

Article

Mandibular Advancement after Pubertal Peak with Acrylic Splint Herbst Appliance Anchored to Four Miniscrews: A Retrospective Controlled Study

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Abstract: Objectives: The treatment of class II patients with mandibular retrusion often involves the use of a Herbst appliance, due to its efficiency and reduced need for compliance. Despite skeletal benefits, undesired dental effects, caused by anchorage loss, could reduce mandibular advancement, especially after the pubertal peak. Although the period between cervical vertebral maturation (CVM) 3 and CMV4 is considered the best choice to maximize the orthopedic outcome, clinicians cannot always treat patients during this ideal time window, as they present at their first visit later. The goal of this study is to evaluate whether the combination of an acrylic splint Herbst appliance with skeletal anchorage and elastic chains in both the upper and lower arch (Skeletal Therapy Manni Telescopic Herbst 4: STM4) could improve the efficiency of functional treatment also in CVM 5–6 patients. Methods: Lateral cephalograms of 10 consecutively treated patients taken at the beginning and at the end of the Herbst phase were analyzed and compared with those of 10 untreated patients of the same sex, age, malocclusion, and skeletal maturation. Results: According to the Pancherz analysis, the treated group of patients showed the significant advancement of the pogonion (4.75 mm), with a reduction in ANB (−3.3°) and Wits (−4.15 mm). The combination of miniscrews and elastic ligatures allowed the labial tipping of the upper incisors (+6.65°) and limited the labial flaring of the lower ones (+3.05°), maintaining the overjet needed for mandibular advancement. Conclusions: The STM4 technique might be an effective protocol for skeletal class II correction after the pubertal peak since it significantly reduces unfavorable dental compensations, increasing the skeletal effects and the esthetic outcome of the orthopedic treatment.

Keywords: class II; skeletal anchorage; miniscrews; esthetics



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1. Introduction

Skeletal class II malocclusion is a very common condition affecting about one third of the Caucasian population [1]; in most cases, it is caused by a mandibular deficiency, resulting in a convex profile and the retrusion of the chin [2]. Thereby, the goal of an orthopedic treatment should be to promote effective mandibular advancement. The current therapeutic options include the use of removable and fixed functional appliances, among which the Herbst appliance (HA), first proposed by Emil Herbst and revived by Hans Pancherz [3,4], is widely used and considered one of the most efficient [5]. The HA has both dental and skeletal effects, including the anterior displacement of the mandible, the reduced sagittal growth of the maxilla, the mesialization of the lower arch, and the distalization of the upper one [6].

While skeletal effects can be considered always favorable for the purpose of effective esthetic correction, dental effects, especially the proclination of the lower incisors and

retroclination of the upper ones, caused by anchorage loss, could reduce the functional space for mandibular advancement, and this represents one of the major limitations of the traditional treatment [7,8]. Consequently, different approaches, including the use of class III elastics and an acrylic splint design in the lower arch, have been proposed to reduce these side effects [9,10], but the results are limited. In contrast, the combination of the Herbst appliance with skeletal anchorage in the lower arch has been reported to ensure a greater mandibular response, leading to greater pogonion advancement and the more effective control of the lower incisors if compared with the traditional Herbst appliance with dental anchorage [11–14]. However, considering that the “working overjet”, which is essential to ensure significant mandibular advancement, is equally conditioned by the position of both the upper and lower incisors, this protocol may not be enough in all cases.

To date, only one study [5] has evaluated the combination of temporary anchorage devices (TADs) in both the upper and lower arch and HA, showing greater pogonion advancement if compared with the presence of miniscrews only in the mandible; however, the data are limited. Another prognostic factor capable of influencing the mandibular response is represented by the skeletal maturation of the patient, which is crucial to set the timing of an appropriate class II treatment [15,16]. According to the cervical vertebral maturation (CVM) method, the period between CVM3 and CVM4 is considered the best choice to maximize the skeletal effects of the orthopedic appliance [17]. Later, the growth potential gradually decreases, reducing the efficacy of the intervention.

However, clinicians do not always have the opportunity to treat patients during this ideal time window, as they present at their first visit in adulthood, and a combined orthodontic–orthognathic treatment is often refused. Some authors have positively evaluated the use of the traditional Herbst appliance (without TADs) in young adults, with good results in terms of facial profile attractiveness [18], although the effects are mainly dento-alveolar [19]. Hence, the aim of this study is to evaluate whether the combination of skeletal anchorage in the upper and lower arch with an acrylic splint Herbst appliance could ensure favorable skeletal effects and reduce typical dento-alveolar compensations in CVM5–CVM6 skeletal class II patients.

