

Herbst appliance anchored to miniscrews in the upper and lower arches vs standard Herbst: A pilot study

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Introduction: The aim of this pilot study was to present the preliminary results of Class II malocclusion treatment using a skeletally anchored Herbst appliance with miniscrews inserted in the maxillary and mandibular arches to improve anchorage control and skeletal effects. **Methods:** The treatment group (TG) consisted of 13 patients (10 males [M], 3 females [F]; mean age of 12.8 years) with Class II Division 1 malocclusion who were treated with the Herbst appliance and miniscrews inserted in the maxillary and mandibular arches. They were compared with a control group (CG) of 13 patients (10 F, 3 M, mean age of 12.2 years) with Class II Division 1 malocclusion treated with the standard Herbst appliance without miniscrews. Lateral cephalograms were taken before and after Herbst treatment, and cephalometric analysis was performed. **Results:** In the TG group SNB (°) increased by 2.9°, whereas in CG group SNB (°) increased by 1.1° ($P = 0.017$). ANB (°) decreased in both groups: -3.3° in the TG group vs -1.3° in the CG group ($P = 0.014$). Pg-OLp distance increased in both groups: 5.70 mm in the TG group and 0.8 mm in the CG group ($P = 0.022$). Mandibular incisors proclined 1.6° in the TG group and 3.7° in the CG group. **Conclusions:** Herbst treatment reinforced with 4 miniscrews (2 in each arch) increased the orthopedic effect of treatment in growing patients with Class II malocclusion. (Am J Orthod Dentofacial Orthop 2019;156:617-25)

Class II malocclusion is 1 of the most common malocclusions, and it affects one third of the white population¹; mandibular retrusion and facial convexity are consistent findings among subjects with Class II malocclusion.²⁻⁴

Many therapeutic options exist to treat patients with Class II malocclusion: functional orthopedics, including fix and removable appliances, is 1 of the recommended therapeutic approaches; the objectives of these treatments are correction of jaw relationship and overjet reduction.³⁻⁵

Among the fixed functional appliances (FFA), the Herbst appliance (HA), proposed by Emil Herbst⁶ and

Hans Pancherz,^{7,8} is widely used and is 1 of the most efficient.

HA has both dental and skeletal effects in patients with Class II malocclusion, including enhanced sagittal position of the mandible, reduced growth of the maxilla, reduction of the overjet, anterior displacement of the mandibular arch, and posterior displacement of the maxillary arch.⁹⁻¹²

Beside these favorable treatment results, side effects resulting from anchorage loss have been reported in the literature: weak control of upper and lower incisors, as well as uncontrolled movement of posterior teeth. Proclination of the mandibular incisors and retroclination of the maxillary incisors could reduce mandibular growth response because of the reduction of the space for mandibular enhancement.^{13,14}

Better control of unfavorable tooth movements may lead to greater skeletal effects; for this reason, different approaches have been proposed to reduce the side effects of Herbst treatment: an acrylic splint design for the lower arch and Class III elastics.¹⁴⁻¹⁶

However, none of these modifications were effective in eliminating proclination of the lower incisors.¹⁴⁻¹⁶ For this reason, skeletal reinforced FFAs were introduced.¹⁷⁻²⁰ Since miniscrews were introduced,²¹

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Fig 1. Acrylic splint Herbst appliance skeletally reinforced with 2 upper and 2 lower miniscrews, ligated with an elastic chain (TG group).

they have been applied in many treatment planning situations to improve or solve the limits of traditional biomechanics.²¹⁻²³ The combination of HA with skeletal anchorage has been described in the literature using miniscrews only in the lower arch to reduce proclination of the mandibular incisors; most of these studies reported improvements in skeletal effects.¹⁷⁻²⁰ Ideally, a skeletally anchored HA using miniscrews in the mandibular and maxillary arch could further improve anchorage control and skeletal effects.

In the present pilot study, the authors present the preliminary results in patients with Class II malocclusion using an HA with miniscrews inserted in the mandibular and maxillary arch as anchorage reinforcement.

MATERIAL AND METHODS

This prospective controlled study was conducted on a sample treatment group (TG) of 13 consecutively treated patients (10 males [M], 3 females [F]; mean age of 12.8 ± 1.5 years) treated with the HA, with miniscrews inserted in the maxillary and mandibular arches to enhance anchorage (Fig 1). The inclusion criteria were the following: Class II skeletal relationships ($ANB \geq 4^\circ$), overjet ≥ 4 mm, bilateral Class II molar relationships $\geq$ half a cusp, patients near the pubertal growth spurt (determined by the cervical vertebral maturation [CVM] method; stage CVM 3). The exclusion criteria were patients affected by systemic diseases, bone pathology, tooth agenesis, premature loss of permanent teeth, poor hygiene, and previous orthodontic treatments.

