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Research

The skeletal and dental effects of two kinds of Herbst appliances

Luiz Carlos Marchi [a], Luis Antonio de Arruda Aidar [b,*], André Tortamano [c], Gladys Cristina Dominguez [c]

[a] Department of Orthodontics, School of Dentistry, Universidade Estadual do Oeste do Paraná–UNIOESTE, Cascavel, PR, Brazil
[b] Department of Orthodontics, School of Dentistry, Universidade Santa Cecília – UNISANTA, Santos, SP, Brazil
[c] Department of Orthodontics, School of Dentistry, Universidade de São Paulo – USP, São Paulo, SP, Brazil

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Background: The dentoskeletal effects of Herbst appliances were reported in several studies. The purpose of this study was to evaluate, using cephalometry, skeletal and dental effects of treatment using two types of Herbst appliances in adolescents with Class II division 1 malocclusion and mandibular retrognathism.
Methods: Seventy-five consecutive adolescents (treated groups: A [steel crowns] and B [acrylic splints]; group C: control) were monitored for 12 months. Lateral radiographs were obtained at baseline (T1) and at the end of the observation period (T2). Cephalometric variables were analyzed using parametric tests.
Results: The results of the two treatment groups were different from those found for the control group. Maxillary growth was restricted, whereas mandibular growth was greater, which resulted in a better sagittal relation. The analysis of dentoalveolar aspects revealed that overjet was reduced due the maxillary incisors tipped palatally and flaring of mandibular incisors, vertical control of maxillary molars and mesial movement of mandibular molars. The three groups had similar extrusion of mandibular molars and preservation of mandibular morphology and facial pattern.
Conclusion: Treatment with two types of Herbst appliance resulted in changes that improved sagittal skeletal and dental relations, regardless of growth. The control of vertical growth pattern did not depend on the type of the Herbst appliance is used; however, in cases of lack of space in the maxillary arch, the Herbst appliance with steel crowns was more efficient.

1. Introduction

Herbst appliances are very efficient in the treatment of Class II malocclusion and mandibular retrognathism [1–5]. In general, sagittal condyle growth is prevalent during the growth peak, whereas dentoalveolar compensation prevails after the peak, with great individual variations [4,6].

The greatest orthopedic response to treatment with Herbst occurs during pubertal growth spurt [6,7]. In contrast, studies have shown that treatment with a Herbst appliance seems not to have any effect on growth and mandibular morphology [2,6] in the long term. The acceleration of mandibular growth at the time of treatment is more important for the correction of Class II malocclusion. After treatment, stable cuspal interdigitation may help to preserve results [4,8,9].

Some studies [4,5,10] have demonstrated the possibility of treatment with Herbst appliances after the growth peak when searching for better stability. Therefore, studies with control groups may be conducted at the time of pubertal growth peak without limiting patient opportunities of undergoing future treatment.

This prospective study evaluated short-term dental and skeletal changes in adolescents with Class II division 1 malocclusion divided into three groups: two groups were treated with Herbst appliances (stainless steel crowns and bands or acrylic splints), and results were compared with changes observed in a control group.

2. Subjects and methods

This study enrolled 75 white Brazilian boys and girls with Class II division 1 malocclusion divided into three groups: group A consisted of 25 adolescents (16 boys and 9 girls) treated with a modified Herbst appliance with steel crowns over the maxillary first molars and mandibular first premolars and orthodontic bands over the maxillary first premolars and mandibular first molars

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

* Corresponding author: Rua Luis Suplicy No. 35, Gonzaga, Santos, São Paulo, CEP 11055-330, Brazil.
E-mail address: luisaidar@uol.com.br (L.A. de Arruda Aidar).

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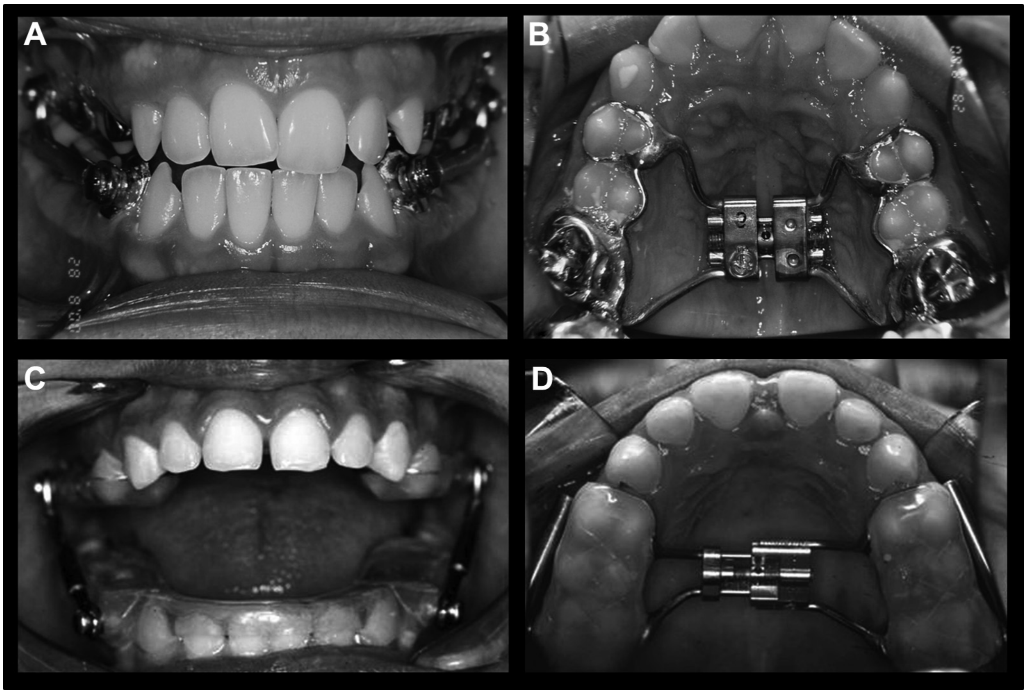

Fig. 1. (A) Crown Herbst appliance and (B) maxillary occlusal view. (C) Acrylic-splint Herbst appliance and (D) maxillary occlusal view.