2. Materials and Methods

2.1. Study Design and Patient Sample

This retrospective controlled study was conducted on a sample treatment group (TG) of 10 consecutively treated patients (6 males (M), 4 females (F); mean age of 15.5 years) treated in a private practice with HA combined with four miniscrews inserted in the upper and lower arch as anchorage reinforcement. This study was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and was approved by the Ethics Committee of Vita-Salute San Raffaele University (approval code DIG-RETRO-1/2021). The inclusion criteria were the following: complete permanent dentition (except third molars), class II skeletal relationship ($A \geq 4^\circ$), overjet ≥ 4 mm, bilateral class II molar relationship $\geq$ half a cusp, patients after the pubertal growth spurt (determined by the cervical vertebral maturation (CVM) method; stage CVM 5–6), refusal of successive combined orthodontic–orthognathic treatment, and provision of signed and informed consent. The exclusion criteria were represented by the presence of systemic disease, bone pathology, tooth agenesis, premature loss of permanent teeth, poor oral hygiene, and previous orthodontic treatments. In order to evaluate the effects of the treatment, a control group (CG) of 10 untreated skeletal class II patients (6 males (M), 4 females (F); mean age of 15.4 years), derived from the Michigan Growth Study (AAOF Craniofacial Growth Legacy Collection), was matched with the TG according to their sex, age, malocclusion, and skeletal maturation.

2.2. Mandibular Advancement Protocol

All patients required preventive palatal expansion and were treated with the following protocol.

- A rapid palatal expander (RPE, A0630-12D 12 mm Leone expansion screw (Leone, Sesto Fiorentino, Italy) was anchored to bands on the upper maxillary molars and to 2 miniscrews inserted in the anterior paramedian region, between the second and third palatal ruga. A 1-visit protocol was applied (i.e., the insertion of the miniscrews and of the orthodontic device at the same appointment). The upper miniscrews were titanium, 11 mm long, with a diameter of 2 mm (Leone, TAD for expanders D2, L11 mm). They were inserted with a CBCT-guided workflow, after local anesthesia. The activation protocol for maxillary expansion was 1 turn per day (0.2 mm each activation) until the planned expansion was completed.
- Meanwhile, the upper arch was bonded with pre-adjusted straight-wire brackets (bidimensional technique) and a 014 nickel–titanium archwire was inserted. The upper archwire sequence then included 16 × 22 NiTi, 17 × 25 NiTi, and 18 × 25 SS.
- After this preliminary phase, the RPE was removed and replaced with an HA (Manni Telescopic Herbst, American Orthodontics, Sheboygan, WI, USA). It consists of a fixed transpalatal bar (cemented onto the first maxillary molars) and a lower, partially removable acrylic splint, which are connected by a bilateral telescope mechanism, maintaining the mandible in a continuously forward position.
- In the maxilla, an additional transpalatal bar, anchored to the same palatal TADs and separated from the Herbst palatal arch, was applied (Figure 1). In the mandible, two miniscrews were inserted bilaterally between the first molar and the second premolar or between the first and the second premolars, 2 weeks after the HA was settled (Figure 1).
- The lower miniscrews used were titanium, 8.0 mm long, with a diameter of 1.4 mm (Osstem Implant Co., Ltd., Seoul, Republic of Korea). After a 1 min rinse with 0.1% gluconate chlorhexidine solution, these devices were inserted under local anesthesia.
- Due to the prevention of anchorage loss, elastic chains (Memory Chain; American Orthodontics, Sheboygan, WI, USA) were used to connect the screws to metallic buttons bonded to the buccal surfaces of the canines [11] in the mandible and to the palatal hooks of the upper first-molar bands in the maxilla (Figure 1).