To evaluate the effects of the treatment on subjects with Class II malocclusion, a control group (CG) of patients treated with standard Herbst without miniscrews (Fig 2) was matched. The CG consisted of 13 consecutively treated subjects (10 F, 3 M, mean age of 12.2 ± 1.3 years). All patients gave informed written consent and were evaluated and treated by the same operator in his private practice (A.M.).

The HA (MTH Herbst, American Orthodontics, Sheboygan, Wis) uses a bilateral telescope mechanism



Fig 2. Standard acrylic splint Herbst without miniscrews (CG group).

consisting of a tube, a plunger, and 2 pivots and 2 locking screws that function to keep the mandible in a continuously anterior position. The length of the tube determined the amount of anterior displacement of the mandible. The upper part consists of a transpalatal bar cemented to the first molars, while the lower part of the HA consisted of an acrylic splint not fixed to the teeth; the lower part can be elevated to allow access for oral hygiene procedures.

The HA was activated initially with a mandibular enhancement of 4-6 mm, then the mandible was advanced in gradual increments (2 mm/2 months) until an edge-to-edge position was achieved. All patients underwent a palatal expansion of about 17.5 and 18 activations in the TG and CG, respectively, using a rapid palatal expander before HA insertion. The activation protocol for palatal expansion was 1 turn per day (0.2 mm each activation) until the expansion planned.

Lower and upper miniscrews were placed 2 weeks and 4 weeks, respectively, after the HA was settled. The orthodontic screws used were titanium, 8.0 mm long, with a diameter of 1.4 mm (Osstem Implant Co, Ltd, Seoul, Korea). The screws are Ti-6Al-4V alloy and can have a head with or without a passing hole for elastics and a 1.5-mm neck. The devices were inserted under local anesthesia, and the patients rinsed their mouth with 0.1% chlorhexidine gluconate solution for 1 minute before miniscrew insertion.

In the maxillary and mandibular arch, miniscrews were placed between the mandibular first and second

Table I. Cephalometric baseline analysis at T0

	TG		CG		Comparison of group at T0
	Mean	SD	Mean	SD	P value
SNA (°)	79.0	3.4	81.7	3.5	0.03
SNB (°)	73.3	2.6	75.7	3.1	0.05
ANB (°)	5.8	2.0	5.4	1.8	1.00
Wits (mm)	3.5	2.4	2.6	1.3	0.54
SN/GoGn (°)	34.1	7.3	33.3	2.9	0.73
Is/PP (°)	108.0	6.3	108.8	8.9	0.96
Ii/GoGn (°)	98.8	6.9	99.7	5.0	0.66
A-OLp (mm)	73.1	4.6	71.9	5.4	0.88
Pg-OLp (mm)	73.3	5.0	74.0	6.9	0.64
Co-OLp (mm)	7.1	2.2	4.7	3.0	0.02
Is-OLp (mm)	78.9	5.6	78.3	5.5	0.93
Ii-OLp (mm)	72.3	5.3	71.8	5.2	0.99
Overjet (mm)	6.6	2.3	6.5	1.1	0.74
Ms-OLp (mm)	51.6	3.7	49.9	5.7	0.38
Mi-OLp (mm)	50.7	3.9	48.8	4.4	0.32

premolars or between the second premolars and the first molars in the attached gingiva depending on the subject's anatomy. Lower miniscrews were ligated with elastic chains (Memory Chain; American Orthodontics, Sheboygan, Wis) to metallic buttons bonded to the mandibular canines on each side, while upper screws were loaded with elastic chains horizontally oriented and ligated to the first molars to control the expected distalization effect of the HA on the maxillary arch (Fig 1).

Both activations were planned to control inclination of the maxillary and mandibular incisors. Elastic chains were changed every 3 or 4 weeks. Lateral cephalograms for all treated subjects were obtained using the same x-ray machine, and taken by the same operator in the same centric relation at the beginning of orthodontic treatment (T0) and after Herbst removal (T1). Centric relation was further verified at the end of comprehensive treatment. All lateral x-rays had the same magnification factor of 1.1, and they were then normalized. Mean ages at T0 and T1 and mean durations of T0-T1 intervals for both treated and control samples were matched.

A cephalometric analysis was performed by hand using landmarks described by Pancherz et al²⁴ for each patient at T0 and T1.

