Original Article

Skeletal Changes of Herbst Appliance Therapy Investigated With More Conventional Cephalometrics and European Norms

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Abstract: We measured the skeletal effects of Herbst appliance treatment in a retrospective sample of 25 boys (aged 10.7–14.5 years) and 25 girls (aged 10.7–14.3 years). Selection criteria were (1) a pretreatment full Class II molar relationship (ANB angle: average, 6.7 degrees; range, 2.5–10.5 degrees) and (2) a posttreatment full Class I or overcorrected Class I molar relationship within 6–8 months. A first *t*-test was used to evaluate variations between pre- and posttreatment cephalometric measures. Then, compared with the appropriate age- and sex-matched European norm, every pre- and posttreatment value was transformed into a *z*-score on the distribution of the norm value and a second *t*-test was performed. The second *t*-test was to study variations between pre- and posttreatment *z*-scores in order to neutralize the effect of natural growth. Posttreatment, the mandible showed a remarkable forward repositioning without opening of the gonial angle, particularly in males. Only ANB and Xi-CF-PTV angles were significantly different when the effect of normal growth was excluded. In males, ramus height and mandibular basal length were significantly increased when total variation was considered (ie, not excluding the effect of normal growth). In females, only the mandibular ramus height was significantly increased. In conclusion, even short-term Herbst therapy can be efficacious, with the most frequent effect being mandibular forward repositioning followed by mandibular ramus elongation. The statistical procedure used counteracts the effect of growth and sex on the results. Moreover, *z*-scores are adimensional measures with which any kind of parameter may be compared and scaled to each other in the perspective of a more reliable mutivariated interpretation of cephalometric variables. (*Angle Orthod* 2001;71:170–176.)

Key Words: Herbst appliance; Conventional cephalometrics; Skeletal effects

INTRODUCTION

The Herbst appliance is widely used to correct Class II malocclusions.[1–9] In addition to distal movement of the upper teeth and mesial movement of the lower teeth, the appliance stimulates growth of the mandible and maxilla and probably also corrects the direction of their growth.[6,10,11]

The effect of Herbst appliance treatment has previously been investigated by means of the Pancherz cephalometric method.[5] However, unlike more conventional cephalometric measures, this specific cephalometric approach does not address dimensional changes or the inclination and location of each dental and skeletal part of the facial complex. Consequently, the effects exerted by the Herbst appliance on each dentoskeletal structure are largely unknown and difficult to compare with the effects of other orthopedic devices that are generally evaluated with more conventional cephalometric parameters. Last, the outcome of Herbst treatment in terms of sex differences is unknown and most of the maxillary and mandibular basal bone modifications arising from its use have not been compared with European standard growth samples.

The aims of this study were to determine (1) the effects of Herbst treatment by means of conventional cephalometric variables and eliminating the effects of natural growth and (2) whether gender affects response to treatment.

SUBJECTS AND METHODS

A retrospective sample of 50 patients, 25 males (aged 10.7–14.5 years) and 25 females (aged 10.7–14.3 years) was selected among Class II malocclusions treated with the Herbst appliance by one author (HP) between 1977 and

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TABLE 1. Paired Samples *t*-Test of Pre- and Posttreatment Cephalometric Variables for Males[a]