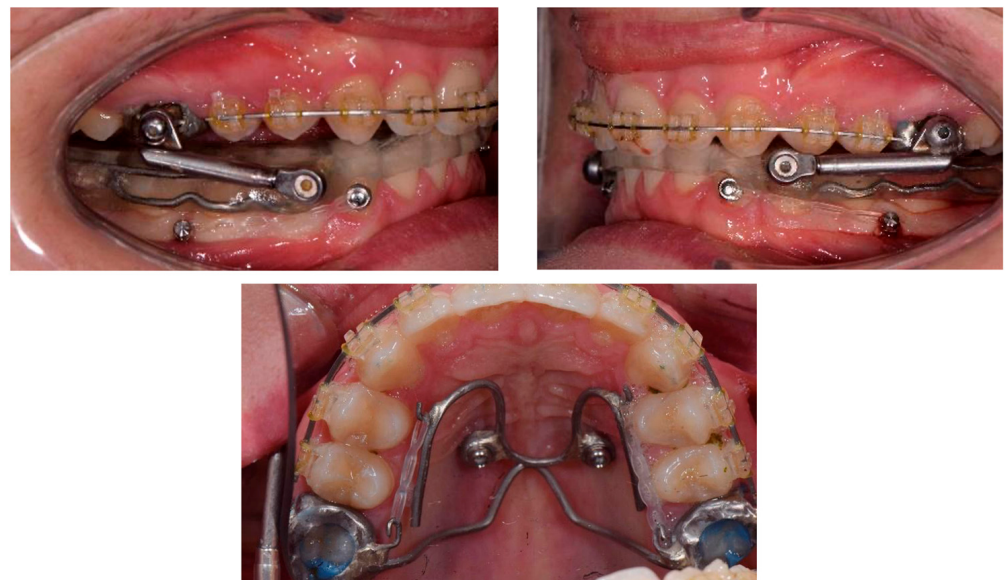


Figure 1. Skeletal anchorage in the upper and lower arch with miniscrews and elastic chains.

The chains were changed every 4 weeks. This technique was named Skeletal Therapy Manni Telescopic Herbst 4 TADs (STM4). The HA was initially activated with a mandibular advancement of 4–6 mm; then, the mandible was further advanced in gradual increments (2 mm every 2 months) until a satisfactory canine class I relation was achieved. Finally, the appliance was removed after 9 months of active treatment. Lateral cephalograms were

taken by the same operator for all treated patients, using the same X-ray machine, at the beginning of the orthodontic treatment (T0) and immediately after Herbst removal (T1). Similarly, in the control group, two consequent lateral cephalograms (T0 and T1) for each patient were downloaded from the database, so that the T0–T1 interval was similar in both groups.

2.3. Variables and Data Collection

A cephalometric Pancherz analysis [20] was performed for each subject from the two groups at T0 and T1, and superimpositions of the two consequent radiographs on the stable anterior cranial base were performed by a unique operator. The measurement landmarks and distances can be seen in Figure 2.