(maxillary Hyrax and mandibular lingual arch) (Fig. 1A and 1B). Mean age at the beginning of treatment (T1) was 12.90 ± 1.25 years (minimum 10.91 years and maximum 15.83 years). Group B consisted of 25 adolescents (16 boys and 9 girls) treated with the Herbst appliance with acrylic splints (maxillary Hyrax and mandibular lingual arch) (Fig. 1C and 1D). Mean age at T1 was 12.61 ± 0.74 year (minimum 10.16 years and maximum 13.75 years). Group C consisted of 25 adolescents (15 boys and 10 girls) who received no treatment (control group). Mean age at T1 was 12.42 ± 0.84 year (minimum 10.16 years and maximum 14.83 years). Treatment duration (groups A and B) and follow-up time (group C) was 12 months.

This study was approved by the Ethics Committee of the School of Dentistry of University of São Paulo (USP) on July 11, 2011 (No. 77/11 CAAE 0088.0.017.000-11).

The groups were selected at the Santa Cecilia University–Santos (Unisanta–group A), University of São Paulo (USP/SP–group B), and West Paraná State University–Cascavel (Unioeste–group C). The patients in groups A and B were treated by two orthodontists.

Inclusion criteria were the same for the three groups: (1) clinical appearance of a retrognathic mandible, (2) Angle Class II division 1 malocclusion with permanent dentition, (3) ANB angle greater than 4.5°, and (4) maximum of skeletal pubertal growth peak [11]. Patients with a markedly vertical growth pattern associated with open bite and who had undergone any previous orthodontic treatment were excluded.

Rapid expansion of the maxilla took place during the first 2 weeks after Herbst appliance placement. Up to 6-mm mandibular advances were carried out at the beginning of the treatment. When necessary, 2- to 3-mm complementary advances were performed in the third month.

Lateral head films in habitual occlusion were analyzed at the following time points: T1, at the beginning of the treatment (groups A and B) or at the beginning of follow-up (group C), and T2, at the end of treatment (12 months for groups A and B) or of follow-up (12 months for group C). Standard cephalometrics (Fig. 2A, 2B, and 2C) were used for analyses of skeletal and dental changes. Cephalometrics and Pancherz analysis [1] (Fig. 2D) with the original occlusal line (OL) and occlusal line perpendicular (OLp) were used as a reference grid for sagittal and vertical registrations, with the following variables: ms/OLp, mi/OLp, is/OLp, ii/OLp, A/OLp, pg/OLp, ms/OLp-A/OLp, mi/OLp-pg/OLp, is/OLp-A/OLp, and ii/OLp-pg/Olp.

Facial pattern was evaluated using the Jarabak quotient (S-Goc/N-Me ×100) [12] and according to the inclination of the mandibular plane (Go-Gn.SN) [13].

Mandibular morphology was evaluated according to gonion angle (total, Ar-Go_c-Me, upper gonion angle, Ar-Go_c.N-Go_c and lower gonion angle, Go_c-Me.N-Go_c) and the mandibular arch (Dc-Xi-PM).

2.1. Statistical analysis

The Kolmogorov–Smirnov test confirmed normal data distribution, and parametric tests were then used. Quantitative variables are described as means and standard deviations. A paired *t*-test was used to compare T1 with T2 in each group. Analysis of variance and the Tukey test for multiple comparisons were used for the comparison of baseline characteristics (T1) of the three groups (SN.GoGn, Jarabak ratio, SNA and SNB) and of differences (T2 − T1) between groups when significant differences were found. The levels of significance were set at $P < 0.05$, $P < 0.01$, and $P < 0.001$.

For the calculation of method error (paired *t*-test) and systematic error (intraclass correlation coefficient), 20% of the lateral radiographs were randomly selected, and the criterion below was established: ≥ 0.75, excellent correlation; ≥ 0.40 and < 0.75, moderate correlation; and < 0.40, poor correlation.

3. Results

Method error was not statistically significant. The results of systematic error revealed excellent correlation. There was excellent equivalence of baseline characteristics in the three groups under study (SN.Go-GN; Jarabak ratio; SNA and SNB).