		Paired Differences			99% Confidence Limits			
Pretreatment	Posttreatment	Mean	SD	SEM	Lower	Upper	t (df = 24)	P Value[b] (2 Tailed)
GO-ME	GO-ME	−1.7118	2.2785	0.4557	−2.9864	−0.4373	−3.7570	0.001***
Xi-Pm	Xi-Pm	−2.1160	1.2895	0.2579	−2.8374	−1.3946	−8.2050	0.000***
BA-ANS	BA-ANS	−0.4980	1.6224	0.3245	−1.4055	0.4096	−1.5350	0.138 NS
McNamara	McNamara	−0.0052	1.4923	0.2985	−0.8399	−0.8295	−0.0170	0.986 NS
CD-GO	CD-GO	−2.8736	3.3079	0.6616	−4.7240	−1.0232	−4.3430	0.000***
Art-Go	Art-Go	−2.2732	3.2458	0.6492	−4.0889	−0.4575	−3.5020	0.002**
NS-ArtPRM2	NS-ArtPRM2	1.1400	2.4896	0.4979	−0.2527	2.5327	2.2890	0.031*
Xi-CF-PTV	Xi-CF-PTV	3.0000	2.8868	0.5774	1.3852	4.6148	5.1960	0.000***
SNA	SNA	0.5000	1.7017	0.3403	−0.4519	1.4519	1.4690	0.155 NS
SNB	SNB	−1.9400	1.6093	0.3219	−2.8402	−1.0398	−6.0270	0.000***
ANB	ANB	2.4400	1.4742	0.2948	1.6153	3.2647	8.2760	0.000***
Ar-GO-ME	Ar-GO-ME	−0.2200	1.8262	0.3652	−1.2416	0.8016	−0.6020	0.553 NS
UAFH	UAFH	−0.5596	1.3308	0.2662	−1.3040	0.1848	−2.1020	0.046*
UPFH	UPFH	−0.4872	1.2110	0.2422	−1.1646	0.1902	−2.0120	0.056 NS
BIS-FH	BIS-FH	−0.5200	2.0589	0.4118	−1.6717	0.6317	−1.2630	0.219 NS

[a] SD, standard deviation; SEM, standard error of the mean; *df,* degree of freedom.
[b] NS, not significant; *, $P < .05$; **, $P < .01$; ***, $P < .001$.

1985 at the Orthodontic Department, University of Lund (Sweden). All patients presented a full molar Class II relationship at the beginning of treatment (mean ANB = 6.7 degrees, ranging from 2.5 degrees to 10.5 degrees) and a full molar Class I (or even Class I overcorrection) at the end of 6–8 months of Herbst therapy. Preformed A4-sheets were superimposed on pre- and posttreatment lateral head films, and 50 selected cephalometric landmarks were marked on each sheet. The sheets were entered into a computer system and analyzed by means of software expressly developed by one of the authors (CM).[12]

To assess the combined error of the method (manual digitizing, telefax transmission of data, and computer processing of the cephalometric landmarks), the whole procedure was performed twice by 2 different operators in 12 (6 pre- and 6 posttreatment) female and 12 (6 pre- and 6 posttreatment) male randomly selected patients. The following formula was used to determine the method error (ME) as $ME = (\Sigma d^2/2n)^{1/2}$, where d is the difference between 2 recordings of a pair and n is the number of double recordings. The mean error was 1.24 mm for linear and 1.10 degrees for angular measures. Radiographic magnification of 7% was corrected for all linear cephalometric measurements.

The mean, standard deviation (SD), and standard error of all cephalometric variables were calculated. Pretreatment and posttreatment variations of both linear and angular measures were statistically analyzed by means of a paired-samples *t*-test. To counteract the effect of growth, a second paired-samples *t*-test was performed with the means of pretreatment and posttreatment *z*-scores of every cephalometric variable compared with the appropriate age- and sex-matched norm of Bhatia-Leighton standard.[13] Posttreatment values following more than 6 months of treatment were standardized on the next age-matched norm.

The *z*-score is probably the most adequate statistical definition for the reader. However, it is important to note that this definition is a little different from what we really did in customizing our software. Indeed, while a *z*-score is generally considered the distance from the midpoint of normal range, in our software, it was the distance from the first standard deviation, in other words, the distance from the upper (or lower) border of the normal range.

When the data are transformed into this standardized form by our customized software, the amount of growth effect on the results was automatically excluded. While the first *t*-test estimated total variation of cephalometric variables (including growth effects), the second one estimated that part of variation mainly due to Herbst appliance (excluding or at least reducing growth effects). The levels of significance were $P < .001$ (***), $P < .01$ (**), and $P < .05$ (*); $P = .05$ was not considered statistically significant.

RESULTS

Males

There was no significant total variation between pre- and posttreatment maxillary sagittal measurements (Table 1) while *z*-score variations (Table 2) were at the border of significance ($P^{z\text{-Sc BA-ANS}} = .038$; $P^{z\text{-Sc SNA}} = .053$). Conversely, while vertical maxillary skeletal changes were observed in terms of total variation ($P^{UAFH} = .046$; $P^{UPFH} = .056$), no such changes were observed in terms of *z*-scores.

