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Dentoskeletal effects of the Bite-Jumping appliance and the Twin-Block appliance in the treatment of skeletal Class II malocclusion: a retrospective controlled clinical trial

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SUMMARY
The current retrospective controlled trial aimed to compare the dentoskeletal effects of the Bite-Jumping (BJ) and the Twin-Block Appliance (TB) in the treatment of skeletal Class II malocclusion. The sample was screened for eligibility criteria including skeletal and dental Class II malocclusion; Cervical Vertebral Maturation at Stage 3 at treatment start, and Functional orthopedic treatment with either a TB or BJ appliances. Twenty-three patients treated with TB, and twenty-three treated with BJ were included. Cephalometric data were compared with a control group of 15 untreated subjects retrieved from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection. Baseline characteristics were similar between groups. A significant increase for the AO-BO dimension, and a significant decrease in the overjet, were registered for both study groups respect to controls. TB was more effective than BJ in increasing the mandibular length (Co-Gn), in reducing the ANB angle and changing the SNB angle. The resulting differences between the two groups could be attributed to the different appliances. In conclusion, both appliances demonstrated a clinical efficacy in treating Class II. TB seems therefore better indicated, respect to BJ, in Class II cases with a predominant component of mandibular hypoplasia.

Key words: functional jaw orthopedics, class II malocclusion, cephalometrics, growing subjects.

Introduction

Skeletal Class II malocclusions are caused by mandibular retrusion in about 80% of the total cases, which prompted many clinicians and researchers to study and typically use functional appliances that stimulate the growth of the mandible for the treatment of these dentoskeletal disharmonies in growing subjects (1-3).

In the 1950s, Martin Schwarz developed the Removable Double Plate Appliance (4, 5), which actually exists in technical variations, among which the Bite-Jumping Appliance (BJ) (6-8) that consists in two removable plates, with an incorporated guide bar in the maxillary plate, which is guided by an inclined plane in a mandibular plate. The articulation of the two bars with the mandibular plate leads the mandible forward when occlusion occurs (4, 6, 8).

The idea of the BJ, in addition, led William Clark to develop the Twin-Block Appliance (TB), which also consists of two separate plates

overlapping with each other with inclined acrylic surfaces that leads the mandible forward when it occludes (9). Furthermore, many modifications to this appliance can be applied, maintaining the same mechanism (10-13).
The use of separate plates in these two methods helps patients to increase their cooperation compared with previously developed functional appliances, maintaining their advantages, and the neuromuscular adaptation to this kind of treatment has been proved by some studies (14-16). Consequently, these appliances had a widespread distribution and became common clinically (5).
In literature several studies analyzed the dentoalveolar and skeletal effects produced by functional appliances, and the majority of them evaluated the effectiveness of a single appliance compared or not to an untreated control group. Evidence suggests that functional appliances are able to produce an elongation of the mandible (Co-Gn) and the magnitude of this effect is dependent on the design of the appliance. The greatest results can be achieved when treatment is performed at pubertal or immediately postpubertal periods of skeletal development (2). A previous systematic review (17) on the mandibular changes produced by functional appliances in Class II malocclusion analyzed the relevant literature from 1966 to 2005 and the results revealed that the Herbst appliance showed the highest efficiency followed by the TB. A subsequent systematic review (18) and meta-analysis including studies published between 1966 and 2016 assessed that BJ was observed to be the most effective device to improve the mandibular length.
Only one study (19) directly compared the dentoalveolar and skeletal changes resulting from treatment using the BJ and the TB appliances, however a limitation of this research was a lack of an untreated control group.
The current retrospective controlled trial aimed to compare the dentoskeletal changes resulting from treatment using the BJ and the TB compared with an untreated control group of subjects with the same malocclusion.

Materials and methods

In this retrospective controlled clinical trial, the cephalometric records of 46 patients with Class II division 1 malocclusion treated either with the Bite-Jumping (BJ) (group 1, 10 F, 13 M, mean age 11.1 ± 1.2), or the Twin-Block (TB) (group 2, 12 F, 11 M, mean age 10.8 ± 1.1 years) were collected. Class II subjects were retrieved from the records of patients treated at the Department of Orthodontics at the University of "Tor Vergata" (TB) and at the University of L'Aquila (BJ).
The study project was approved by the Ethical Committee at the University of Rome, and informed consent was obtained from the subjects' parents for the treatment and for the potential use of their data for research purposes.
The subjects were selected according to the following inclusion criteria: overjet greater than 5 mm, bilateral full Class II or end-to-end molar relationships, ANB angle greater than 4 degrees, improvement in facial profile when the lower jaw was postured in a forward position, cervical vertebrae maturation (CVM) stage 3 at T1 and lateral cephalograms available at two time periods: T1, at the start of treatment; and T2 at the end of functional treatment. Sample size calculation (G*Power version 3.1.9.2, Universität Düsseldorf, Germany) revealed that for an effect size f of 0.7, a first type error of 0.008 and a power of 0.95, a total sample size of 51 subjects was needed.
Treatment with functional appliances was discontinued with the achievement of Class I molar relationships.
All patients involved in the study were asked to wear the appliance 16 hours a day until the end of treatment. As occurs in studies involving any removable device, compliance with the instructions of the orthodontist and staff varied among the patients.
Both appliances were constructed with the same amount of mandibular advancement. The lower jaw was postured forward in a Class I or overcorrected Class I molar relationship to stimulate mandibular growth. The anterior advancement