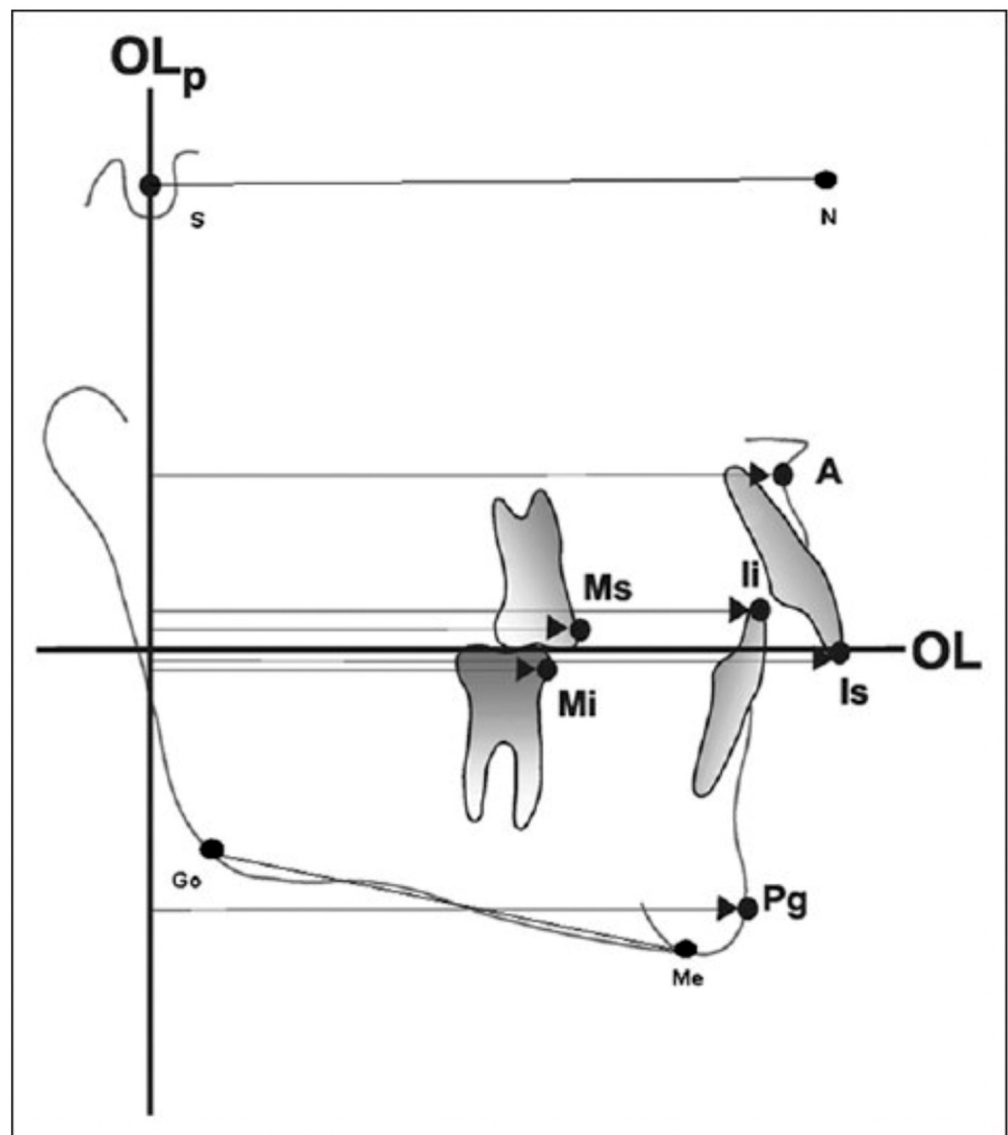


Figure 2. Pancherz analysis: measurement landmarks and distances. Maxillary bone base A/Olp: distance from Point A to the Olp line (mm). Mandibular bone base Pg/Olp: distance from Pg to the Olp line (mm). Maxillary molar position Ms/Olp, distance from Ms to the Olp line (mm). Mandibular molar position Mi/Olp, distance from Mi to the Olp line (mm). Overjet Is/Olp Li/Olp. maxillary incisor minus mandibular incisor (mm). Maxillary incisor position Is/Olp, distance from Is to the Olp line (mm). Mandibular incisor position Li/Olp, distance from Li to the Olp line (mm).

Some other variables, not originally included in the original Pancherz sagittal analysis, were also added: maxillary incisor inclination (Is/PP), mandibular incisor inclination (Ii/GoGn), skeletal divergence (SN/GoGn), Wits appraisal (Wits), overjet (OJ), and overbite (OB). Intraclass correlation coefficients (ICC) were calculated for linear and angular measurements for 6 randomly selected cephalograms. Tracing was performed by the same operator in one step after a 12-week interval. The mean ICC value was greater than 0.99 for both the linear and angular variables.

2.4. Statistical Analysis

The entire sample was divided into two groups according to the treatment. The normal distributions of the quantitative variables were tested using the Kolmogorov–Smirnov test. Therefore, data are reported as the mean $\pm$ standard deviation (M $\pm$ SD) and median (iqr) for continuous measures and frequencies and percentages (%) for all categorical variables. A non-parametric approach was adopted to assess any statistical differences between groups. Wilcoxon’s sum rank test for independent samples was adopted to assess any statistical differences between the groups at baseline for continuous variables and the chi-squared test for categorical ones. The assessment of treatment differences was performed using Wilcoxon’s sum rank test on the radiological point differences between the times of observation, while the chi-squared test was adopted to assess any statistical differences between the categorical variables. Two linear regression models were obtained in order to assess the Pg-OLp prediction based on the treatment group. The first linear regression model was a raw model implemented on the Pg-OLp difference as a dependent variable and treatment as a regressor, while the second model was adjusted for the A-OLp difference.

3. Results

Table 1 shows a description of the whole sample at baseline (T0) in order to assess the homogeneity of the patients in the two groups (age, sex, and CVM stage): the baseline age was 15.5 years in the TG and 15.4 years in the CG; the sex distribution and CVM stage were equal between the groups (six males (four CVM5 and two CVM6) and four females (one CVM5 and three CVM6)). The cephalometric baseline analysis showed the absence of differences in the vertical and sagittal skeletal dimensions, skeletal relations, molar and incisor sagittal positions, incisor inclination, and overbite (Table 1). The only difference was found for the overjet at baseline: the treated group showed a higher mean value (7.75 ± 3.34 mm) compared with the control group (4.78 ± 1.56 mm). The skeletal and dento-alveolar changes after Herbst treatment are reported in Tables 2 and 3.