Mandibular ramus height and mandibular corpus length were significantly increased ($P^{CD\text{-}GO} < .001$; $P^{AR\text{-}GO} < .002$; $P^{GO\text{-}ME} < .001$; $P^{Xi\text{-}PM} < .001$), but these changes were not confirmed in terms of *z*-scores ($P^{z\text{-Sc CD-GO}} > .09$; $P^{z\text{-Sc GO-ME}} > .13$; $P^{z\text{-Sc Xi-PM}} > .09$). Only AR-GO *z*-score appeared to be increased ($P^{z\text{-Sc AR-GO}} = .03$).

TABLE 2. Paired Samples *t*-Test of Pre- and Posttreatment *z*-Scores for Males[a]

Pretreatment	Posttreatment	Paired Differences Mean	SD	SEM	99% Confidence Limits Lower	Upper	t ($df = 24$)	P Value[b] (2 Tailed)
z-Sc GO-ME	z-Sc GO-ME	−0.2347	0.7656	0.1531	−0.6630	0.1936	−1.5320	0.1380 NS
z-Sc Xi-Pm	z-Sc Xi-Pm	−0.3421	0.9923	0.1985	−0.8971	0.2130	−1.7240	0.0980 NS
z-Sc BA-ANS	z-Sc BA-ANS	0.1781	0.4044	0.0809	−0.0481	0.4043	2.2020	0.0380*
z-Sc McNamara	z-Sc McNamara	0.2233	0.6584	0.1317	−0.1450	0.5915	1.6950	0.1030 NS
z-Sc CD-GO	z-Sc CD-GO	−0.3651	1.0539	0.2108	−0.9546	0.2245	−1.7320	0.0960 NS
z-Sc Art-Go	z-Sc Art-Go	−0.4375	0.9457	0.1891	−0.9665	0.0915	−2.3130	0.0300*
z-Sc NS-ArtPRM2	z-Sc NS-ArtPRM2	0.2624	0.6067	0.1213	−0.0770	0.6017	2.1620	0.0410*
z-Sc Xi-Cf-PTV	z-Sc Xi-CF-PTV	0.7333	1.0574	0.2115	0.1418	1.3248	3.4680	0.0020**
z-Sc SNA	z-Sc SNA	0.2039	0.4999	0.1000	−0.0757	0.4835	2.0390	0.0530 NS
z-Sc SNB	z-Sc SNB	−0.2452	0.5003	0.1001	−0.5251	0.0347	−2.4510	0.0220*
z-Sc ANB	z-Sc ANB	1.1310	0.7925	0.1585	0.6876	1.5743	7.1350	0.0000***
z-Sc Ar-GO-ME	z-Sc Ar-GO-ME	−0.0101	0.4716	0.0943	−0.2739	0.2538	−0.1070	0.9160 NS
z-Sc UAFH	z-Sc UAFH	−0.2224	1.2254	0.2451	−0.9078	0.4631	−0.9070	0.3730 NS
z-Sc UPFH	z-Sc UPFH	−0.0895	0.9803	0.1961	−0.6378	0.4589	−0.4560	0.6520 NS
z-Sc BIS-FH	z-Sc BIS-FH	−0.2589	0.9066	0.1813	−0.7660	0.2483	−1.4280	0.1660 NS

[a] SD, standard deviation; SEM, standard error of the mean; *df,* degree of freedom.
[b] NS, not significant; *, $P < .05$; **, $P < .01$; ***, $P < .001$.

