | 52.63| 8.98  | NS     | 30.80 | 6.63| 0.00 | 9.00  | NS     | 3.30  | 6.43| NS     |
| Dolichofacial            | 24 | 32.30 | 5.74 | 50.73| 25.02 | NS     | 31.16 | 6.44| 0.00 | 10.00| NS     | 5.14  | 5.10| NS     |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = $p \leq 0.05$

** = $p \leq 0.05$, significant difference in vertical pattern subgroup
duration of treatment of nine months, there was a mean increase in mandibular length of approximately 4 mm. However, this was not significantly different to that which might have been expected in a normal untreated population.\(^{24}\)

Data related to the angulation of the lower incisors to the mandibular plane during Herbst appliance treatment are presented in Table VII. Significant pretreatment and post-Herbst differences existed between the vertical groups, typified by a reduced average lower incisor angulation evident in the dolichofacial group. No significant differences were seen between the groups for changes in the lower incisor angulation during Herbst appliance treatment.

Data related to the distance between Pog’ and Pog are presented in Table IX. There were significant differences between the vertical groups, before and after Herbst appliance treatment. The mean values are further illustrated in Figure 2. The distance, on average, was smaller in the dolichofacial group, which reflected less horizontal expression of the bony chin at both time points. This is consistent with the previously-reported average rates of change in mandibular length in 96 untreated dolichofacial, mesofacial and brachyfacial growing subjects from the same population and source.\(^{24}\)

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**Table VII.** Lower incisor to mandibular plane (degrees).

| Pretreatment | After Herbst | Change during Herbst treatment |
|--------------|-------------|--------------------------------|
| N | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 91 | 97.29 | 7.61 | 74.96 | 122.44 | * | 101.30 | 8.36 | 74.96 | 122.44 | * | 3.98 | 5.59 | NS |
| Brachyfacial | 26 | 98.73 | 7.51 | 74.96 | 109.23 | NS | 103.50 | 9.06 | 74.96 | 119.74 | NS | 4.78 | 6.74 | NS |
| Mesofacial | 41 | 98.21 | 8.27 | 84.03 | 122.44 | NS | 102.30 | 7.38 | 84.03 | 122.44 | NS | 4.13 | 5.22 | NS |
| Dolichofacial | 24 | 94.16 | 5.69 | 81.15 | 106.93 | ** | 97.00 | 7.97 | 78.77 | 114.13 | ** | 2.88 | 4.55 | NS |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = \(p \leq 0.05\)

** = \(p \leq 0.05\), significant difference in vertical pattern subgroup

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**Table VIII.** Mandibular length (Co-Gn) (mm).

| Pretreatment | After Herbst | Change during Herbst treatment |
|--------------|-------------|--------------------------------|
| N | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 91 | 104.10 | 5.57 | 89.39 | 117.62 | NS | 108.10 | 5.54 | 91.16 | 122.66 | NS | 4.02 | 3.92 | NS |
| Brachyfacial | 26 | 105.60 | 5.75 | 97.08 | 117.62 | NS | 109.80 | 9.96 | 99.00 | 122.66 | NS | 4.18 | 3.82 | NS |
| Mesofacial | 41 | 104.30 | 5.11 | 93.05 | 117.04 | NS | 108.10 | 5.25 | 94.89 | 121.72 | NS | 3.82 | 4.61 | NS |
| Dolichofacial | 24 | 102.30 | 5.85 | 89.39 | 113.02 | NS | 106.40 | 5.25 | 91.16 | 118.62 | NS | 4.19 | 2.65 | NS |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = \(p \leq 0.05\)

** = \(p \leq 0.05\), significant difference in vertical pattern subgroup

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**Table IX.** Pog’ to Pog (mm).

| Pretreatment | After Herbst | Change during Herbst treatment |
|--------------|-------------|--------------------------------|
| N | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 91 | 48.85 | 6.18 | 30.43 | 61.11 | * | 51.73 | 6.78 | 31.04 | 69.55 | * | 2.89 | 4.09 | NS |
| Brachyfacial | 26 | 50.70 | 5.18 | 42.82 | 60.21 | NS | 53.79 | 5.74 | 41.99 | 69.55 | NS | 3.09 | 3.87 | NS |
| Mesofacial | 41 | 49.61 | 5.78 | 36.17 | 61.11 | NS | 52.63 | 5.54 | 36.89 | 63.69 | NS | 3.02 | 3.70 | NS |
| Dolichofacial | 24 | 45.54 | 6.75 | 30.43 | 56.16 | ** | 47.98 | 7.49 | 31.04 | 64.05 | ** | 2.45 | 5.00 | NS |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = \(p \leq 0.05\)