Table 1. Description of the whole sample according to treatment at baseline T0. N:20. All data are shown as mean $\pm$ SD, median (iqr) for continuous variables and as n (%) for proportional ones.

	CG		TG		p Value *
	Mean $\pm$ SD	Median (iqr)	Mean $\pm$ SD	Median (iqr)	
Age (years)	15.4 $\pm$ 1.29	15.1 (2.08)	15.55 $\pm$ 1.66	15.35 (2.8)	0.90
Sex					
Female	4 (40.00)		4 (40.00)		0.99
Male	6 (60.00)		6 (60.00)		
Skeletal					
Maturation					
cs4	5 (50.00)		5 (50.00)		0.99
cs5	5 (50.00)		5 (50.00)		
Is-OLp (mm)	80.88 $\pm$ 6.35	80.5 (6.25)	80.80 $\pm$ 8.58	81.25 (8.125)	0.96
Ii-OLp (mm)	76.10 $\pm$ 6.15	76.5 (4.25)	73.05 $\pm$ 7.38	72.25 (6.37)	0.22
A-OLp (mm)	74.91 $\pm$ 5.19	73.5 (3.5)	75.65 $\pm$ 7.37	76.5 (3.375)	0.42
Pg-OLp (mm)	76.15 $\pm$ 6.283	76.10 (6.30)	75.15 $\pm$ 7.28	75 (6.75)	0.73
SNA (°)	83.8 $\pm$ 2.63	84.5 (2.25)	81.95 $\pm$ 2.9	81.75 (3.62)	0.13
SNB (°)	78.7 $\pm$ 2.37	79 (1.12)	76.1 $\pm$ 2.83	75.25 (4.38)	0.08

Table 1. *Cont.*

	CG		TG		<i>p</i> Value *
	Mean $\pm$ SD	Median (iqr)	Mean $\pm$ SD	Median (iqr)	
ANB (°)	5.1 $\pm$ 0.99	5 (1)	5.8 $\pm$ 1.08	6 (1.25)	0.14
Wits (mm)	4.65 $\pm$ 2.82	4.87 (3.43)	7.1 $\pm$ 2.39	7.75 (2.38)	0.07
SN/GoGn (°)	28.05 $\pm$ 4.34	27.5 (5)	26.9 $\pm$ 5.42	25 (7.62)	0.42
Is/PP (°)	109.65 $\pm$ 7.82	111.5 (15.5)	109.2 $\pm$ 10.24	110.5 (14.25)	0.90
II/GoGn (°)	97.2 $\pm$ 4.91	97.5 (6.5)	96.9 $\pm$ 4.48	97.75 (7.62)	0.81
Ms-OLp (mm)	54.38 $\pm$ 3.85	53.32 (4.75)	52.15 $\pm$ 6.51	52.5 (4.25)	0.47
Mi-OLp (mm)	54.34 $\pm$ 4.4	53.98 (4.20)	51.5 $\pm$ 6.63	51.5 (7.25)	0.30
OJ (mm)	4.78 $\pm$ 1.56	4.42 (0.33)	7.75 $\pm$ 3.34	7.25 (2.25)	<0.01
OB (mm)	3.40 $\pm$ 1.39	3.5 (1)	3.90 $\pm$ 2.01	4 (2.50)	0.54

* Wilcoxon sum rank test for continuous variables and Fisher's exact test for proportional ones. CG: control group; TG: treatment group. See Section 2.3 and Figure 1 for measurement landmarks and distances.

Table 2. Description of the whole sample according to treatment at T1. N:20. All data are shown as mean $\pm$ SD, median (iqr) for continuous variables and as n (%) for proportional ones.

