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Retrospective comparison of dental and skeletal effects in the treatment of Class II malocclusion between Herbst and Xbow appliances

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Introduction: The purpose of this research was to compare dentoskeletal changes produced by Herbst and Xbow appliances in late mixed/early permanent dentition patients with Class II Division 1 malocclusion to an untreated control group. **Methods:** The retrospective cohort consisted of 41 patients treated with the Herbst appliance on average for 14 months (mean age of 11.3 years), 41 patients treated with Xbow appliance on average for 14 months (mean age of 11.11 years), and an untreated control sample of 25 patients followed on average for 21 months (mean age of 11.9 years). All patients had Class II Division 1 malocclusion characteristics. Lateral cephalometric radiographs were taken before and after phase 1 treatment/follow-up. Data were analyzed by an analysis of variance followed by Tukey post-hoc tests. **Results:** Although there was a high equivalence among the groups in the pretreatment cephalometric values, 4 variables showed differences (U6-FHp, L6-FHp, LAFH, and PP-U1). When comparing the mean changes (before and after phase 1 treatment/follow-up), incisor mandibular plane angle (IMPA), Wits appraisal, L6-FHp, Co-Pog, and PP-U1 measurements showed statistically significant differences. In addition, more relative mesial movement of the mandibular molars (an additional 2.4 mm) and a larger increase in mandibular length (an additional 3.2 mm) was noted for the Herbst group. **Conclusions:** Class II correction using Herbst and Xbow occurred in both groups through improvement in the maxillomandibular relationship and labial inclination of the mandibular incisors, as well as a relatively increased mesialization of the mandibular molars. Although both appliances improve occlusal features, the portrayed changes were not always similar. Herbst seems to produce more mandibular size increase over a similar treatment period. (Am J Orthod Dentofacial Orthop 2021;■:■-■)

Several orthopedic appliance types have been used for the correction of Class II malocclusion, aiming to possibly improve functional, muscular, skeletal, and dental disharmonies.[1-3] A wide array of related published articles have been summarized through several systematic reviews with or without meta-analysis.

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Submitted, September 2019; revised and accepted, May 2020.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2020.05.021

The Herbst appliance is widely known for its relative effectiveness in correcting Class II malocclusions. It is most commonly used as a fixed device that repositions the jaw to a more anterior and downward position displacing the condyles away from the articular eminence.[4-8] This is thought to facilitate condylar bone apposition; hence, increasing overall mandibular size dimensions. Several papers have considered the efficiency of the Herbst appliance in the Class II correction during early permanent dentition. But only one study evaluated changes produced by the Herbst appliance in mixed dentition patients, and it concluded that the effects of the Herbst appliance were mainly dentoalveolar.[5] Several different designs of the Herbst appliance have been reported in the literature.[6-11]

The Xbow appliance is a fixed Class II corrector, with only a few published studies reporting its effectiveness and mechanism of Class II malocclusion correction.[12-17]

Fig 1. Modified Herbst appliance.

A recent study reported that the immediate changes in patients treated with the Xbow appliance were associated with more dental than skeletal changes.[12]

Only 1 previous study directly compared the Xbow appliance to another form of Class II correction. Ehsani et al[17] investigated skeletal and dental differences after orthodontic treatment in which the Xbow and Twin-block appliance among patients with Class II malocclusion and concluded that the Class II correction using an Xbow or Twin-block followed by fixed devices occurred by means of a relatively similar combination of dental and skeletal effects. Nevertheless, they noted that the magnitude of mandibular skeletal increase when using the Twin-block was more significant (around 3 mm more).

To date, no study has directly compared the treatment results of Class II malocclusion treatment between Herbst and Xbow fixed Class II appliances. Therefore, the objective of this retrospective clinical research is to evaluate the dental and skeletal cephalometric effects produced by these appliances in young patients with Class II Division 1 malocclusion during late mixed dentition or early permanent dentition and to compare those change with an untreated Class II malocclusion control group.