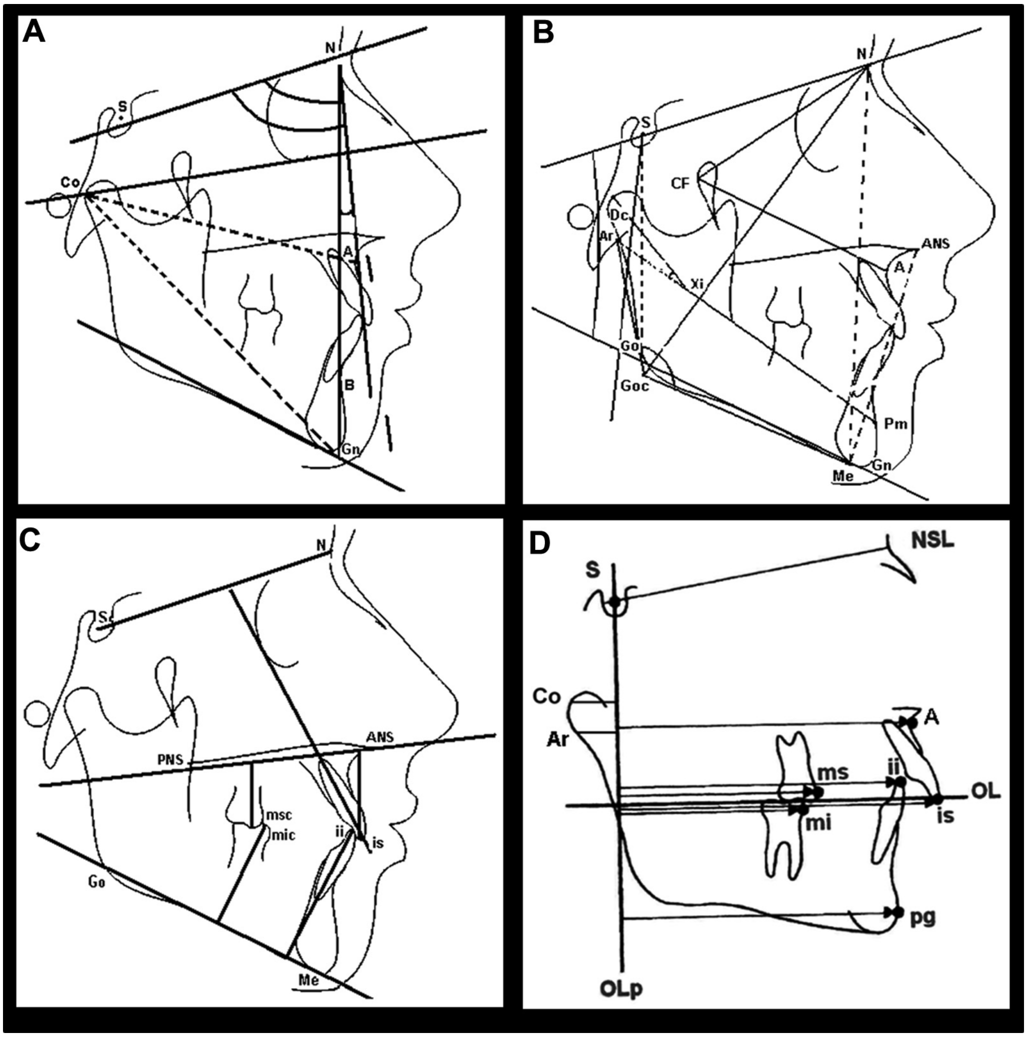

Fig. 2. (A) Reference points and lines used in the evaluation of maxillary and mandibular components and maxillary–mandibular relation. (B) Reference points and lines used in evaluation of vertical components. (C) Reference points and lines used in evaluation of maxillary and mandibular dentoalveolar components. (D) Measuring points and reference grid (OL and OLp) used in cephalometric analysis.

The maxilla as advanced in the three groups but at a higher rate in the control group (SNA, group A, $P < 0.05$; group B, $P < 0.001$; group C, $P < 0.05$). The mandible also moved forward in the three groups, but at a higher rate in the two treatment groups (SNB, group A, $P < 0.001$; group B, $P < 0.001$; group C, $P < 0.01$). The comparison of the three groups did not reveal any differences in variations of facial growth patterns between T1 and T2 (Jarabak ratio, Go-GN.SN). Mean results did not show any changes or differences in mandibular morphology in the three groups (Ar-Go_c-Me, Ar-Go_c-N, N-Go_c-Me, and Dc-Xi-PM).

In groups A and B, there was retroinclination of maxillary incisors that was greater in group B (1/SN, groups A and B, $P < 0.001$). In groups A and B, mandibular incisors moved forward (IMPA, $P < 0.001$), with no differences between groups.

There were significant differences in the position of maxillary first molars between treatment groups. In group A, they moved distally, but molar movement was limited in group B (ms/OLp − ss/OLp, group A, $P < 0.001$; group B, $P < 0.01$). In both groups A and B, mandibular first molars moved mesially (mi/OLp minus pg/OLp, groups A and B, $P < 0.001$), with no differences between groups.

Maxillary incisors moved vertically in the three groups. Movement was greater and significant in group B when compared with groups A and C (1-PP, group A, $P < 0.01$; groups B and C, $P < 0.001$). The vertical movement of mandibular incisors was limited in groups A and B but significant in group C (1-GoMe, $P < 0.001$).There were no differences between groups A and B.

There were no vertical changes of the maxillary first molars in groups A and B. Mandibular first molars moved upward in the three study groups (6-GoMe, Groups A, B, and C, $P < 0.001$), but there were no significant differences between groups. Occlusal plane rotation was counterclockwise in group C but clockwise in the two treatment groups (OL.NS, groups A and B, $P < 0.001$) (Tables 1 and 2).