	CG		TG		<i>p</i> Value *
	Mean $\pm$ SD	Median (iqr)	Mean $\pm$ SD	Median (iqr)	
Is-OLp (mm)	81.11 $\pm$ 6.48	80.53 (5.97)	82.15 $\pm$ 7.8	81.5 (5.25)	0.57
Ii-OLp (mm)	76.15 $\pm$ 6.59	76.55 (3.87)	78.1 $\pm$ 7.92	78.5 (5.75)	0.52
A-OLp (mm)	74.91 $\pm$ 5.19	73.89 (3.87)	75.35 $\pm$ 7.39	75.75 (4.75)	0.73
Pg-OLp (mm)	76.46 $\pm$ 6.61	76.55 (6.3)	79.9 $\pm$ 7.38	79 (5.88)	0.21
SNA (°)	83.95 $\pm$ 2.47	84.75 (2.38)	81.8 $\pm$ 3.11	81 (3.88)	0.12
SNB (°)	78.9 $\pm$ 2.48	79.5 (1.38)	79.3 $\pm$ 3.09	78.75 (3.12)	0.93
ANB (°)	5.05 $\pm$ 0.98	5 (0.75)	2.5 $\pm$ 1.35	2.75 (2.12)	<0.01
Wits (mm)	4.38 $\pm$ 2.91	4.42 (3.98)	2.95 $\pm$ 2.94	3.5 (3.5)	0.30
SN/GoGn (°)	28.05 $\pm$ 4.11	27.25 (4.75)	26.25 $\pm$ 5.16	24.5 (7)	0.32
Is/PP (°)	109.6 $\pm$ 6.51	110.25 (12)	115.85 $\pm$ 3.28	115.5 (4.38)	0.03
II/GoGn (°)	97.15 $\pm$ 4.74	97.25 (4.25)	99.95 $\pm$ 5.5	100.25 (8)	0.36
Ms-OLp (mm)	54.42 $\pm$ 3.81	53.32 (4.76)	52.3 $\pm$ 7.02	52 (6.38)	0.38
Mi-OLp (mm)	54.38 $\pm$ 4.5	53.98 (4.2)	56.05 $\pm$ 6.64	57 (7.38)	0.51
OJ (mm)	4.96 $\pm$ 1.63	4.42 (0.77)	4.05 $\pm$ 1.32	3.75 (1.75)	0.21
OB (mm)	3.35 $\pm$ 1.60	3.50 (2.25)	1.50 $\pm$ 1.20	1.75 (1)	0.02

* Wilcoxon sum rank test for continuous variables and Fisher's exact test for proportional ones.

Table 3. Description of the whole sample's differences according to treatment. N:20. All data are shown as mean $\pm$ SD, median (iqr) for continuous variables and as n (%) for proportional ones.

	CG T1-T0		TG T1-T0		<i>p</i> Value *
	Mean $\pm$ SD	Median (iqr)	Mean $\pm$ SD	Median (iqr)	
Is-OLp (mm)	0.1 $\pm$ 0.32	0 (0)	1.35 $\pm$ 2.6	1.75 (1.88)	0.02
Ii-OLp (mm)	−0.1 $\pm$ 0.88	0 (0)	5.05 $\pm$ 1.04	5 (1.25)	<0.01
A-OLp (mm)	0 $\pm$ 0	0 (0)	−0.3 $\pm$ 0.75	−0.25 (0.88)	0.20
Pg-OLp (mm)	0.3 $\pm$ 0.48	0 (0.75)	4.75 $\pm$ 1.11	4.5 (0.75)	<0.01
SNA (°)	0.15 $\pm$ 0.41	0 (0.38)	−0.15 $\pm$ 1.42	0 (1)	0.25
SNB (°)	0.2 $\pm$ 0.48	0 (0.38)	3.2 $\pm$ 1.51	3 (1.25)	<0.01
ANB (°)	−0.05 $\pm$ 0.37	0 (0.38)	−3.3 $\pm$ 1.23	−3.5 (2)	<0.01
Wits (mm)	−0.2 $\pm$ 0.63	0 (0.75)	−4.15 $\pm$ 3.36	−4.5 (4.75)	<0.01
SN/GoGn (°)	0 $\pm$ 0.71	0 (0.75)	−0.65 $\pm$ 0.91	−0.5 (0.88)	0.10
Is/PP (°)	−0.05 $\pm$ 1.91	−0.5 (3.25)	6.65 $\pm$ 12.41	4 (17.38)	0.34
II/GoGn (°)	−0.05 $\pm$ 1.61	0 (1)	3.05 $\pm$ 3.63	3 (3.62)	0.02
Ms-OLp (mm)	0 $\pm$ 0	0 (0)	0.15 $\pm$ 1.35	0.25 (1.38)	0.42
Mi-OLp (mm)	0 $\pm$ 0	0 (0)	4.55 $\pm$ 0.96	4.5 (0.5)	<0.01
OJ (mm)	0.17 $\pm$ 0.9	0 (0.44)	−3.7 $\pm$ 3.30	−3 (2.00)	<0.01
OB (mm)	−0.05 $\pm$ 0.43	0 (0)	−2.40 $\pm$ 1.66	−2.25 (3)	<0.01

* Wilcoxon sum rank test for continuous variables and Fisher's exact test for proportional ones.