TABLE 3. Paired Samples *t*-Test of Pre- and Posttreatment Cephalometric Variables for Females[a]

Pretreatment	Posttreatment	Paired Differences Mean	SD	SEM	99% Confidence Limits Lower	Upper	t ($df = 24$)	P Value[b] (2 Tailed)
GO-ME	GO-ME	−1.6387	6.0806	1.2161	−5.0402	1.7627	−1.3480	0.1900 NS
Xi-Pm	Xi-Pm	−1.2364	2.6025	0.5205	−2.6922	0.2194	−2.3750	0.0260*
BA-ANS	BA-ANS	−1.3206	10.7721	2.1544	−7.3464	4.7052	−0.6130	0.5460 NS
McNamara	McNamara	0.4256	1.6788	0.3358	−0.5135	1.3647	1.2680	0.2170 NS
CD-GO	CD-GO	−2.7753	5.4593	1.0919	−5.8292	0.2785	−2.5420	0.0180*
Art-Go	Art-Go	−1.4044	3.5144	0.7029	−3.3703	0.5615	−1.9980	0.0570 NS
NS-ArtPRM2	NS-ArtPRM2	0.2200	15.0659	3.0132	−8.2077	8.6477	0.0730	0.9420 NS
Xi-CF-PTV	Xi-CF-PTV	1.9000	3.7277	0.7455	−0.1852	3.9852	2.5480	0.0180*
SNA	SNA	0.6400	1.8115	0.3623	−0.3734	1.6534	1.7660	0.0900 NS
SNB	SNB	−1.200	1.5745	0.3149	−2.0808	−0.3192	−3.8110	0.0010***
ANB	ANB	1.8400	2.2487	0.4497	0.5821	3.0979	4.0910	0.0000***
Ar-GO-ME	Ar-GO-ME	−0.3200	2.5531	0.5106	−1.7482	1.1082	−0.6270	0.5370 NS
UAFH	UAFH	0.0504	2.3073	0.4615	−1.2403	1.3411	0.1090	0.9140 NS
UPFH	UPFH	−0.0640	1.6325	0.3265	−0.9772	0.8492	−0.1960	0.8460 NS
BIS-FH	BIS-FH	−0.4600	2.1061	0.4212	−1.6382	0.7181	−1.0920	0.2860 NS

[a] SD, standard deviation; SEM, standard error of the mean; *df,* degree of freedom.
[b] NS, not significant; *, $p < .05$; **, $P < .01$; ***, $P < .001$.

There were significant changes in total variation of SNB and ANB angles ($P < .001$). ANB and Xi-CF-PTV angles were also significantly changed in terms of *z*-score ($P < .001$). No significant changes were detected for the gonial angle.

Females

None of the investigated sagittal maxillary measures, either in terms of total variation or in *z*-scores, significantly differed between pre- and posttreatment (Tables 3 and 4). Similarly, no differences were detected in vertical maxillary variables. Only mandibular ramus height increased ($P^{CD\text{-}GO} = .018$; $P^{AR\text{-}GO} = .057$). The *z*-score of the increased AR-GO was at the border of significance ($P^{z\text{-}Sc\ AR\text{-}GO} = .056$).

Also, females showed significant changes of total variation of SNB and ANB angles ($P < .001$). ANB angle significantly changed also in terms of *z*-score ($P = .001$). No significant changes were observed for the gonial angle.

DISCUSSION

In clinical orthodontics, the correction of the facial complex is the result of the final rearrangement of many cephalometric variables.[14] Consequently, the positive or negative variation of any one measure can never explain by itself the correction of the whole face. Conventional cephalometrics is not sufficiently powerful to take into account the interactions between measurements. In addition, it does not allow an effective comparison between angular and linear

TABLE 4. Paired Samples *t*-Test of Pre- and Posttreatment *z*-Scores for Females[a]