MATERIAL AND METHODS

This retrospective study was approved by the Ethics Committee of the Faculty of Dentistry of Bauru, University of São Paulo, Brazil (protocol no. 82197317.1.0000.5417).

The sample size was calculated by assuming an alpha of 5%, a beta of 20%, and a mean clinically meaningful difference of 3.6 mm with a standard deviation of 3.8 mm for Co-Pog.[18] On the basis of these parameters, a minimal sample size of 36 patients was needed per group. An effect size of 0.5 would be discernable with this sample size.

The Herbst group comprised 41 patients (20 males and 21 females), with an initial mean age of 11 years 3 months and final mean age of 12 years 6 months, who were treated with the modified Herbst appliance (Fig 1) for approximatively 14 months. All patients were treated by a single clinician (M.R.A.) at the Orthodontics Clinic of the Faculty of Dentistry of Bauru. Initial cephalogram (T1) was obtained 2 weeks before the appliance was installed and the final cephalogram (T2) approximately 4 weeks after removal of the Herbst appliance to potentially eliminate any mandibular postural advancement caused by the appliance. Fixed orthodontic appliances were placed around 4 weeks after Herbst therapy to let the occlusion settled. The initial characteristics of this group can be seen in Table 1.

The Xbow group consisted of 41 patients (21 males and 20 females), with a mean initial age of 11 years 11 months and final mean age of 12 years and 3 months, treated for an average of 14 months (Fig 2). The sample obtained was treated by a different single clinician in the private clinic of the inventor of the Xbow appliance (Duncan W. Higgins). Initial cephalogram (T1) was obtained between 2 and 4 weeks before the appliance was installed and the final cephalogram (T2)

Table I. Descriptive statistics of the sample

Variable	Mean values: Control	Herbst	Xbow	P value
Age at T1 (y)	11.90	11.31	11.11	0.673
Age at T2 (y)	13.70[a]	12.59[b]	12.39[b]	0.000*
Treatment/observation	1.82[a]	1.28[b]	1.28[b]	0.001*

Note. Different letters indicate statistically significant differences.
*Statistically significant at $P < 0.05$.

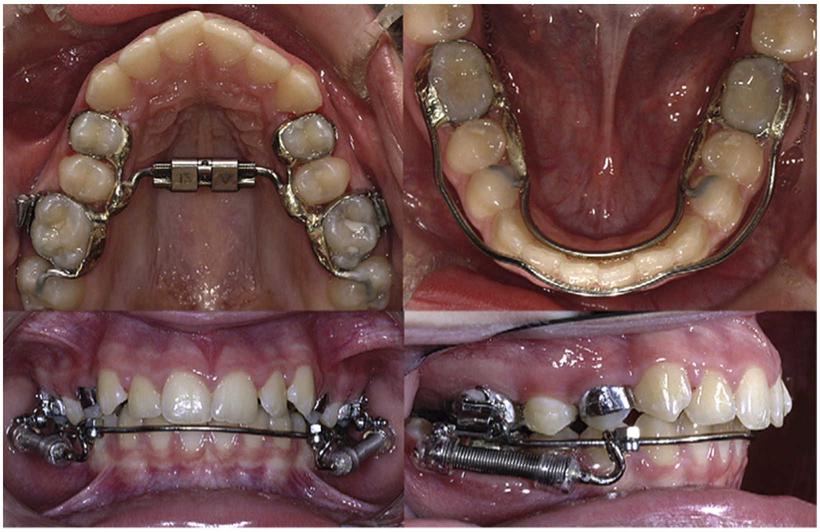

Fig 2. Xbow appliance.

approximately 4 months after the removal of the Xbow appliance to eliminate any mandibular postural advancement and/or the dentoalveolar compensation caused by the appliance. Fixed orthodontic appliances were placed around 4 months after Xbow therapy. The initial characteristics of this group can be seen in Table I.

The control group included 25 patients (16 males and 9 females), with an initial mean age of 11 years 9 months and final mean age of 13 years 7 months, who were followed up for 1 year 8 months. This group was selected from the longitudinal growth study sample from the University of Toronto Burlington Growth Study (Department of Orthodontics, University of Toronto, Toronto, Ontario, Canada).