Regarding the skeletal parameters, significant differences were found considering the mandibular sagittal position (SNB, $p < 0.01$ and Pg-OLP, $p < 0.01$) and skeletal relation (ANB, $p < 0.01$, Wits $p < 0.01$), while no significant differences were found in the maxillary bone length (A-OLP, $p = 0.20$) and vertical dimension (SN/GoGn, $p = 0.10$). Regarding dental changes, the sagittal position of the upper incisor (Is-OLP mm) increased in both groups ($p = 0.02$); similarly, the sagittal position (Ii-OLP mm) and inclination (Ii/GoGn°) of the lower incisors increased in both groups ($p < 0.01$ and $p = 0.02$, respectively). The upper molar position (Ms-OLP) slightly increased in both groups ($p = 0.42$), while the lower molar (Mi-OLP mm) moved forward in the TG and remained stable in the CG ($p < 0.01$). Finally, the overjet (OJ mm) and overbite (OB mm) significantly decreased in the TG, while they remained almost stable in the CG ($p < 0.01$). The linear regression model (Table 4) shows a significant positive association between the type of treatment and Pg-OLP (Beta: 4.45 (3.7 to 5.2)), which remains after correction for A-OLP (Beta: 4.58 (3.81 to 5.36)).

Table 4. Linear regression model of Pg-OLP (mm) difference as dependent variable and regressor.

	Model 1				Model 2			
	Coefficient	Stand. Err.	CI 95%	p Value	Coefficient	Stand. Err.	CI 95%	p Value
(Intercept)	0.3	0.27	−0.23 to 0.83	0.27	0.3	0.27	−0.23 to 0.83	0.26
Group (Cases)	4.45	0.38	3.7 to 5.2	<0.01	4.58	0.4	3.81 to 5.36	<0.01
A-OLP					0.44	0.38	−0.3 to 1.18	0.24

4. Discussion

The orthopedic treatment of class II patients with mandibular retrusion often involves the use of an HA due to its proven efficiency and the reduced requirement for compliance. Despite the skeletal benefits, some undesired dental effects—including the lingual tipping of the upper incisors, the labial flaring of the lower ones, the distal movement of the upper molars, and the mesialization of lower ones—caused by anchorage loss could hinder the desired mandibular advancement [21]. Thereby, the combination of the Herbst appliance with TADs, connected to the upper and lower arch through elastic chains (STM4), might result in minimizing the anchorage loss and promoting a greater esthetic result [5]. However, most studies have analyzed the benefits of combining the HA and miniscrews only in growing patients, with skeletal maturation between CVM3 and CMV4 [5,11]. After this favorable moment, the traditional HA exhibits limited skeletal effects and an increase in dental ones [22]. However, orthodontists do not always have the chance to treat patients during this ideal time window, as they present at their first visit after the pubertal peak, and a future combined orthodontic–orthognathic treatment is often refused, as was the case for these patients. Some authors have positively evaluated the use of the traditional Herbst appliance (without TADs) in young adults, with good results regarding facial profile attractiveness, although the effects were mainly dento-alveolar [19].

To date, no study has previously evaluated the effects of a TAD-supported acrylic splint Herbst appliance in the post-pubertal period, when spontaneous skeletal growth could occur but is generally limited, with the exception of a case report [23].

In this study, the aim was to compare the skeletal and dental outcomes of the treated group with those of untreated subjects after the pubertal peak, when growth is generally very modest. The study evaluated nonrandomized but consecutively treated patients and compared them with untreated subjects having the same sex, age, malocclusion, and skeletal maturation.

Patients and controls were analyzed at baseline for dissimilarity in the assessed parameters between the groups. As this was the first study on this protocol, a single post-treatment evaluation was performed. As expected, during the T0-T1 interval (about 9 months), the control group of untreated patients showed no variation in the maxillary base length (0 mm) and the clinically non-significant forward movement of the mandible (0.3 mm), with limited changes in the ANB (−0.05°) and Wits appraisal (−0.2 mm). Conversely, the treated

group of patients showed the significant advancement of the mandible (4.75 mm), with a significant reduction in the ANB angle (-3.3°) and Wits (-4.15 mm).

The achievement of such skeletal benefits might result from the meticulous control of the anchorage in both arches. The use of TADs and elastic chains in the lower arch allowed the limited proclination of the lower incisors (3.05°) and successfully controlled their sagittal position (Ii-OLP +5.05 mm, considering the advancement of the whole mandible of 4.75 mm).