Skeletal and dentoalveolar variables and the Pancherz analysis [1] are shown in Tables 3 and 4. Skeletal and dental changes that contributed to the correction of molars and of overjet in groups A and B are shown in Figures 3, 4, 5, and 6.

4. Discussion

The analysis of baseline morphological characteristics of the three groups under study, evaluated using the skeletal variable, revealed that the groups were homogeneous.

Sagittal and vertical effects of the different types of Herbst appliances have been intensively studied [1,3,4,13–16]. Some authors [2,16] found that maxillary growth was limited, but others

Table 1
Comparison of skeletal and dentoalveolar variables between T1 and T2 (paired *t*-test) in groups A, B, and C

Variable	Group A			Group B			Group C		
	T1	T2	*P*	T1	T2	*P*	T1	T2	*P*
Skeletal	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
SNA	81.02 ± 2.87	80.34 ± 3.12	*	80.78 ± 3.74	79.84 ± 3.60	***	81.54 ± 3.84	81.96 ± 3.61	*
SNB	74.90 ± 2.71	76.26 ± 2.94	***	74.76 ± 3.72	76.24 ± 3.55	***	75.26 ± 3.29	75.70 ± 3.15	**
ANB	6.12 ± 1.32	4.08 ± 1.58	***	6.02 ± 1.37	3.60 ± 1.51	***	6.28 ± 1.34	6.26 ± 1.49	NS
A-Nperp	2.26 ± 3.31	1.34 ± 3.45	*	1.58 ± 3.21	0.70 ± 3.05	***	2.68 ± 2.92	2.90 ± 2.49	NS
P-Nperp	−5.52 ± 5.54	−2.82 ± 5.94	***	−5.88 ± 5.66	−4.16 ± 5.50	***	−5.18 ± 5.31	−4.38 ± 5.06	*
Co-A	93.38 ± 4.85	93.60 ± 4.50	NS	93.94± 4.84	95.02 ± 5.39	**	92.94 ± 6.06	94.88 ± 5.70	***
Co-Gn	113.76 ± 5.12	118.52 ± 5.26	***	115.36 ± 5.34	120.88 ± 6.16	***	113.12± 6.92	115.70 ± 6.48	***
LAFH	67.24 ± 4.82	69.48 ± 5.12	***	69.80 ± 5.17	73.16 ± 5.49	***	68.00 ± 6.19	69.82 ± 6.50	***
Maxillary height	55.20 ± 3.57	56.04 ± 3.51	*	53.68 ± 3.89	54.76 ± 3.47	*	52.66 ± 2.87	52.94 ± 3.04	NS
Growth pattern									
Go-Gn.SN	34.72 ± 4.50	34.48 ± 4.79	NS	35.12 ± 6.98	34.82 ± 6.56	NS	33.78 ± 5.69	33.20 ± 5.90	NS
Jarabak ratio	65.86 ± 3.29	66.30 ± 3.68	NS	65.71 ± 5.67	66.56 ± 5.57	**	65.87 ± 4.06	66.26 ± 3.67	NS
Mandibular morphology									
Go$_c$-Me.Ar-Go$_c$	120.74 ± 5.35	120.82 ± 5.07	NS	119.74 ± 7.79	120.32 ± 8.17	NS	120.46 ± 5.74	120.10 ± 5.57	NS
Ar-Go$_c$.N-Goc	50.54 ± 3.97	49.96 ± 3.80	*	50.26 ± 3.33	49.86 ± 3.47	*	50.46 ± 3.33	50.10 ± 3.30	NS
Goc-Me.N-Go$_c$	70.20 ± 3.33	70.86 ± 3.35	**	69.84 ± 6.21	70.86 ± 6.44	***	69.88 ± 5.67	70.36 ± 5.93	NS
Dc-Xi-Pm	31.04 ± 2.98	31.74 ± 3.47	*	34.84 ± 7.34	35.10 ± 7.61	NS	32.32 ± 4.67	32.66 ± 4.65	NS
Dentoalveolar									
1-PP	29.04 ± 2.70	29.76 ± 2.50	**	31.24 ± 3.30	33.02 ± 3.10	***	29.76 ± 2.97	30.52 ± 2.98	***
6-PP	22.62 ± 1.87	22.38 ± 1.79	NS	23.68 ± 2.23	23.10 ± 2.67	NS	21.76 ± 2.29	22.94 ± 2.05	***
1-GoMe	42.78 ± 3.10	42.94 ± 3.39	NS	43.28 ± 3.75	43.56 ± 3.84	NS	42.76 ± 3.76	43.58 ± 4.10	***
6-GoMe	30.80 ± 3.30	32.14 ± 2.94	***	29.98 ± 1.90	31.72 ± 2.53	***	30.38 ± 3.64	31.68 ± 3.85	***
1/S N	109.56 ± 7.04	106.16 ± 7.36	***	111.66 ± 7.81	103.72 ± 7.36	***	105.28 ± 9.87	105.28 ± 10.26	NS
IMPA	94.36 ± 5.67	102.02 ± 7.13	***	92.04 ± 6.75	98.22 ± 6.63	***	93.84 ± 5.52	94.20 ± 4.51	NS

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS, not significant.

did not [3,17]. In this study, although there were some different results for some variables between T1 and T2 in groups A and B, there was restriction of the anterior maxillary movement (+0.54 mm and +0.20 mm) compared to the control group (−1.42 mm).