The samples were selected according to the following inclusion criteria: (1) Class II Division 1 (greater than one-half cusp Class II molar on both sides); (2) ANB angle, ≥4.5°; (3) overjet, >4 mm; (4) absence of agenesis or loss of permanent teeth; (5) absence of supernumerary teeth; and (6) dental arches with no to mild crowding.

Patients requiring teeth extraction and/or orthognathic surgery or syndromic patients were excluded.

For a direct comparison among the groups, the measurements of the control group were annualized[1] and adjusted to an average time frame of 1 year and 2 months follow-up to be compared with the treated groups (average available time frame of 1 year 2 months).

Cephalograms of each patient were obtained in pretreatment (T1) and posttreatment (T2). They were digitized and had their marks identified by a single operator (R.R.A.P) in the Dolphin Imaging software (version 11.5; Dolphin Imaging and Management Solutions, Chatsworth, Calif), which also corrected the magnification factors of the different radiographic machines in which the lateral cephalograms were taken. All patients per group were imaged by the same radiographic machine, but those machines were different between groups. Cephalometric variables can be observed in Table II. Posttreatment changes were calculated from T2 − T1. The reference lines and planes used in this study are shown in Table III and Figures 3 and 4.

To determine the reliability of the measurements, 20 cephalograms were randomly selected, traced, and digitized by a single operator, blinded as to treatment

Table II. Results of intergroup comparison of the pretreatment cephalometric variables

	Control (n = 25)		Herbst (n = 41)		Xbow (n = 41)		
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P value*
A-Na Perp (mm)	2.32	3.26	3.28	2.88	2.60	2.65	0.223
Pg-Na Perp (mm)	−4.50	5.38	−3.50	4.61	−3.72	5.74	0.117
Co-Pog (mm)	101.82	4.09	104.79	5.82	100.32	6.71	0.679
Go-Pg (mm)	67.42	3.72	70.87	4.83	66.03	5.84	0.587
Wits appraisal (mm)	3.10	2.53	4.11	2.42	4.14	2.33	0.300
Frankfort-mandibular plane angle (°)	23.54	3.70	24.23	4.78	23.53	5.25	0.761
SGo (mm)	68.29	5.15	71.04	5.11	68.45	6.23	0.061
LAFH (mm)	57.83[a]	3.23	63.67[b]	4.88	60.16[a]	5.27	<0.001*
PP-U1 (°)	107.49[a]	6.13	116.65[b]	5.57	110.09[b]	9.00	<0.001*
Incisor mandibular plane angle (°)	98.68	5.81	99.23	5.56	97.71	6.06	0.493
U6-FHp (mm)	56.28[a]	4.25	55.84[a]	4.54	51.87[b]	3.81	<0.001*
L6-FHp (mm)	55.75[a]	4.25	54.21[a]	4.71	50.97[b]	4.07	<0.001*

Note. Data analyzed using 1-way analysis of variance followed by a Tukey post-hoc test. Different letters indicate statistically significant differences. *Statistically significant at $P < 0.05$.

Table III. Results of intergroup comparison of the treatment/observation changes

	Control (n = 25)		Herbst (n = 41)		Xbow (n = 41)		
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P value*
A-Na Perp (mm)	0.00	0.73	−0.39	2.03	0.69	2.73	0.075
Pg-Na Perp (mm)	0.47	1.38	1.26	3.30	2.34	3.72	0.059
Co-Pog (mm)	2.66[ab]	1.47	4.71[a]	4.59	1.53[b]	4.08	0.001*
Go-Pg (mm)	1.41	0.90	3.02	4.25	1.46	5.01	0.157
Wits appraisal (mm)	0.08[a]	0.39	−3.11[b]	2.37	−2.44[b]	2.05	<0.001*
Frankfort-mandibular plane angle (°)	−0.70	1.17	0.34	2.25	−0.72	2.78	0.074
SGo (mm)	2.97	1.98	3.05	4.46	1.07	5.08	0.078
LAFH (mm)	1.53	1.19	2.45	3.34	1.26	3.83	0.225
PP-U1 (°)	−0.08[a]	1.30	−3.77[b]	6.17	−0.65[ab]	8.55	0.040*
Incisor mandibular plane angle (°)	0.05[a]	0.77	4.74[b]	5.62	4.29[b]	4.26	<0.001*
U6-FHp (mm)	1.67	0.64	1.38	4.38	0.56	4.73	0.485
L6-FHp (mm)	1.43[a]	0.68	6.32[b]	4.49	3.89[a]	5.10	<0.001*