Superimpositions of the radiographs on the stable bone structures of the anterior cranial base were performed to transfer the occlusal line and the occlusal line perpendicular from T0 to T1 cephalometric analysis. Variables not included in the Pancherz sagittal analysis were also added, such as mandibular incisor proclination (Ii/GoGn) and skeletal divergence (SN/GoGn). The

Table II. Descriptive statistics

	TG		CG		P value
	Mean	SD	Mean	SD	
N (subject)	13		13		
Age T0	12.8	1.5	12.2	1.3	0.25
Age T1	13.7	1.4	13.2	1.3	0.29
Treatment time (months)	10.0	0.8	10.8	2.1	0.30
M:F	10:3		3:10		
CMV	3		3		

operator (C.C.) was blinded with respect to group classifications.

Statistical analysis

Descriptive statistics (means and standard deviations) of all continuous variables were evaluated (Table I). The Shapiro-Wilk test was used to estimate the normal distribution of the data.

Baseline *t* test for normal data, and Mann-Whitney test for non-normal data, were performed to analyze the homogeneity of groups.

The estimated *P* values were adjusted for multiple comparisons, and when the adjusted *P* value was <0.05, the differences were considered to be significant. Data were acquired and analyzed using SPSS Statistics 22 software (IBM, Armonk, NY). A *t* test was also used to analyze the age at T0 in both the TG and CG groups.

To compare the absolute variations in cephalometric values after treatment between the TG and CG groups, the Mann-Whitney test was used.

A linear mixed effects model test was also performed to investigate the absolute variations in cephalometric values in the TG and CG groups, and their associations of sex, age, and treatment group. ANB angle and Co-OLp were studied using the linear mixed-effects model with a log transformation of the dependent variables.

The likelihood ratio test was used as a test of statistical significance.

Error method

The same operator who analyzed the cephalograms repeated the measurements for a total of 10 randomly selected patients. The intraclass correlation coefficient values for linear and angular values were 0.82 and 0.91, respectively.

RESULTS

The descriptive statistics of the treated cases are reported in Table II. The mean treatment times were 10.0 ± 0.8 months in the TG group and

Table III. Mann-Whitney test T1-T0

	TG, T1-T0		CG, T1-T0		Comparison among groups
	Mean	SD	Mean	SD	P value
SNA (°)	-0.7	1.6	-1.0	2.1	0.62
SNB (°)	2.9	1.8	1.1	2.8	0.02
ANB (°)	-3.3	1.8	-1.3	1.3	0.01
Wits (mm)	-4.4	2.4	-2.1	2.2	0.10
SN/GoGn (°)	-0.5	2.1	2.2	2.7	0.01
Is/PP (°)	5.1	7.7	1.0	9.4	0.33
Ii/GoGn (°)	1.6	5.6	3.7	4.2	0.40
A-OLp (mm)	1.1	2.1	1.2	3.0	0.98
Pg-OLp (mm)	5.7	3.5	0.8	4.2	0.02
Co-OLp (mm)	0.4	1.7	0.5	3.0	0.73
Is-OLp (mm)	2.2	4.0	1.3	2.7	0.44
Ii-OLp (mm)	6.0	2.7	5.2	3.1	0.62
Overjet (mm)	-3.7	2.6	-3.8	1.9	0.44
Ms-OLp (mm)	0.8	3.1	-0.9	3.1	0.33
Mi-OLp (mm)	5.4	2.5	4.3	3.3	0.51

10.8 ± 2.1 months in the CG group, and all patients successfully reached molar Class I relationships with a correct overjet.

Two band breakages were observed in the TG, whereas 1 palatal arch debond was noted in the CG.

Cephalometric baseline analysis showed that the 2 groups of patients were homogeneous at T0 for age and CVM stage (Tables I and II).

The baseline age was 12.8 ± 1.5 years for the TG group and 12.2 ± 1.3 years for the CG group (Table I).

The groups showed differences only in sex distribution: 10 boys and 3 girls in the TG group and 3 boys and 10 girls in the CG group.

At baseline, no differences were found in vertical dimension, skeletal class, maxillary bone, molar position, overjet, proclination of maxillary incisors, or proclination of mandibular incisors ($P > 0.05$). At T0, the only differences were found in SNA (°) ($P = 0.032$) and SNB (°) ($P = 0.048$). SNB (°) was greater in the CG group (mean: 75.7 ± 3.1) than in the TG group (mean: 73.3 ± 2.6). Condyle distance from the vertical line OLp was higher in the TG group (mean: 7.1 ± 2.2) than in the CG group (mean: 4.7 ± 3.0) (Table I).

Skeletal and dentoalveolar changes after Herbst treatment in the 2 groups are reported in Table III.