The mandibular response to the orthopedic stimulus was favorable in both groups, with no significant differences between them, which corroborates findings of numerous studies in the literature [3,6–8,14–17]. The comparison of the treatment groups with the control group revealed an increase in growth (Co-Gn) two times greater in group B and a lower orthopedic response in group A. This trend was confirmed for all variables (pg/OLp + ar/OLp, pg/OLp + co/OLp). Our results are in agreement with previous findings [7,15,17], although other studies did not use a control group with participants at growth peak. In contrast, Franchi et al. [17] studied the effect of acrylic-splint Herbst appliances in patients at the same maturation phase and during the same treatment time as in our study, and their findings corroborate our results. The analysis of

Table 2
Comparisons of differences of skeletal and dentoalveolar variables between groups from T1 to T2 (analysis of variance and Tukey test for multiple comparisons)

Variables	Group A	Group B	Group C	*P*	Tukey test for multiple comparisons (p)
Skeletal	Mean ± SD	Mean ± SD	Mean ± SD		
SNA	−0.68 ± 1.29	−0.94 ± 1.09	0.42 ± 0.85	***	A × B (NS); A × C***; B × C***
SNB	1.36 ± 1.37	1.48 ± 1.02	0.44 ± 0.70	***	A × B (NS); A × C (NS); B × C*
ANB	−2.04 ± 3.46	−2.42 ± 0.73	−0.02 ± 0.53	***	A × B (NS); A × C***; B × C***
A-Nperp	−0.92 ± 2.13	−0.88 ± 0.98	0.22 ± 1.06	*	A × B (NS); A × C**; B × C***
P-Nperp	2.70 ± 2.84	1.72 ± 2.34	0.80 ± 1.71	NS	
Co-A	0.22 ± 2.67	1.08 ± 1.66	1.94 ± 1.38	*	A × B (NS); A × C**; B × C (NS)
Co-Gn	4.76 ± 2.81	5.52 ± 2.40	2.58 ± 1.87	***	A × B (NS); A × C*; B × C***
LAFH	2.24 ± 1.73	3.36 ± 2.01	1.82 ± 1.41	**	A × B**; A × C (NS); B × C***
Maxillary height	0.84 ± 1.55	1.08 ± 2.27	0.28 ± 1.13	NS	
Growth standard					
Go-Gn.SN	−0.24 ± 1.92	−0.30 ± 1.77	−0.58 ± 1.45	NS	
Jarabak ratio	0.44 ± 1.76	0.84 ± 1.41	0.39 ± 1.24	NS	
Mandibular morphology					
Ar-Go$_c$-Me	0.08 ± 1.40	0.58 ± 2.52	−0.36 ± 3.00	NS	
Ar-Go$_c$-N	−0.58 ± 1.05	−0.40 ± 1.38	−0.36 ± 1.19	NS	
N-Go$_c$-Me	0.66 ± 0.95	1.02 ± 1.41	O.48 ± 1.37	NS	
Dc-Xi-Pm	0.70 ± 1.62	0.26 ± 1.20	0.34 ± 1.08	NS	
Dentoalveolar					
1-PP	0.72 ± 1.21	1.78 ± 1.23	0.76 ± 0.98	**	A × B***; A × C (NS); B × C***
6-PP	−0.24 ± 1.32	−0.58 ± 1.72	1.18 ± 0.97	***	A × B (NS); A × C***; B × C***
1-GoMe	0.16 ± 1.12	0.28 ± 1.01	0.82 ± 0.78	*	A × B (NS); A × C (p) = **; B × C*
6-GoMe	1.34 ± 1.24	1.74 ± 1.09	1.30 ± 0.79	NS	
1/S N	−3.40 ± 3.79	−7.94 ± 5.51	0.00 ± 2.28	***	A × B***; A × C***; B × C***
IMPA	7.66 ± 5.04	6.18 ± 3.60	0.36 ± 2.69	***	A × B (NS); A × C***; B × C***

* $P< 0.05$; ** $P< 0.01$; *** $P< 0.001$; NS, Not significant.

Table 3
Comparison of Pancherz's analysis of variables between T1 and T2 (paired *t*-test)