Note. Data analyzed using 1-way analysis of variance followed by a Tukey post-hoc test. Different letters indicate statistically significant differences. *Statistically significant at $P < 0.05$.

groups and period after 1 month of the initial tracing. The difference between the first and second measurements of each cephalogram was determined, and the Dahlberg formula[19] was applied to visualize the casual error according to Houston.[20] The systematic error was determined by comparing the measurements by means of the paired *t* test.

Statistical analysis

All the quantitative measurements passed the Kolmogorov-Smirnov normality test. For comparison among the 3 groups, 1-way analysis of variance and Tukey post-hoc tests were used when indicated. An independent *t* test was used for gender comparisons.

In all tests, a significance level of 5% ($P < 0.05$) was adopted. All statistical procedures were conducted by using the SPSS software (version 25; IBM, Armonk, NY).

RESULTS

The measurement error of the method did not exceed 1.2° (Frankfort-mandibular plane angle) and 1.2 mm (A-Na-Perp), whereas the paired *t* test did not reveal statistically significant differences for systematic errors.

A comparative analysis of the initial cephalometric values (T1) was carried out to investigate the equivalence of the 3 groups. Although there was a high equivalence among the groups in the pretreatment cephalometric values, 4 variables showed significant differences among the groups (Table II). Of the linear measurements, the maxillary molar (U6-FHp; 4.41 mm) and mandibular molar (L6-FHp; 4.78 mm) were more mesialized in the control group than the Xbow group. Regarding the LAFH variable, the Herbst group showed greater anteroinferior facial length (3.23 mm) when compared with the Xbow and control groups. The inclination of the

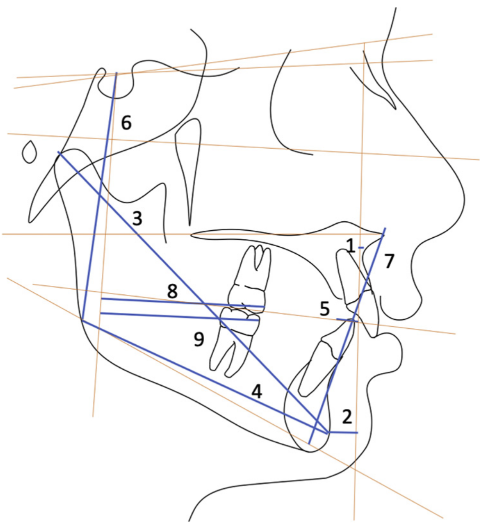

Fig 3. Landmarks and linear measurements: **1,** A-Na Perp; **2,** Pg-Na Perp; **3,** Co-Pog; **4,** Go-Pg; **5,** Wits appraisal; **6,** SGo; **7,** LAFH; **8,** U6-FHp; **9,** L6-FHp.