SNB (°) increased 2.9° in the TG group, whereas SNB (°) increased 1.1° in the CG group ($P = 0.017$). ANB (°) decreased in both groups: -3.3° in the TG group vs -1.3° in the CG group ($P = 0.014$).

The Pg-OLp distance increased 5.7 mm in TG group. The CG group showed a Pg point advancement of 0.8 mm ($P = 0.022$).

Vertical dimension (SN/GoGn) decreased slightly in the TG group (0.5°) and increased 2.2° in the CG group ($P = 0.007$).

A-OLp distance increased 1.1 mm in TG group. The CG group showed an A-point advancement of 1.2 mm.

The position of the maxillary incisors combines 2 distances: maxillary bone length and the distance between Is and the vertical line OLp. In the TG group, the position of the maxillary incisors increased 2.2 mm and the upper incisors proclined 5.1°. The CG group showed proclination of the maxillary incisors by 1.3°. The Is-OLp distance increased by 1.3 mm in the CG group.

The position of the mandibular incisors combines 2 distances: mandibular bone length and the distance between Ii and the vertical line OLp. In the TG group, the Ii-OLp distance and the inclination of the mandibular incisors increased by 6.0 mm and 1.6°, respectively. The CG group showed a proclination of the mandibular incisors of 3.7°, and the Ii-OLp distance increased by 5.2 mm.

Both groups showed a reduction of overjet: -3.7 mm in the TG group and -3.8 mm in the CG group.

With regard to the position of the molars, a mean +0.8 mm forward movement was observed for maxillary molars in the TG group, whereas in the CG group, the mean value was -0.9 mm. The changes in the mandibular molars were similar in both groups: 5.4 mm in the TG and 4.3 mm in the CG.

Linear mixed model analysis with covariate age, time, group, and sex are reported in Tables IV-VII, respectively.

DISCUSSION

Miniscrews have been shown to be effective in assisting in placement of FFAs and in improving the skeletal effect of functional devices, such as the Forsus Fatigue Resistant Device (3M Unitek Corp, Monrovia, Calif) and the HA. In all these approaches, 2 miniscrews are applied to the mandibular arch to reduce the main undesirable effect of proclination of the incisors.^{17-20,25-27} In this study, we evaluated the Herbst treatment using 4 miniscrews, and investigated the advantages of FFA skeletally anchored to both arches: the hypothesis to be tested was an improved skeletal correction of the overjet when compared with a standard Herbst treatment.

Both Class II treatments were effective in correction of Class II malocclusion, with bilateral molar Class I achievement in all patients, with overjet reduction and mesial movement of mandibular molars.

Both groups of patients were homogeneous at baseline for age and CVM stage (stage 3 CVM), and there was no significant difference in age at T0 between groups ($P = 0.24$); no differences in cephalometric data were shown ($P > 0.05$); the only difference was for sex, but

Table IV. Descriptive statistics and output of linear mixed model (covariate: age)

Variable	Parameter	Estimation	SD	95% CI		LR adjusted P value
				Lower bound	Upper bound	
Age						
	SNA (°)	1.03	0.45	0.11	1.95	0.03
	SNB (°)	0.84	0.37	0.07	1.61	0.03
	ANB (°)	1.02	1.03	0.96	1.07	0.53
	Wits (mm)	0.00	0.23	−0.47	0.47	0.99
	SN/GoGn (°)	−0.07	0.78	−1.66	1.52	0.93
	Is/PP (°)	0.73	0.71	−0.72	2.19	0.31
	Ii/GoGn (°)	−0.59	0.66	−1.94	0.76	0.38
	A-OLp (mm)	−0.59	0.64	−1.91	0.74	0.37
	Pg-OLp (mm)	0.08	0.79	−1.55	1.71	0.92
	Co-OLp (mm)	1.07	1.03	1.01	1.13	0.03
	Is-OLp (mm)	−0.10	0.75	−1.65	1.44	0.89
	Ii-OLp (mm)	−0.15	0.67	−1.53	1.23	0.82
	Overjet (mm)	0.14	0.16	−0.20	0.48	0.41
	Ms-OLp (mm)	−0.64	0.52	−1.71	0.44	0.23
	Mi-OLp (mm)	0.06	0.48	−0.93	1.05	0.91
LR likelihood ratio						

LR, likelihood ratio.