Pretreatment	Posttreatment	Paired Differences Mean	SD	SEM	99% Confidence Limits Lower	Upper	*t* (*df* = 24)	*P* Value (2 Tailed)
z-Sc GO-ME	z-Sc GO-Me	−0.1780	1.7675	0.3535	−1.1667	0.8107	−0.5040	0.6190 NS
z-Sc Xi-Pm	z-Sc Xi-Pm	−0.2072	0.9942	0.1988	−0.7634	0.4389	−1.0420	0.3080 NS
z-Sc BA-ANS	z-Sc BA-ANS	−0.2545	3.1093	0.6219	−1.9938	1.4848	−0.4090	0.6860 NS
z-Sc McNamara	z-Sc McNamara	0.0807	0.6893	0.1379	−0.3048	0.4664	0.5860	0.5630 NS
z-Sc CD-GO	z-Sc CD-GO	−0.6109	1.6838	0.3368	−1.5528	0.3310	−1.8140	0.0820 NS
z-Sc Art-Go	z-Sc Art-Go	−0.3917	0.9743	0.1949	−0.9368	0.1533	−2.0100	0.0560 NS
z-Sc NS-ArtPRM2	z-Sc NS-ArtPRM2	0.2381	3.5118	0.7024	−1.7264	2.2025	0.3390	0.7380 NS
z-Sc Xi-CF-PTV	z-Sc Xi-CF-PTV	0.6667	1.3375	0.2675	−0.0815	1.4148	2.4920	0.0200*
z-Sc SNA	z-Sc SNA	0.1610	0.6680	0.1336	−0.2127	0.5347	1.2050	0.2400 NS
z-Sc SNB	z-Sc SNB	−0.2525	0.6639	0.1328	−0.6239	0.1188	−1.9020	0.0690 NS
z-Sc ANB	z-Sc ANB	0.7895	1.0016	0.2003	0.2293	1.3498	3.9410	0.0010***
z-Sc Ar-GO-ME	z-Sc Ar-GO-ME	−0.2029	0.5759	0.1152	−0.5250	0.1193	−1.7610	0.0910 NS
z-Sc UAFH	z-Sc UAFH	0.1204	0.8095	0.1619	−0.3324	0.5732	0.7440	0.4640 NS
z-Sc UPFH	z-Sc UPFH	−0.0734	0.7117	0.1423	−0.4716	0.3247	−0.5160	0.6110 NS
z-Sc BIS-FH	z-Sc BIS-FH	−0.2099	0.7216	0.1443	−0.6135	0.1938	−1.4540	0.1590 NS

[a] SD, standard deviation; SEM, standard error of the mean; *df,* degree of freedom.
[b] NS, not significant; *, $P < .05$; **, $P < .01$; ***, $P < .001$.

measurements (as well as different intensity of variation between the same unit of measure) or the correlation between vertical and sagittal derangements. In other words, at the moment, the state of the art does not address the multivariated interpretation of cephalometric variables.[15]

The procedure described here overcomes the limits of conventional cephalometrics. We investigated the effects of Herbst appliances using a large number of conventional cephalometric parameters and a combination of several cephalometric techniques. Only those linear and angular skeletal measurements that have been previously studied in European samples were selected and incorporated in the procedure, expressly to compare the data of our treated sample with the European norms, matched for sex and age (Figure 1). Data were easily managed by means of expressly devised software, the output being in millimeters, in angular degrees, and in *z*-score units. The output of linear and angular variables in terms of *z*-scores was intentionally introduced in the procedure, with the aim of making them truly comparable. Indeed, different from any pre- and posttreatment variation of parameters, *z*-score changes are adimensional changes with which any kind of parameter may be compared and scaled to each other (irrespective of whether pounds, angle degrees, gallons, or inches are being compared). That is the essential precondition to be introduced to multivariated interpretation of these variables.

In addition, pre- and posttreatment cephalometric variations evaluated in terms of *z*-score allowed us to establish to what extent changes in skeletal measures depended on growth. In other words, by matching our absolute values for sex and age with an acknowledged European standard sample like the Bathia-Leighton group, we also avoided (and to some extent excluded) the effects of natural growth on our results.