** = \(p \leq 0.05\), significant difference in vertical pattern subgroup
Data related to the facial axis angle are presented in Table X and illustrated in Figure 3. Obvious significant differences were found between the vertical groups, before and after Herbst appliance treatment. No significant changes occurred in the facial axis angle with Herbst treatment in any of the vertical groups. The data for the mandibular plane angle are presented in Table XI and illustrated in Figure 4. The pre- and post-Herbst appliance treatment average values for all vertical groups were different. Because the mandibular plane angle was the defining vertical group criterion for sample selection, this finding was not unexpected. During Herbst treatment, there was little change in the mean mandibular plane angle within any of the groups, and none of the changes in mean were statistically significant. The post-Herbst mean for the brachyfacial group still reflected brachyfacial values and that for the dolichofacial group still reflected dolichofacial values.

Significant correlations between changes in the above measurements and pretreatment CVMS stage, incisal overbite and overjet are presented in Table XII. It is apparent that changes in upper incisor angulation, Pog’ to Pog and mandibular length were related, respectively, to the pretreatment incisal overjet, overbite and CVMS.
In order to control the limitations of the present study, efforts were made to gather a homogeneous Class II sample which was treated by one clinician using similar versions of the Herbst appliance. The sample was divided into significantly different vertical groups on the basis of the mandibular plane angle. During the cephalometric analysis, all efforts were made to eliminate errors in landmark location.25

The results of this study support the findings of previous studies, in that the Herbst appliance is a useful method of correcting Class II dental relationships. In the presented sample, the majority of the malocclusions were corrected to a Class I or greater molar relationship, after an average treatment time of nine months. At the end of the Herbst phase, a comparable reduction in ANB angulation was also seen in all vertical groups. However, when the mean post-Herbst ANB values were compared with traditionally-accepted cephalometric averages for Class I individuals, the inter-arch relationships for most patients were still found to be Class II. It is worthwhile noting that subjects in the dolichofacial group commenced treatment and appeared to remain significantly more Class II, during the Herbst appliance phase.

The identified dental changes are similar to those that have been reported in previous studies. A significant lower incisor proclination occurred in all groups.13,27,28 However, the average increase in lower incisor proclination of four degrees seen in the present sample is less than the average 10 degrees reported by Pancherz and others.1,29-31 The reduced incisor proclination may be partly explained by differences in molar relationship.

### Table X. Facial axis angle (degrees).

| Pretreatment | After Herbst | Change during Herbst treatment |
|--------------|--------------|--------------------------------|
| N | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 91  | 87.88 | 5.15 | 74.82 | 100.16 | * | 88.08 | 5.43 | 74.82 | 102.85 | * | 0.20 | 2.28 | NS |
| Brachyfacial | 26  | 91.96 | 4.27 | 83.76 | 100.16 | ** | 91.91 | 5.16 | 81.50 | 102.85 | ** | -0.04 | 2.53 | NS |
| Mesofacial | 41  | 88.45 | 3.32 | 81.10 | 97.48 | ** | 88.84 | 3.37 | 79.83 | 97.48 | ** | 0.39 | 1.99 | NS |
| Dolichofacial | 24 | 82.48 | 3.88 | 74.82 | 89.90 | ** | 82.63 | 4.23 | 74.82 | 97.78 | ** | 0.15 | 2.53 | NS |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = p ≤ 0.05

** = p ≤ 0.05, significant difference in vertical pattern subgroup.

### Table XI. Mandibular plane angle (degrees).

| Pretreatment | After Herbst | Change during Herbst treatment |
|--------------|--------------|--------------------------------|
| N | Mean | SD | Min | Max | Signif | Mean | SD | Min | Max | Signif | Mean | SD | Signif |
| Total sample | 91  | 25.29 | 5.92 | 11.74 | 39.43 | * | 25.95 | 5.95 | 12.44 | 40.16 | * | 0.69 | 2.47 | NS |
| Brachyfacial | 26  | 18.68 | 2.98 | 11.74 | 23.00 | ** | 20.50 | 3.88 | 12.44 | 29.05 | ** | 1.53 | 2.24 | NS |
| Mesofacial | 41  | 25.00 | 1.96 | 25.35 | 28.87 | ** | 25.07 | 2.94 | 18.17 | 30.46 | ** | 0.32 | 2.45 | NS |
| Dolichofacial | 24 | 32.93 | 3.23 | 29.02 | 39.43 | ** | 33.35 | 3.90 | 27.21 | 40.16 | ** | 0.42 | 2.61 | NS |

SD = Standard deviation, Min = minimum value, Max = maximum value, Signif = ANOVA, significant differences in means, NS = Not significant.