Similarly, the combination of miniscrews and elastic ligatures in the upper arch prevented the lingual tipping of the upper incisors and, indeed, enabled an increase in the Is-PP angle ($+6.65^\circ$) and the forward movement of them (Is-OPL 1.35 mm). In the treated group, A point moved slightly backward (SNA = -0.15° , A-OLP = -0.3 mm, not significant) despite the presence of the upper elastic ligatures. This could be explained considering the labial tipping of the incisors, with the root moving backward, causing the A point to recede. Although the buccal tipping of the lower incisors reduced the useful space for mandibular advancement by 3.05° , the greater proclination of the upper incisors ($+6.65^\circ$) compensated for this loss, increasing the working space. Thus, the maintenance of an appropriate overjet might be crucial in explaining mandibular protrusion [8].

The Herbst appliance generally exerts a backward force on the maxillary dentition and an anterior force onto the mandibular dentition, with the distalization of the upper molars and the mesialization of the lower ones [24,25]. In this case, the skeletal anchorage allowed the mild mesialization of both the maxillary (0.15 mm) and mandibular (4.55 mm considering the advancement of the mandible of 4.75 mm) molars. Such control of the tooth position has both esthetic and functional value: on the one hand, it preserves or increases the initial overjet, which is mandatory to promote significant pogonion advancement; on the other hand, it avoids the opening of the nasolabial angle, as is usually observed after the use of an HA. Moreover, since anchoring the arches with TADs reduces dental compensation, this could facilitate eventual future maxillofacial surgery, if the therapy had only partial esthetic success [26]. Nonetheless, the success of this protocol is related to the TADs' stability: one of the limitations could be the modest failure rate of buccal miniscrews [27–29] placed without surgical guidance between the mandibular second premolar and the first molar, due to the limited availability of bone in this area. This problem can be easily overcome by repositioning the failed TAD between the second and first lower premolars, without compromising the results of the therapy. Replacing a miniscerw in the bicuspid area is a simple and minimally invasive option for both the patient and the orthodontist.

Indeed, in the maxilla, the anterior paramedian region of the palate is considered an extremely safe site for TAD insertion [30], especially with a CBCT-guided protocol [31], with a low risk to root lesions and a very high success rate. Conversely, in addition to a higher radiation dose, in the case of a TAD failure, reinsertion involves disassembling the upper appliance and replanning the workflow.

In the present study, two lower miniscrews failed and were immediately reinserted, with no significant consequences for the therapy. This was in accordance with the mean failure rate reported in the literature [28,29]; on the other hand, none of the upper TADs failed.

The acrylic splint Herbst appliance is generally associated with limited emergencies, complications, and failures [32]; in this study, no significant problems were encountered during the treatment, except for some discomfort in the early stages of the patients' adaptation to the Herbst appliance.

In post-pubertal patients, requiring a bone-borne maxillary expansion, this protocol, combining palatal miniscrews in the upper arch and inter-radicular ones in the mandible, could represent the best option. However, if transverse correction is not required, a different approach with four buccal TADs, as described by other authors [5], should be considered and validated.

The absence of double bite at the end of the Herbst phase was verified for all patients by clinical and cephalometric evaluation by observing the stability of the distance between the cervical vertebrae and the posterior edge of the mandible at T0 and T1.

Despite the promising results achieved, a larger sample size is necessary to confirm these conclusions; the presence of a control group with post-pubertal patients treated by the traditional HA, without skeletal anchorage, might also allow further evaluation regarding the therapeutic efficacy of the technique and its influence on facial esthetics. Moreover, a limitation of the study lies in the individual compliance at the end of the Herbst phase, with the use of class II elastics, which may affect the final esthetic outcome of the entire therapy. Finally, although these data are currently being collected, a long-term evaluation of treated patients would be necessary to assess the stability of the treatment.

5. Conclusions

This study on class II skeletal malocclusions in post pubertal patients treated with the Manni Telescopic Herbst Appliance, combined with upper and lower miniscrews and elastic chains (STM4 technique), led to the following conclusions:

- The STM4 technique might be an effective protocol for the skeletal correction of class II malocclusions after the pubertal peak (CVM5 and CVM6 patients);
- The STM4 technique might be able to reduce unfavorable dental compensations, especially at the level of the molars and incisors, increasing the orthopedic outcome of the treatment;
- The STM4 technique allows the mean pogonion advancement of 4.75 mm (clinically significant).

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