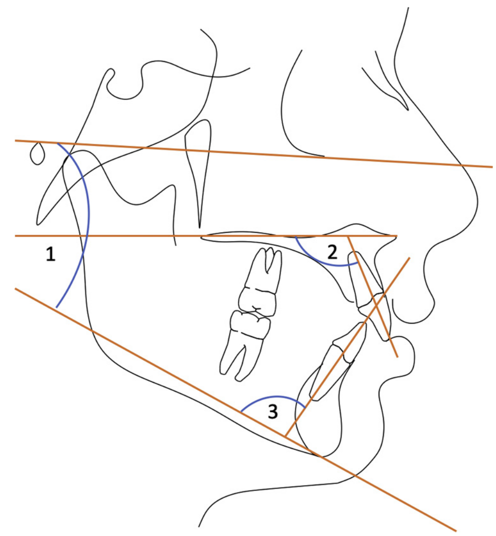

Fig 4. Landmarks and angular measurements: **1,** Frankfort-mandibular plane angle; **2,** PP-U1; **3,** incisor mandibular plane angle.

maxillary incisors (PP-U1) was approximately 9° more protruded in the Herbst group than in the control group. Overall this likely implies that the control group had increased facial vertical features.

The variations of the cephalometric measurements between T1 and T2 are presented in Table III. When comparing the mean changes (T2 − T1), IMPA, Wits appraisal, L6, Co-Pog, and PP-U1 measurements showed statistically significant differences (see below).

The Herbst group showed a significant improvement in the maxillomandibular relationship (Wits appraisal) compared with the control group (−3.11 mm; standard deviation [SD], 2.37 mm). The mandibular incisors showed significant labial movement in the Herbst (4.74°; SD, 5.62°) in relation to the control group. The mandibular molar presented significant relative mesialization in the Herbst group against the control group (6.32 mm; SD, 4.49 mm). The maxillary incisors (PP-U1) presented significant retrusion (−3.77°; SD, 6.17°) in relation to the control group.

Significant improvement was observed in the Xbow group in relation to the maxillomandibular relationship (Wits appraisal), which decreased significantly (−2.44 mm; SD, 2.05 mm) compared with the control group.

Co-Pg showed a greater increase in the Herbst group (3.18 mm) than in the Xbow group. The mandibular molar also presented significant relative mesialization in the Herbst group (2.43 mm) than in the Xbow group.

Results of gender comparison of the Herbst and Xbow treatment changes are presented in Table IV and V. When comparing the mean changes (T2 − T1) between females and males, measurements did not show statistically significant differences.

DISCUSSION

Previous studies have investigated the effects of the Herbst[8,10,11] and Xbow[12-17] appliances individually and compared them with other orthopedic appliances[9,17,21] but not between themselves. Therefore, the direct comparison between the differences in treatment of these 2 functional appliances, but more importantly, including an untreated control group, has not been reported. The results of this study suggested an improvement in the Class II occlusal relation as a result of mostly dental and some skeletal changes for both approaches, but with the Herbst producing increased mandibular skeletal changes. However, the magnitude of these changes could or not be considered clinically relevant on the basis of the patient's characteristics and the magnitude of initial skeletal sagittal discrepancy.

The purpose of including an untreated control group for comparison is that it may serve as an estimate of what should have happened in the treated patients if no treatment was provided. Therefore, the true effect (in this case, the use of the Herbst and Xbow appliances) can be appreciated and differentiated from expected normal craniofacial changes. Therefore, it was desirable to have a control group with growth potential (magnitude and direction) similar for both treated groups. In this study, the control group also had similar Class II malocclusion characteristics.

Table IV. Results of gender comparison of the Herbst treatment changes

	Female (n = 21)		Male (n = 20)		
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*
A-Na Perp (mm)	−0.38	2.03	−0.40	2.09	0.982
Pg-Na Perp (mm)	1.23	3.02	1.28	3.65	0.964
Co-Pog (mm)	5.47	3.20	3.91	5.68	0.282
Go-Pg (mm)	3.07	3.34	2.97	5.14	0.940
Wits appraisal (mm)	−3.47	2.63	−2.75	2.06	0.326
Frankfort-mandibular plane angle (°)	0.17	2.31	0.51	2.23	0.640
SGo (mm)	4.05	2.67	2.00	5.67	0.143
LAFH (mm)	2.51	2.43	2.38	4.15	0.903
PP-U1 (°)	−4.58	7.41	−2.91	4.55	0.394
Incisor mandibular plane angle (°)	4.51	4.61	4.975	6.64	0.797
U6-FHp (mm)	1.89	4.43	0.84	4.37	0.450
L6-FHp (mm)	6.91	4.80	5.70	4.16	0.393

Note. Data analyzed using an independent *t* test.