Table V. Descriptive statistics and output of linear mixed model (variable: time)

Variable	Parameter	Estimation	SE	95% CI		LR adjusted P value
				Lower bound	Upper bound	
Time						
T0	SNA (°)	0.00	0.00	0.00	0.00	0.00
T1		−1.68	0.51	−2.69	−0.66	
T0	SNB (°)	0.00	0.00	—	—	0.03
T1		1.30	0.56	0.16	2.43	
T0	ANB (°)	0.00	0.00	—	—	0.24
T1		−1.09	1.07	−1.25	−0.94	—
T0	Wits (mm)	0.00	0.00	—	—	0.00
T1		−3.25	0.53	−4.33	−2.17	
T0	SN/GoGn (°)	0.00	0.00	—	—	0.29
T1		0.90	0.84	−0.78	2.59	
T0	Is/PP (°)	0.00	0.00	—	—	0.18
T1		2.44	1.77	−1.16	6.05	
T0	Ii/GoGn (°)	0.00	0.00	—	—	0.38
T1		−2.08	2.33	−6.95	2.79	
T0	A-OLp (mm)	0.00	0.00	—	—	0.03
T1		1.65	0.73	0.20	3.11	
T0	Pg-OLp (mm)	0.00	0.00	—	—	0.01
T1		3.18	1.09	0.99	5.37	
T0	Co-OLp (mm)	0.00	0.00	—	—	0.63
T1		−1.03	1.07	−1.18	−0.90	
T0	Is-OLp (mm)	0.00	0.00	—	—	0.04
T1		1.90	0.91	0.08	3.72	—
T0	Ii-OLp (mm)	0.00	0.00	—	—	0.00
T1		5.70	0.80	4.10	7.30	
T0	Overjet (mm)	0.00	0.00	—	—	0.62
T1		0.26	0.52	−0.82	1.34	—
T0	Ms-OLp (mm)	0.00	0.00	—	—	0.86
T1		0.11	0.61	−1.10	1.33	
T0	Mi-OLp (mm)	0.00	0.00	—	—	0.00
T1		4.84	0.70	3.44	6.24	

SE, standard error; LR, likelihood ratio.

Table VI. Descriptive statistics and output of linear mixed model (fixed effect: group)

Variable	Parameter	Mean	SD	Estimation	SE	95% CI		LR adjusted P value
						Lower bound	Upper bound	
Group								
TG	SNA (°)	−0.70	1.60	−3.66	1.42	−6.57	−0.75	0.02
CG		−1.00	2.10	0.00	0.00	—	—	
TG	SNB (°)	2.90	1.80	−2.65	1.17	−5.05	−0.25	0.03
CG		1.10	2.80	0.00	0.00	—	—	
TG	ANB (°)	−3.30	1.80	1.07	1.08	0.91	1.26	0.42
CG		−1.30	1.30	0.00	0.00	—	—	
TG	Wits (mm)	−4.40	2.40	−0.37	0.71	−1.82	1.09	0.61
CG		−2.10	2.20	0.00	0.00	—	—	
TG	SN/GoGn (°)	−0.50	2.10	1.23	2.46	−3.83	6.29	0.62
CG		2.20	2.70	0.00	0.00	—	—	
TG	Is/PP (°)	5.10	7.70	0.96	2.18	−3.51	5.44	0.66
CG		1.00	9.40	0.00	0.00	—	—	
TG	Ii/GoGn (°)	1.60	5.60	−1.35	2.03	−5.52	2.82	0.51
CG		3.70	4.20	0.00	0.00	—	—	
TG	A-OLp (mm)	1.10	2.10	−0.97	2.04	−5.18	3.23	0.64
CG		1.20	3.00	0.00	0.00	—	—	
TG	Pg-OLp (mm)	5.70	3.50	−4.71	2.52	−9.88	0.46	0.07
CG		0.80	4.20	0.00	0.00	—	—	
TG	Co-OLp (mm)	0.40	1.70	1.31	1.09	1.09	1.57	0.01
CG		0.50	3.00	0.00	0.00	—	—	
TG	Is-OLp (mm)	2.20	4.00	−1.46	2.37	−6.34	3.43	0.55
CG		1.30	2.70	0.00	0.00	—	—	
TG	Ii-OLp (mm)	6.00	2.70	−1.50	2.14	−5.90	2.91	0.49
CG		5.20	3.10	0.00	0.00	—	—	
TG	Overjet (mm)	−3.70	2.60	−0.13	0.51	−1.19	0.93	0.80
CG		−3.80	1.90	0.00	0.00	—	—	
TG	Ms-OLp (mm)	0.80	3.10	−0.38	1.66	−3.80	3.03	0.82
CG		−0.90	3.10	0.00	0.00	—	—	
TG	Mi-OLp (mm)	5.40	2.50	−0.20	1.53	−3.35	2.96	0.90
CG		4.30	3.30	0.00	0.00	—	—	
SE, standard error; LR, likelihood ratio.								