* = p ≤ 0.05

** = p ≤ 0.05, significant difference in vertical pattern subgroup.

### Table XII. Significant correlation of cephalometric variables with pretreatment variables.

| CVMS | Overbite | Overjet |
|------|----------|---------|
| Upper Incisor to APog | 0.08 | 1.00 | 0.00* |
| Pog’-Pog | 0.10 | 0.00* | 0.35 |
| Mandibular Length | 0.00* | 0.70 | 0.21 |

ANOVA * p ≤ 0.05
An equivalent average increase in mandibular length (Co-Gn) of approximately 4 mm was found in all groups during the Herbst treatment. This is comparable with peak annual mandibular growth increases of 4.2 to 4.5 mm, previously reported, in addition to mandibular growth increments in Class II individuals treated with the Herbst appliance (3.9 mm). Despite these positive changes, an increase in mandibular length does not necessarily lead to an improvement in chin position, especially in dolichofacial subjects. This is due to the interaction of the horizontal and vertical factors during growth and is highlighted by differences in the horizontal projection of pogonion seen in the different vertical facial groups. Although there was considerable individual variation within the groups, on average there was less overall horizontal chin projection at the end of Herbst appliance treatment in the dolichofacial group.

Only small average changes were found for the facial axis and mandibular plane angles during the Herbst phase. The rotational changes identified in response to treatment were similar to previous reports which suggested that the underlying vertical facial pattern is unlikely to change as a result of treatment. No evidence was found in the present study to support the expectation of a predictable forward mandibular rotation in dolichofacial subjects, which has been previously reported to accompany maxillary molar intrusion associated with the Herbst appliance. Despite considerable Class II correction, the pre-existing brachyfacial and dolichofacial patterns seemingly remained unchanged following Herbst appliance treatment.

It is not surprising that a significant correlation was found between increased pretreatment overbite and greater forward movement of pogonion during Herbst treatment. Increased overbite occurred more frequently in the patients in the brachyfacial group. These patients likely experience relatively greater horizontal change in the movement of the bony chin during normal mandibular growth.

Previous advocates for the use of the Herbst appliance have recommended commencing treatment at the peak of the mandibular growth spurt. In addition to achieving potentially greater increases in mandibular length, a shorter retention period and the interlocking of the permanent occlusion have been identified as favourable factors in the maintenance of Class II correction. Patients in the present sample were treated during peak mandibular growth, as defined by CVMS 3. In contrast with previous findings, greater increases in mandibular length were found in the sampled patients commencing in an earlier CVMS stage, with greater potential mandibular growth remaining. This may also be explained, in part, by the relatively small number of patients who were treated prior to CVMS stage 3.

As expected, all cephalometric measurements were accompanied by a range of individual variation. An explanation might be found in the occurrence of Class II malocclusions in a wide variety of human craniofacial configurations. The vertical and rotational effects of the Herbst appliance treatment identified in the present study are important and relevant in day-to-day clinical practice. However, results of this study do not support the idea that the vertical facial pattern or the direction of facial growth of an individual can be reliably altered with the Herbst appliance. It appears difficult, if not impossible, to significantly alter an inherent underlying vertical pattern. Therefore, when planning treatment for a young Class II patient, a vertical pattern that differs significantly from the average should not be expected to change. While sound occlusal results and a positive facial change may be achieved, there is an expectation that a significant dolichofacial pattern would remain long, no matter what appliances are used to attempt a change. If the projected eventual mature face does not fall within normal vertical limits, without excessive soft tissue convexity and lip strain, consideration may still be given to eventual orthognathic surgical correction.

Conclusions

Within the limitations of the study, the following conclusions may be drawn:

1. Treatment with the Herbst appliance in rapidly-
maturing Class II subjects is likely to result in reduction in the ANB angle and anterior overjet.

2. Treatment is likely to be accompanied by significant changes in upper and lower incisor angulation.

3. Treatment in growing patients is likely to be accompanied by increases in absolute mandibular length, with greater increases in length more likely to occur in subjects for whom there are greater expectations of future growth.

4. Treatment may be accompanied by significant increases in horizontal chin projection, with greater projection more likely in subjects with brachyfacial patterns.

5. Treatment is likely to be accompanied by small changes in the mandibular plane and facial axis angles. There is a reasonable expectation that brachyfacial faces will remain short and dolicho facial faces will remain long.

6. Considerable individual variation is likely to be seen.

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