Table V. Results of gender comparison of the Xbow treatment changes

	Female (n = 21)		Male (n = 20)		
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*
A-Na Perp (mm)	1.00	2.60	0.38	2.88	0.475
Pg-Na Perp (mm)	3.09	3.47	1.62	3.90	0.212
Co-Pog (mm)	1.74	4.58	1.32	7.24	0.587
Go-Pg (mm)	1.94	5.67	0.94	4.29	0.528
Wits appraisal (mm)	−2.62	2.12	−2.25	2.01	0.560
Frankfort-mandibular plane angle (°)	−1.36	2.51	−0.10	2.93	0.147
SGo (mm)	1.51	4.42	0.63	5.71	0.583
LAFH (mm)	1.50	3.09	1.03	4.50	0.702
PP-U1 (°)	−1.88	10.11	0.63	6.56	0.353
Incisor mandibular plane angle (°)	3.83	3.58	4.76	4.93	0.491
U6-FHp (mm)	1.08	5.22	0.01	4.21	0.475
L6-FHp (mm)	4.65	5.66	3.09	4.46	0.335

Note. Data analyzed using an independent *t* test.

Both experimental groups produced a small restriction on the normal expected mesial movement of the maxillary molars, with an additional relative mesial movement of the mandibular molars. It has to be considered that mandibular molars still moved forward as part of normal forward and downward nasomaxillary and mandibular unit displacements, but the total displacements of molars were different than those observed in the untreated control group (leeway space effect). In addition, the increase in the angulation of the mandibular incisors reduced the overbite and the overjet.

Skeletally, an improvement in the maxillomandibular relationship occurred, whereas the vertical changes were insignificant. Although in both experimental groups an increase in the effective length of the mandibular body was noted, for the Herbst group, the increase was larger (around 3.2 mm), whereas the amount of restriction of the relative mesial movement of the mandibular molar for the Xbow group (around 2.4 mm more) were notable differences between the 2 active intervention groups than in the untreated group changes. A possible explanation of the smaller mandibular size changes with the Xbow approach is based on the fact that the Forsus springs of the Xbow appliance do not permanently protrude the mandible forward, out of the glenoid fossa, as patients can force the condyle back into its original position if enough occlusal force is exerted. In those patients, additional mandibular growth would not necessarily be expected. This has been reported in several other studies involving nonprotruding Class II correctors.[22-25]

Regarding the mesial movement of the mandibular molars, the use of mandibular lingual arches in both experimental approaches could reduce the natural mesial migration of the molars in both treatment approaches than would normally be expected. In this study, the Herbst group mesial movement was 6.32 mm, and for the Xbow group, only 3.89 mm, being this difference statistically significant. A possible explanation is related to the fact that the difference of around 2.4 mm is similar to the amount of additional skeletal sagittal changes within the Herbst group. This implies that the molars are displaced relatively more as part of the overall mandibular size increase with the Herbst approach than the Xbow approach.

Several studies in the literature show significant increases in mandibular length in adolescent patients (Co-Gn or Co-Pog) treated with the Herbst appliance, as reported by Pancherz[7,26] (2.2 mm) and Windmiller[27] (3.4 mm). A recent study[12] that evaluated the skeletal and dental effects of the Xbow appliance in a short time showed an average of nearly 15% of total overjet correction; the remaining 25% of the change was due to normal growth. In this retrospective study, it was observed that the mandibular length increased more in the Herbst group (4.71 mm) than in the Xbow group (1.53 mm). A similar retrospective study[17] compared the efficacy of Xbow and Twin-block followed by complete fixed appliances. Similar results were found, except for a small increase in sagittal correction with Twin-block because of a greater increase in mandibular length (around 3 mm). It is important to take into consideration that Herbst and Xbow are conceptually different (Xbow is a nonpermanent protrusive Class II corrector).[12] In contrast to the Twin-block or Herbst that positions the jaw forward, the Xbow does not position the jaw out of the glenoid fossa permanently. How much this is actually done is difficult to quantify. The patient is always able to return the condyle to the glenoid fossa in the mouth closure and intercuspation. This may explain some of the dentoalveolar and skeletal differences noted between both therapeutic approaches.