SE, standard error; LR, likelihood ratio.

the linear mixed-effects model that was performed showed that difference in sex did not significantly affect the treatment effects among the groups; the only variables with statistical effects were A-OLp and Ms-OLp (Table VII). However, the same analysis showed a significant effect of TG on pogonion changes over time. Because of the fair measurement repeatability, it can be assumed that some of the differences observed could fall in the margins of error; moreover, a cautious interpretation of results should be taken because of the possible difference in growth spurt between the groups.

The 4-miniscrew Herbst treatment resulted in a greater skeletal effect and a better control of retroclination of the maxillary incisor and proclination of the mandibular incisor compared with the CG; in particular, Pg-OLp showed a mean increase of 5.7 mm in the TG, which is considerably higher than the CG advancement (mean 0.8 mm) or data published in the literature.^{12,27,28} The greater skeletal results were also confirmed by the ANB (°) and Wits (mm) modifications achieved. A

standard HA therapy generally improved pogonion position of 0.8–2.2 mm^{12,27,28,29} and obtained a skeletal correction up to 65% of the Class II relationships.

Pogonion advancement was greater than that observed in studies on HA with skeletal anchorage applied only in the mandibular arch; most of these studies reported improvement in skeletal effects.^{18–20} Manni et al¹⁷ evaluated the effectiveness of Herbst treatment with an HA acrylic splint anchored to miniscrews in the mandibular arch with 2 types of ligations; they showed that the skeletal anchorage reduced flaring of the mandibular incisors and that the elastic chain increased the orthopedic effect of the Herbst treatment.

Bremen et al²⁵ assessed whether loss of mandibular anchorage during treatment with Herbst/multibracket appliances can be prevented using interraderic miniscrew anchorage. They showed that this anchorage did reduce proclination of the mandibular labial

Table VII. Descriptive statistics and output of linear mixed model (variable: sex)

Variable	Parameter	Estimation	SE	95% CI		LR adjusted P value
				Lower bound	Upper bound	
Sex						
F	SNA (°)	−0.74	1.44	−3.69	2.22	0.61
M		0.00	0.00	—	—	
F	SNB (°)	0.15	1.19	−2.29	2.59	0.90
M		0.00	0.00	—	—	
F	ANB (°)	0.99	1.08	0.84	1.17	0.94
M		0.00	0.00	—	—	—
F	Wits (mm)	−0.30	0.72	−1.77	1.18	0.68
M		0.00	0.00	—	—	
F	SN/GoGn (°)	0.82	2.50	−4.32	5.95	0.75
M		0.00	0.00	—	—	
F	Is/PP (°)	−0.91	2.22	−5.47	3.65	0.69
M		0.00	0.00	—	—	
F	Ii/GoGn (°)	1.46	2.06	−2.78	5.70	0.49
M		0.00	0.00	—	—	
F	A-OLp (mm)	−4.83	2.07	−9.09	−0.57	0.03
M		0.00	0.00	—	—	
F	Pg-OLp (mm)	−2.96	2.55	−8.20	2.29	0.26
M		0.00	0.00	—	—	
F	Co-OLp (mm)	1.17	1.09	0.97	1.41	0.09
M		0.00	0.00	—	—	
F	Is-OLp (mm)	−3.67	2.41	−8.63	1.28	0.14
M		0.00	0.00	—	—	—
F	Ii-OLp (mm)	−3.21	2.17	−7.67	1.25	0.15
M		0.00	0.00	—	—	
F	Overjet (mm)	−0.26	0.52	−1.34	0.82	0.62
M		0.00	0.00	—	—	—
F	Ms-OLp (mm)	−3.97	1.68	−7.43	−0.51	0.03
M		0.00	0.00	—	—	
F	Mi-OLp (mm)	−2.67	1.55	−5.86	0.53	0.10
M		0.00	0.00	—	—	
SE, standard error; LR, likelihood ratio						

SE, standard error; LR, likelihood ratio.

segment to a small extent. The authors found statistically significant differences in anchorage preservation between the study and CGs, even if they were small and were unlikely to be of clinical relevance.