Variables	Group A			Group B			Group C		
	T1	T2	*P*	T1	T2	*P*	T1	T2	*P*
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
is/OLp (mm)	89.18 ± 4.16	89.66 ± 4.47	NS	90.38 ± 5.33	90.06 ± 6.01	NS	90.06 ± 4.66	91.78 ± 4.65	***
ii/OLp (mm)	80.52 ± 5.30	86.00 ± 4.64	***	79.42 ± 4.78	85.98 ± 5.84	***	81.32 ± 5.20	83.20 ± 5.07	***
Ms/OLp (mm)	56.12 ± 4.04	55.18 ± 3.92	*	55.00 ± 4.11	55.26 ± 4.75	NS	56.02 ± 4.50	58.38 ± 4.48	***
Mi/OLp (mm)	54.50 ± 3.94	59.96 ± 4.06	***	52.84 ± 3.66	58.92 ± 4.66	***	54.62 ± 5.27	56.88 ± 5.10	***
A/OLp (mm)	79.62 ± 4.23	80.50 ± 4.16	*	78.88 ± 3.41	80.10 ± 4.09	***	80.52 ± 4.30	81.94 ± 4.19	***
pg/OLp (mm)	78.74 ± 5.05	82.60 ± 5.58	***	78.10 ± 4.84	82.70 ± 5.98	***	80.74 ± 4.98	82.86 ± 5.17	***
ar/OLp (mm)	10.68 ± 2.52	10.44 ± 2.58	NS	12.02 ± 3.45	11.94 ± 3.63	NS	9.72 ± 3.49	10.10 ± 3.52	**
co/OLp (mm)	13.14 ± 2.58	13.10 ± 2.53	NS	14.30 ± 3.46	13.96 ± 3.56	NS	11.84 ± 3.38	12.14 ± 3.51	NS
is/OLp minus ii/OLp	8.66 ± 2.62	3.66 ± 2.06	***	10.96 ± 2.81	4.08 ± 1.80	***	8.74 ± 3.45	8.58 ± 3.74	NS
Ms/OLp minus mi/OLp	1.64 ± 1.50	−4.12 ± 2.64	***	2.16 ± 1.44	−3.66 ± 2.18	***	1.40 ± 1.80	1. 50 ± 1.69	NS
pg/OLp + ar/OLp	89.42 ± 4.85	92.86 ± 5.57	***	90.12 ± 5.31	94.64 ± 6.10	***	90.46 ± 5.84	92.96 ± 5.99	***
pg/OLp + co/OLp	91.88 ± 5.11	95.40 ± 5.73	***	92.40 ± 5.59	96.66 ± 6.49	***	92.58 ± 5.97	95.00 ± 6.12	***
is/OLp minus A/OLp	9.56 ± 2.63	9.16 ± 3.03	NS	11.50 ± 2.85	9.96 ± 2.60	***	9.54 ± 3.52	9.84 ± 3.98	NS
ii/OLp minus pg/OLp	1.78 ± 3.03	3.40 ± 3.29	***	1.32 ± 4.70	3.28 ± 4.30	***	0.58 ± 4.41	0.34 ± 4.64	NS
Ms/OLp minus A/OLp	−23.50 ± 2.11	−25.32 ± 2.05	***	−23.88 ± 2.19	−24.84 ± 2.40	**	−24.60 ± 2.67	−23.56 ± 2.77	***
Mi/OLp minus pg/OLp	−24.24 ± 2.69	−22.64 ± 3.19	***	−25.26 ± 3.40	−23.78 ± 3.98	***	−26.12 ± 4.46	−25.98 ± 4.42	NS
OL.NS (°)	18.94 ± 3.73	21.00 ± 3.44	***	18.36 ± 4.60	22.18 ± 5.10	***	19.48 ± 4.93	19.14 ± 4.84	NS

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS, not significant.

flowcharts (Figs. 3, 4, 5, and 6) revealed that group A had a greater orthopedic response for the correction of overjet and group B had a clear skeletal effect on molar correction. Other studies [7,15,18] also found more marked orthopedic results when using Herbst appliances with splints. In our study, the ANB angle decreased significantly in groups A and B, which promoted the correction of mandibular retrognathism.

In addition to the orthopedic effects of treatment on the correction of Class II malocclusion, there were compensation mechanisms, as shown in several other studies [1,2,4,7,15]. The result of distal movement (ms/Lop–A/LOp) of maxillary molars was greater in group A (2.76 mm) than in group B (1.95 mm) and similar to those reported in previous studies [1,14,17]. This effect of the Herbst appliances with stainless steel crowns may be useful to obtain space in the maxillary arch, in the case of lack of space for canines, for example. Mandibular molars moved mesially (mi/Lop–pg/LOp) at practically the same rate (groups A and B), in agreement with previous findings [1,3,17]. There was vertical movement (groups A, B, and C) and the maxillary incisors tipped palatally (groups A and B) between T1 and T2, which was greater in group B, probably due to the excessive buccal inclination found in this group at T1. Lip sealing resulting from mandibular advancement when using the Herbst appliance, together with maxillary expansion in the two groups, may explain this movement [19]. Mandibular incisors protruded (ii/Lop–pg/LOp) similarly in groups A and B. There was a restriction of the vertical displacement of the lower incisors in groups A and B, probably due to forward movement. Therefore, this movement of mandibular incisors may be said to be unavoidable, because mandibular advancement and the mechanism of the Herbst appliance release forces that facilitate the loss of anchorage [15,17,18,20].

The occlusal plane (SN.LO) had a clockwise rotation in groups A and B because of the vertical control of maxillary molars (6-PP), while in group B, the interoclusal acrylic splints limited posterior vertical movement. Treatment did not result in significant vertical changes in the mandibular molars (6-GoMe) compared with the control group. Our results confirm findings in other studies despite

Table 4
Comparisons of differences of the Pancherz's analysis of variance between groups from T1 to T2 (analysis of variance and Tukey test for multiple comparisons)