In regard to the mandibular incisor inclination, it is observed that most of the authors who study the effects of orthopedic appliances always found a degree of buccal inclination of the mandibular incisors.[1-3,28] In the control group, the mandibular incisors remained stable (0.05°) in relation to the mandibular plane (IMPA). A significant vestibularization was observed in the mandibular incisors in the Herbst (4.74°) and Xbow (4.29°) groups, which corroborated the results reported previously by Moro et al[11] and Ehsani et al[17] for each appliance, respectively. This buccal inclination of the mandibular incisors probably occurs because of the mesial forces applied on the incisors, induced by the force mechanisms of the Herbst and Xbow appliances, which produce effective downward and forward forces over them. This observation is corroborated by studies by Pancherz,[6,26] who also visualized an increase in the inclination of the mandibular incisors relative to the mandibular plane (IMPA) of 5.4°.

Limitations for this study included the following: (1) samples were not randomized, which are generally accepted as the best possible trial design when addressing therapeutic effects; (2) the timing of the peak growth of the patients in the sample was not measured, and it may be considered impactful for the interpretation of the results; (3) reported results do not address long-term stability; (4) the use of a historical untreated control sample has its potential drawbacks, as noted before. There is some mounting evidence that secular trends imply that craniofacial growth from historical samples may not be completely similar to current samples. Therefore, the use of historical samples might be considered unwise by some; (5) the lateral cephalograms taken in T2 were performed at different time frames, around 4 weeks for the Herbst device and 4 months for the Xbow device. This may imply that there was more postural mandibular change relapse before the Xbow approach T2 x-rays. To our knowledge, there is no study that verifies the immediate effectiveness of the orthopedic treatment of the Xbow, only for the Herbst appliance. However, we think that this is a unique study, although 1 of the limitations is the difference in the second lateral cephalogram (T2) between the groups; and (6) the expansion screw is part of the Xbow appliance setup. It is not always activated. These were not controlled in the present analysis.

CONCLUSIONS

1. Treatment with the Herbst and Xbow appliances in patients with Class II malocclusion produced dental and skeletal alterations favorable to Class II correction, with more dental than skeletal changes, although with subtle differences between them.
2. Both treated groups showed a significant labial inclination (4°-5°) of the mandibular incisors compared with the control group. Maxillary incisors were significantly retruded (3.8°) with the Herbst appliance treatment.
3. The mandibular molars were displaced more mesially (2.4 mm) in the Herbst group than in the Xbow group.
4. There was a more significant increase in mandibular length (around 3 mm) in the Herbst group than in the Xbow group.
5. When a more significant mandibular size increase is sought, the Herbst appliance should be the

appliance of choice. However, when more dentoalveolar effects are sought, the Xbow is a reasonable alternative.