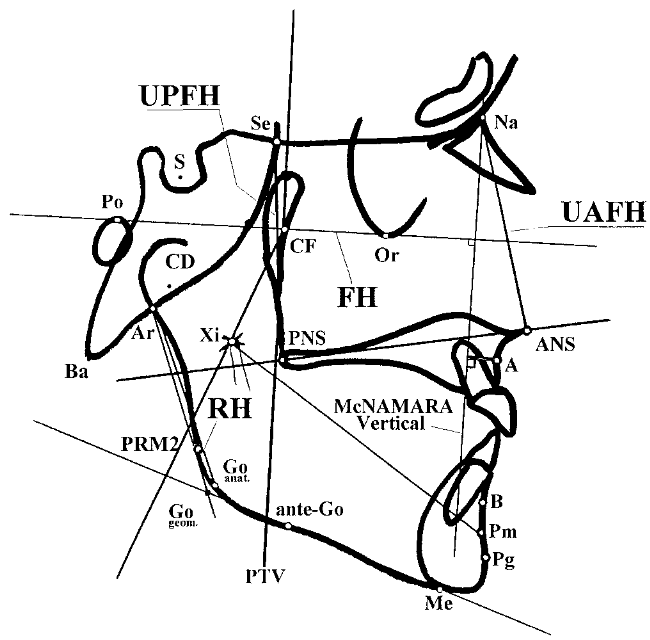

FIGURE 1. Cephalometric trace showing the landmarks and parameters selected for investigation. Linear cephalometric parameters; vertical skeletal: UAFH (upper anterior facial height), Na-ANS; UPFH (upper posterior facial height), Sellion--PNS; RH (ramus height), Ar anat--GO anat, CD--GO anat. Horizontal skeletal: McNamara (distance to this vert), A-vert McNamara; Ba--ANS (Basion--Ant Nasal Spine), Ba--ANS; Corpus (mandibular corpus length), GO anat--ME, Xi-Pm. Angular cephalometric parameters; vertical skeletal: BIS-FH (facial to palatal plane angle), ANS-PNS/FH; Ar-GO-ME (articolare gonion menton angle), Ar-GO-ME. Horizontal skeletal: Xi-CF-PTV (Xi-CF-vert PTV angle), Xi-CF-PTV; NS-Art PRM2 (the angle between N-S plane and Art-PRM2 plane), SNA, S-N-A, SNB, S-N-B, ANB, A-N-B.

TABLE 5. Advantages of Annualized z-Scores

- Neutralization of growth influence on treatment results, as well as discrepancies caused by sex and age differences within the sample. Once the control sample is selected, each patient will be compared to the corresponding growing norm (matched for sex and age), and the resulting *z*-score can be compared with that of subjects of different sex and age.
- Normal values (z-score = 0) are easily and immediately distinguished from abnormal ones (z-score > 0 means excess; z-score < 0 means deficit).
- Comparability between different treatment lengths within the sample, overcoming the problem of annualization of treatments.
- Comparability of linear and angular cephalometric variables.
- Comparability of different variation rates within the same unit of measure (cephalometric parameters do not always change degrees or millimeters at the same rate).
- Comparability of horizontal and vertical facial dimensions.
- Detailed overview of differential skeletal diagnosis.
- Comparability between pre- and posttreatment cephalometric records, avoiding the questionable method of tracing superimpositions.

With this assumption, it could be argued that the effects of growth can appear constant for the sample, meaning that pre- and posttreatment *z*-scores should be the same if growth were the only factor. Actually we assumed that growth effects were constant, but only within each single age- and sex-group of norm. In other words, it is more appropriate to say that, if growth was the only factor, *z*-scores should always be null or zero but not always the same. Indeed, it can easily be understood that, because every age- and sex-group of a normal sample (as well as of a pathological one) preserves its different range of normal values with its own different means and own different minimum and maximum values, we can consider constant ordering of the sample by different age- and sex-classes or groups.

Transforming data in this standardized form of *z*-score, these class differences were absolutely respected and, on the basis of x-rays and birthdates of patients (±6 months), pretreatment and posttreatment values were automatically ordered by age- and sex-classes. Posttreatment values following more than 6 months of treatment were standardized on the next age-matched norm. Although approximate, this annualizing method of *z*-scores offered us many relevant advantages, listed in Table 5. We do not claim that this is the ideal method for clinical investigations, but it is a reliable tool to discuss in terms of a multivariated interpretation of cephalometric variables.[15]

Another objection to this method is that normal growth can be easily mistaken with treatment effects. The growth pattern of our treated skeletal Class II sample was significantly lower than normal growth, and this is the main reason why the increasing effect of normal growth on measurements could often overlap the treatment effects. To some extent, our sample measurements were not properly matchable or comparable with the Bathia-Leighton norms because of their different growth rate.