Cephalometric variable	Group A	Group B	Group C	*P*	Tukey test for multiple comparisons
	Mean ± SD	Mean ± SD	Mean ± SD		
is/OLp (mm)	0.48 ± 1.53	−0.32 ± 1.99	1.72 ± 1.57	***	A × B (NS); A × C***; B × C***
ii/OLp (mm)	5.48 ± 1.71	6.56 ± 2.15	1.88 ± 1.52	***	A × B (NS); A × C***; B × C***
ms/OLp (mm)	−0.94 ± 1.72	0.26 ± 1.98	2.46 ± 1.17	***	A × B**; A × C***; B × C***
mi/OLp (mm)	5.46 ± 1.98	6.08 ± 1.85	2.26 ± 1.66	***	A × B (NS); A × C***; B × C***
A/OLp (mm)	0.88 ± 1.62	1.22 ± 1.28	1.42 ± 1.00	NS	
pg/OLp (mm)	3.86 ± 2.10	4.60 ± 2.63	2.12 ± 1.41	***	A × B (NS); A × C (NS); B × C**
ar/OLp (mm)	−0.24 ± 1.05	−0.08 ± 1.62	0.38 ± 0.63	NS	
co/OLp (mm)	−0.04 ± 1.13	−0.34 ± 1.62	0.30 ± 1.15	NS	
is/OLp minus ii/OLp	−5.00 ± 1.94	−6.68 ± 2.03	−0.16 ± 1.12		A × B**; A × C***; B × C***
ms/OLp minus mi/OLp	−5.76 ± 2.57	−5.82 ± 2.26	0.10 ± 1.11	***	A × B (NS); A × C***; B × C***
pg/OLp + ar/OLp	3.44 ± 2.04	4.52 ± 1.71	2.50 ± 1.46	***	A × B (NS); A × C (NS); B × C**
pg/OLp + co/OLp	3.52 ± 2.30	4.26 ± 2.17	2.42 ± 1.91	*	A × B (NS); A × C (NS); B × C**
is/OLp minus A/OLp	−0.40 ± 1.40	−1.54 ± 1.75	0.44 ± 1.43	***	A × B (NS); A × C**; B × C***
ii/OLp minus pg/OLp	1.62 ± 1.84	1.96 ± 1.70	−0.24 ± 1.17	***	A × B (NS); A × C***; B × C***
ms/OLp minus A/OLp	−1.82 ± 1.51	−0.96 ± 1.90	−1.04 ± 1.10	***	A × B*; A × C***; B × C***
mi/OLp minus pg/OLp	−1.60 ± 1.17	−1.48 ± 1.69	−0.14 ± 0.84	***	A × B (NS); A × C***; B × C***
OL.NS (°)	2.06 ± 1.87	3.82 ± 2.90	−0.34 ± 1.00	***	A × B**; A × C***; B × C***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS, not significant.

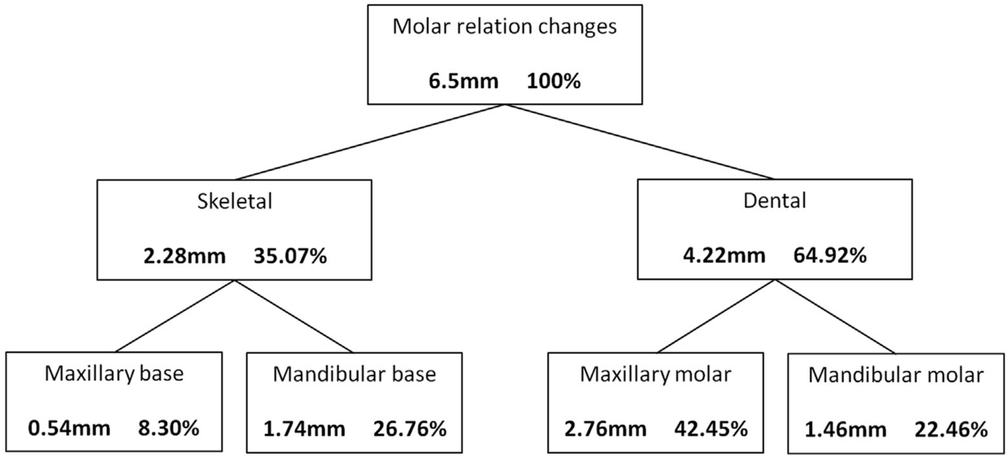

Fig. 3. Mechanism of molar correction (T1 × T2) in group A, considering growth changes in control group (group C).

differences in methods [3,18], but other studies found greater vertical movement of mandibular molars [1,21].

In this study, the height of the lower third of the face (ENA-Me) had a significant increase in the three groups [1,3], probably due to the increase in the effective length of the maxilla and the mandible. The increase in anterior facial height was parallel to the downward growth of the mandibular plane. These findings were expected, as the increase of anterior facial height during treatment results from the geometric effect of anterior mandibular repositioning and the increase in mandibular length.

Facial patterns in groups A and B were preserved, and the evaluation of the 6-PP variable in groups A and B was not significantly different between T1 and T2 and confirmed the vertical control of the posterior area of the maxilla. Patients in the two treatment groups underwent rapid maxillary expansion in the beginning of the treatment, which resulted in clinically confirmed downward and backward rotation of the mandible [19].

The high pull of the tubes of the Herbst appliance and the favorable growth pattern of the patients in groups A and B were positive contributions along treatment and compensated for the deleterious baseline vertical effects of rapid maxillary expansion on the correction of the transverse component of malocclusion. Therefore, the balance between anterior facial height (N-Me) and posterior facial height (S-Goc) was preserved, and facial pattern was not changed [2,13,15,22].

Although the upper gonion angle (Ar-Go_C-N) decreased significantly in group A, the lower gonion angle increased in groups A and B, and mandibular morphology (Ar-Go_C-Me) did not change in the treatment groups. Similar findings were reported by Franchi et al. [17], who evaluated patients at the same maturation stage as the patients in this study.