REFERENCES

1. De Almeida MR, Henriques JF, Ursi W. Comparative study of the Fränkel (FR-2) and bionator appliances in the treatment of Class II malocclusion. Am J Orthod Dentofacial Orthop 2002;121:458-66.
2. Rodrigues de Almeida M, Castanha Henriques JF, Rodrigues de Almeida R, Ursi W. Treatment effects produced by Fränkel appliance in patients with Class II, Division 1 malocclusion. Angle Orthod 2002;72:418-25.
3. Almeida MR, Henriques JF, Almeida RR, Almeida-Pedrin RR, Ursi W. Treatment effects produced by the bionator appliance. Comparison with an untreated Class II sample. Eur J Orthod 2004;26:65-72.
4. Keim RG, Gottlieb EL, Nelson AH, Vogels DS 3rd. 2002 JCO study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends. J Clin Orthod 2002;42:625-40.
5. De Almeida MR, Henriques JF, de Almeida RR, Weber U, McNamara JA Jr. Short-term treatment effects produced by the Herbst appliance in the mixed dentition. Angle Orthod 2005;75:540-7.
6. Moro A, Janson G, Moresca R, de Freitas MR, Henriques JF. Comparative study of complications during Herbst treatment with Cantilever Bite Jumper and removable mandibular acrylic splint. Dental Press J Orthod 2011;16:29.e1-7.
7. Pancherz H. Treatment of Class II malocclusions by jumping the bite with the Herbst appliance. A cephalometric investigation. Am J Orthod 1979;76:423-42.
8. 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.
9. Valant JR, Sinclair PM. Treatment effects of the Herbst appliance. Am J Orthod Dentofacial Orthop 1989;95:138-47.
10. McNamara JA Jr, Howe RP, Dischinger TG. A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion. Am J Orthod Dentofacial Orthop 1990;98:134-44.
11. Moro A, Janson G, de Freitas MR, Henriques JF, Petrelli NE, Lauris JP. Class II correction with the Cantilever Bite Jumper. Angle Orthod 2009;79:221-9.
12. Flores-Mir C, Barnett GA, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009; 136:822-32.
13. Aziz T, Nassar U, Flores-Mir C. Prediction of lower incisor proclination during Xbow treatment based on initial cephalometric variables. Angle Orthod 2012;82:472-9.
14. Flores-Mir C, Young A, Greiss A, Woynorowski M, Peng J. Lower incisor inclination changes during Xbow treatment according to vertical facial type. Angle Orthod 2010;80:1075-80.
15. Erbas B, Kocadereli I. Upper airway changes after Xbow appliance therapy evaluated with cone beam computed tomography. Angle Orthod 2014;84:693-700.
16. Miller RA, Tieu L, Flores-Mir C. Incisor inclination changes produced by two compliance-free Class II correction protocols for the treatment of mild to moderate Class II malocclusions. Angle Orthod 2013;83:431-6.
17. Ehsani S, Nebbe B, Normando D, Lagravere MO, Flores-Mir C. Dental and skeletal changes in mild to moderate Class II malocclusions treated by either a Twin-block or Xbow appliance followed by full fixed orthodontic treatment. Angle Orthod 2015;85: 997-1002.
18. Yang X, Zhu Y, Long H, Zhou Y, Jian F, Ye N, et al. The effectiveness of the Herbst appliance for patients with Class II malocclusion: a meta-analysis. Eur J Orthod 2016;38:324-33.
19. Dahlberg G. Errors of estimation. In: Statistical Methods for Medical and Biological Students. London: George Allen & Unwin; 1940. p. 122-32.
20. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
21. Schaefer AT, McNamara JA Jr, 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.
22. Flores-Mir C. Can we extract useful and scientifically sound information from retrospective nonrandomized trials to be applied in orthodontic evidence-based practice treatments? Am J Orthod Dentofacial Orthop 2007;131:707-8: discussion 708-9.
23. Cope JB, Buschang PH, Cope DD, Parker J, Blackwood HO 3rd. Quantitative evaluation of craniofacial changes with Jasper Jumper therapy. Angle Orthod 1994;64:113-22.
24. Covell DA Jr, Trammell DW, Boero RP, West R. A cephalometric study of Class II Division 1 malocclusions treated with the Jasper Jumper appliance. Angle Orthod 1999;69:311-20.
25. Nalbantgil D, Arun T, Sayinsu K, Fulya I. Skeletal, dental and soft-tissue changes induced by the Jasper Jumper appliance in late adolescence. Angle Orthod 2005;75:426-36.
26. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. Am J Orthod 1982; 82:104-13.
27. Windmiller EC. The acrylic-splint Herbst appliance: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1993;104: 73-84.
28. McNamara JA Jr, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy on Class II patients. Am J Orthod 1985;88:91-110.