In agreement with results from other clinical research found in the literature, a slight skeletal divergence (SN/GoGn) of -0.5° was observed during treatment in the TG. The modification of the same parameter in the CG was also small (2.2°), even if statistically significant from the TG. In other studies with skeletally reinforced FFA, divergence remains stable with variations from -0.7° to 0.8° .^{18–20,26}

In the TG, the mandibular incisors showed a proclination of 1.6° ; these results are similar to those previously published using skeletal anchorage reinforcement and are significantly lower than other approaches; Pancherz published other solutions to reduce the effect of inclinations of the mandibular incisors, such as premolar anchorage, premolar-molar anchorage, pelott

anchorage, labial lingual anchorage, and Class III elastics (150 g), nevertheless all the systems produced an proclination of incisors between 3.1° and 12.1° after Herbst treatment.¹⁶

With regard to the upper incisors, they showed no statistically significant differences in either group; data from the literature suggest that the position of the maxillary incisors is less affected by Herbst therapy and they generally move palatally or remain stable when an HA acrylic splint is used.³⁰ In both groups, maxillary incisors became slightly labially tipped; these results may be because of the design of the appliance. Miniscrews could have had a key role on the maxillary first molars instead: using traditional FFAs, they usually move distally because of anchorage loss, whereas using a skeletal reinforced anchorage, a mesial movement of 0.8 mm was observed.^{31,32}

Miniscrew stability is extremely important in the success of this approach; in this study, a failure rate of

30.7% was experienced; previously published articles^{17,19,20} reported skeletal anchorage failure of between 17.5% and 30% with Herbst-like appliances, while 2 of 16 patients suffered miniscrew failure with the Forsus Fatigue Resistant Device³³; in those cases where temporary anchorage devices failed, they were replaced and the treatments were successfully completed. The same approach has been used in this study. Success of therapy can be considered, even if a miniscrew has to be replaced; a single miniscrew failure can be considered less clinically relevant, even though it can cause patient discomfort. The same success cannot be assumed when miniplates are used as skeletal anchorage,³⁴ because of the more invasive surgery needed to place the miniplates.

CONCLUSIONS

This pilot study on Class II Division 1 malocclusion ingrowing patients treated with an HA acrylic splint, skeletally reinforced with 2 upper and 2 lower miniscrews, ligated with an elastic chain, led to the following conclusions:

1. A dento-skeletal correction of the malocclusion was achieved.
2. A pogonion advancement of 5.7 mm was observed.
3. Anchorage reinforcement using miniscrews reduced flaring of the mandibular incisor.
4. The upper molars showed a slightly forward movement in HA with miniscrew anchorage.