Otherwise, in every cephalometric variable of our Herbst-treated sample, the slope of pre- and posttreatment mean variation was always greater than that of the Bathia-Leighton standard (ie, always greater than the slope of any untreated skeletal Class II sample; see, eg, the Droschl[16] Class II sample). It means that our sample treated with Herbst therapy, although interacting with the natural lower pathologic rate of growth of skeletal Class II patients, was able to activate more than a normal rate of growth, inducing a faster and unmistakable increase of bone. Such relevant facts can only be due to treatment effects and not to the naturally reduced growth in this kind of patient.

Sagittal maxillary changes

Different from previous findings was that maxillary backward correction occurred mainly in male maxillary protrusive cases (high positive *z*-scores of A-point to McNamara-vertical before treatment).[8] Such skeletal headgear effect was not so pronounced since only the pre- and posttreatment *z*-score variation was statistically significant ($P^{z\text{-Sc BA-ANS}} = .038$; $P^{z\text{-Sc SNA}} = .053$). Valant and Sinclair[17] also observed a certain inhibition of sagittal maxillary growth. Wieslander[9,18] obtained an inhibitory effect, although he used the headgear and the Herbst appliance together. This backward maxillary effect was not observed in our female sample.

Vertical maxillary changes

The expected skeletal vertical correction of the maxilla differed between males and females. Clinical backward and upward tilting of the palatal plane was frequent in males but not in females. However, statistical analysis of pre- and posttreatment measures of UPFH (upper posterior facial height) and of UAFH (upper anterior facial height) showed that, rather than a treatment result, male maxillary tipping seemed to be more an effect of natural growth.

Sagittal mandibular changes

Pretreatment mandibular basal length was remarkably reduced and, at the end of treatment, all basal length deficiencies significantly improved but not in terms of *z*-scores and only in males. Consequently, these changes were probably growth related. On the other hand, in 72% of our male sample, mandibular basal length increased more than the European norms. This is in agreement with several previous studies where a significant treatment influence on mandibular growth was observed.[2,4,5,7,10,17,19]

Vertical mandibular changes

Our results support the hypothesis of stimulation of condylar growth first proposed by Pancherz.[4] More recently, roentgenographic observations confirmed this remarkable condylar remodeling.[20–23] However, this result could be due to further remodeling on the posterior border of the mandibular ramus.

Our findings, although limited to a specific age range, are in agreement with previous studies that suggest that the Herbst appliance is effective as a vertical posterior orthopedic activator of the mandible.[7,24] In this perspective, the remarkable increase of ramus height contributes to the correction of a sagittal skeletal Class II by means of mandibular forward rotation. Moreover, in males with skeletal open bite, the Herbst appliance could help to counteract the excessive downward growth of the posterior part of the maxillary basal bone. These considerations confirm that the Herbst appliance can confidently be used in skeletal Class II patients with vertical growth patterns.[19,23]

Morphological and positional mandibular changes

Morphological changes have been described in the gonial angle of the mandible after Herbst treatment, but we did not detected significant changes in the AR-GO-ME angle, either considering total variation or *z*-scores alone.[4,7,18,24] Conversely, the mandible underwent a remarkable forward repositioning, as largely demonstrated by the significant reduction of ANB angle in both statistical *t*-tests. Rather than an apparent correction that is subject to short-term relapse, this is a true skeletal repositioning of the mandible.[25] Indeed, it could even reflect an anterior translation of the glenoid fossa.[4,18,23] These observations support the hypothesis that mandibular morphology is under strong genetic control while mandibular dimensions and position are more susceptible to orthopedic influence.[26]

CONCLUSIONS

The analysis of changes occurring in maxillary and mandibular cephalometric variables, especially considered in terms of *z*-score, gives a measure of the selective skeletal effects consequent to Herbst treatment. The appliance favorably affected sagittal and vertical maxillary jaw base position only in males. A large mandibular forward repositioning occurred in both sexes and mandibular corpus length increased in a large part of the sample. Through the specific range of age in our sample, the Herbst appliance was an effective vertical posterior orthopedic activator of ramus height.

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