Finally, all patients in this study underwent a second orthodontic treatment phase, with fixed appliances to refine occlusion. When that phase is completed, further evaluations will be conducted to check stability of facial patterns from the beginning to the end of the orthodontic treatment.

5. Conclusion

The treatment with two types of Herbst appliance resulted in changes that improved sagittal skeletal and dental relations, regardless of growth. The control of vertical growth pattern did not depend on the type of the Herbst appliance is used; however, in cases of lack of space in the maxillary arch, the Herbst appliance with steel crowns was more efficient.

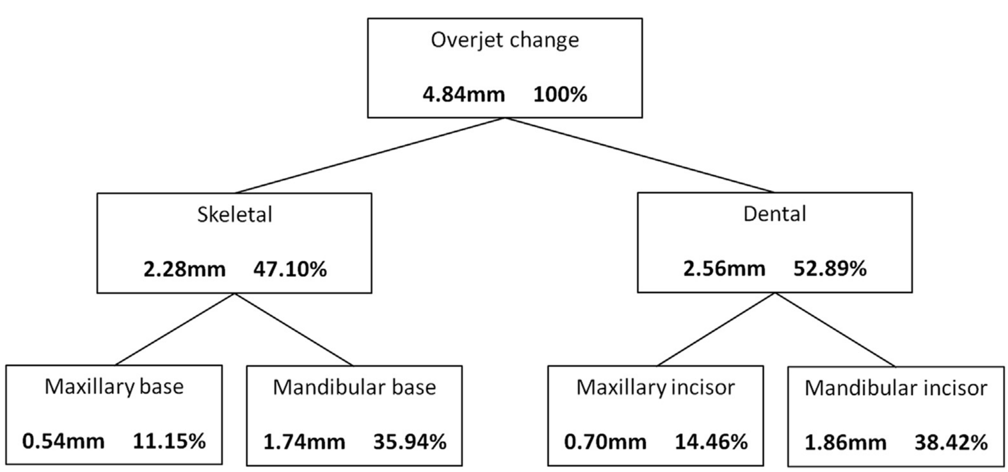

Fig. 4. Mechanism of overjet correction (T1 × T2) in group A, considering growth changes in control group (group C).

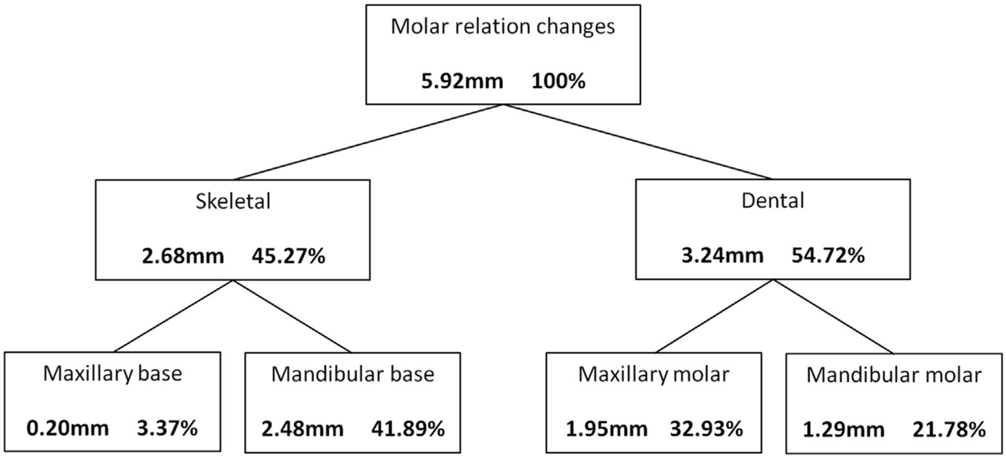

Fig. 5. Mechanism of molar correction (T1 × T2) in group B, considering growth changes in control group (group C).

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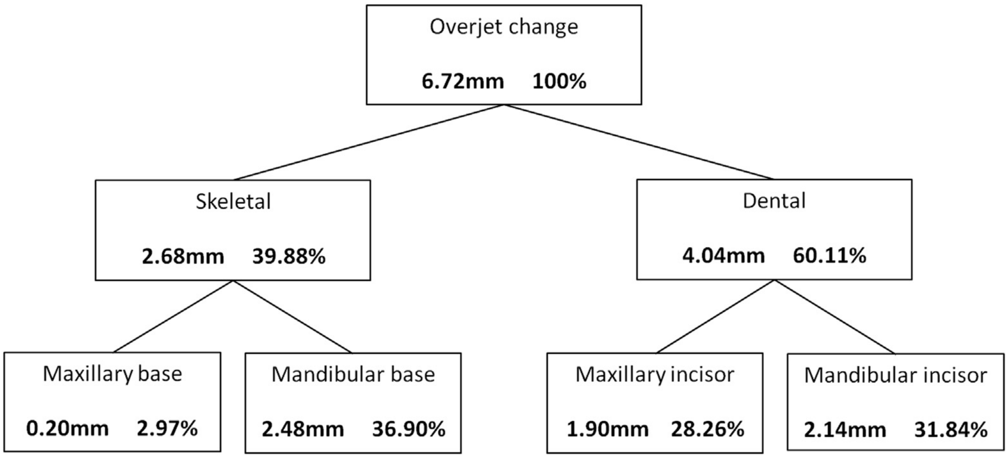

Fig. 6. Mechanism of overjet correction (T1 × T2) in group B, considering growth changes in control group (group C).