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REFERENCES

1. Proffit WR, Fields HW Jr, Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES-III survey. *Int J Adult Orthod Orthognath Surg* 1998;13:97-106.
2. Ngan PW, Byczek E, Scheick J. Longitudinal evaluation of growth changes in Class II Division 1 subjects. *Semin Orthod* 1997;3:222-31.
3. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA Jr. Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review. *Am J Orthod Dentofacial Orthop* 2006;129:599.e1-12.
4. LaHaye MB, Buschang PH, Alexander RG, Boley JC. Orthodontic treatment changes of chin position in Class II Division 1 patients. *Am J Orthod Dentofacial Orthop* 2006;130:732-41.
5. McNamara JA Jr, Brudon WL. *Orthodontics and dentofacial orthopedics*. Ann Arbor, MI: Needham Press, Inc; 2001. p. 73.
6. Herbst E. 1909 Verhandlungen des V. Internationalen Zahnärztlichen Kongresses; 1909; p. 351-3.
7. Pancherz H. The Herbst appliance: its biologic effects and clinical use. *Am J Orthod* 1985;87:1-20.
8. 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.
9. Wigal TG, Dischinger T, Martin C, Razmus T, Gunel E, Ngan P. Stability of Class II treatment with an edgewise crowned Herbst appliance in the early mixed dentition: skeletal and dental changes. *Am J Orthod Dentofacial Orthop* 2011;140:210-23.
10. Ruf S, Pancherz H. Herbst/multibracket appliance treatment of Class II Division 1 malocclusions in early and late adulthood. A prospective cephalometric study of consecutively treated subjects. *Eur J Orthod* 2006;28:352-60.
11. Ruf S, Pancherz H. The effect of Herbst appliance treatment on the mandibular plane angle: a cephalometric roentgenographic study. *Am J Orthod Dentofacial Orthop* 1996;110:225-9.
12. Tomblyn T, Rogers M, Andrews L 2nd, Martin C, Tremont T, Gunel E, et al. Cephalometric study of Class II Division 1 patients treated with an extended-duration, reinforced, banded Herbst appliance followed by fixed appliances. *Am J Orthod Dentofacial Orthop* 2016;150:818-30.
13. Weschler D, Pancherz H. Efficiency of three mandibular anchorage forms in Herbst treatment: a cephalometric investigation. *Angle Orthod* 2005;75:23-7.
14. Pancherz H, Hansen K. Mandibular anchorage in Herbst treatment. *Eur J Orthod* 1988;10:149-64.
15. Franchi L, Baccetti T, McNamara JA Jr. Treatment and posttreatment effects of acrylic splint Herbst appliance therapy. *Am J Orthod Dentofacial Orthop* 1999;115:429-38.
16. Flores-Mir C, Ayeh A, Goswami A, Charkhandeh S. Skeletal and dental changes in Class II Division 1 malocclusions treated with splint-type Herbst appliances. A systematic review. *Angle Orthod* 2007;77:376-81.
17. Manni A, Pasini M, Mazzotta L, Mutinelli S, Nuzzo C, Grassi FR, et al. Comparison between an acrylic splint Herbst and an acrylic splint miniscrew-Herbst for mandibular incisors proclination control. *Int J Dent* 2014;2014:173-87.
18. Luzi C, Luzi V, Melsen B. Mini-implants and the efficiency of Herbst treatment: a preliminary study. *Prog Orthod* 2013;14:21.
19. Manni A, Mutinelli S, Pasini M, Mazzotta L, Cozzani M. Herbst appliance anchored to miniscrews with 2 types of ligation: effectiveness in skeletal Class II treatment. *Am J Orthod Dentofacial Orthop* 2016;149:871-80.
20. Batista KBD, Lima T, Palomares N, Carvalho FA, Quintão C, Miguel JAM, et al. Herbst appliance with skeletal anchorage versus dental anchorage in adolescents with Class II malocclusion: study protocol for a randomised controlled trial. *Trials* 2017;18:564.
21. Kanomi R. Mini-implant for orthodontic anchorage. *J Clin Orthod* 1997;31:763-7.
22. Silvestrini Biavati A, Tecco S, Migliorati M, Festa F, Marzo G, Gherlone E, et al. Three-dimensional tomographic mapping related to primary stability and structural miniscrew characteristics. *Orthod Craniofac Res* 2011;14:88-99.
23. Manni A, Lupini D, Cozzani M. Bone-anchored intermaxillary elastics in an asymmetric Class II malocclusion: a case report. *Int Orthod* 2017;15:263-77.
24. Pancherz H, Hensen K. Occlusal changes during and after Herbst treatment: a cephalometric investigation. *Eur J Orthod* 1986;8:215-28.
25. Bremen JV, Ludwig B, Ruf S. Anchorage loss due to Herbst mechanism-preventable through miniscrews? *Eur J Orthod* 2015;37:462-6.

26. Unal T, Celikoglu M, Candirli C. Evaluation of the effects of skeletal anchored Forsus FRD using miniplates inserted on mandibular symphysis: a new approach for the treatment of Class II malocclusion. *Angle Orthod* 2015;85:413-9.
27. Eissa O, El-Shennawy M, Gaballah S, El-Meehy G, El Bialy T. Treatment outcomes of Class II malocclusion cases treated with miniscrew-anchored Forsus Fatigue Resistant Device: a randomized controlled trial. *Angle Orthod* 2017; 87:824-33.
28. Bock NC, Gndant E, Ruf S. Occlusal stability after Herbst treatment of patients with retrognathic and prognathic facial types: a pilot study. *J Orofac Orthop* 2016;77:160-7.
29. VanLaecken R, Martin CA, Dischinger T, Razmus T, Ngan P. Treatment effects of the edgewise Herbst appliance: a cephalometric and tomographic investigation. *Am J Orthod Dentofacial Orthop* 2006;130:582-93.
30. Valant JR, Sinclair PM. Treatment effects of the Herbst appliance. *Am J Orthod Dentofacial Orthop* 1989;95:138-47.
31. Cacciatore G, Huanca Ghislanzoni LT, Alvetto L, Giuntini V, Franchi L. Treatment and posttreatment effects induced by the Forsus appliance: a controlled clinical study. *Angle Orthod* 2014; 84:1010-7.
32. Elkordy SA, Abouelezz AM, Salah Fayed MM, Attia KH, Rahman Ishaq RA, Mostafa YA. Three-dimensional effects of the mini-implant-anchored Forsus Fatigue Resistant Device: a randomized controlled trial. *Angle Orthod* 2016;86:292-305.
33. Aslan BI, Kucukkaraca E, Turkoz C, Dincer M. Treatment effects of the Forsus Fatigue Resistant Device used with miniscrew anchorage. *Angle Orthod* 2014;84:76-87.
34. Ozbilek S, Gungor AY, Celik S. Effects of skeletally anchored Class II elastics: a pilot study and new approach for treating Class II malocclusion. *Angle Orthod* 2017;87:505-12.