should not exceed more than 70% of the most protrusive position.
Fifteen subjects with untreated Class II division 1 malocclusion were selected from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection (http://www.aaoflegacycollection.org, Bolton–Brush Growth Study, Michigan Growth Study, Denver Growth Study, Oregon Growth Study, and Iowa Growth Study) (Group 3).
The treated and the control samples were selected according to skeletal maturity at the start of treatment evaluated by means of the cervical vertebral maturation (CVM) method. The CVM method can be used to identify individual skeletal maturity in growing subjects and it can replace the hand-wrist radiograph (18). CVM staging was performed by an expert examiner (CP).
The demographic data of Bite-Jumping group, Twin-Block group and control group are reported in Table 1.
The practitioners who performed the treatment were blind to the fact that the patients would be part of a clinical study. Similarly, the examiners who analyzed lateral cephalograms of treated patients before and after treatment were blind as to the origin of the films and to the group to which individual patients belonged (double-blind design of the study).

Cephalometric analysis

All lateral cephalograms of each patient were hand traced in a single session. After masking patients' information by an independent operator (blinding procedure), tracings were performed at T1 and T2 by one investigator (MT). Landmark location and the accuracy of the anatomical outlines were verified by a second (CP). Any discrepancies as to landmark placement were resolved by mutual agreement.
ViewBox software (Viewbox 4.0, dHAL Software, Kifissia, Greece) was used for all the groups, and differences between T1 and T2 measurements were also calculated.
Twelve variables (8 angular and 4 linear) were generated for each tracing. The angle between the long axis of the upper central incisor and the plane passing through anterior and posterior nasal spine (U1^ANS-PNS), the angle between the long axis of the lower central incisor and the mandibular plane (L1^Go-Me), the distance between the perpendicular projections to functional occlusal plane of A point and B point (AO-BO), the angle between Frankfurt plane and mandibular plane (FMA), the distance between Condilion and Gnathion point (Co-Gn), and the distance between Condilion and Gonion point (Co-Go) were considered set as the primary outcomes.
The following measurements were also collected and set as secondary outcomes: the angle at Nasion between Sella and A point (SNA), the angle at Nasion between Sella and B point (SNB), the angle at Nasion between A and B point (ANB), the angle between mandibular plane and the plane passing through anterior and posterior nasal spine (Go-Me^ANS-PNS), the gonial angle between the plane passing through Articulare and Gonion and the plane passing through Gonion and Menton (Ar-Go^Go-Me).

Table 1 - Demographics for the treatment and control groups.

	T1		*T2*		*T2-T1 interval*
	Mean age ± SD	*CVM stages*	*Mean age ± SD*	*CVM stages*	*Mean age ± SD*
Group 1 Bite-Jumping (n=23, 10f 13 m)	11.1 ± 1.2	23 CS3	13.1 ± 1.4	19 CS4 4 CS5	2.0 ± 0.9
Group 2 Twin-Block (n=23, 12f 11m)	10.8 ± 1.1	23 CS3	13.0 ± 1.3	21 CS4 2 CS5	2.2 ± 1.1
Group 3 Controls (n=15, 7f 8m)	10.7 ± 0.9	15 CS3	12.6 ± 1	10 CS4 5 CS5	1.9 ± 0.4

Error of the method

To evaluate the error of the method, 20 randomly selected tracings were repeated after two weeks, and Intra-Class Correlation (ICC) coefficient was used to calculate intra-rater agreement between the two sets of measurements.

Statistical analysis

A Shapiro-Wilk normality test was used to assess the modality of data distribution ($p < 0.05$), then a One-way ANOVA was used to compare the cephalometric data of the three groups at baseline, and descriptive statistics were performed. To compare the effects of TB treatment, BJ treatment, and of growth in untreated controls, the differences between T1 and T2 measurements were used for subsequent analysis. Primary and secondary outcomes were analyzed independently: One-way ANOVA was used to detect any statistically significant difference among the three groups for the selected variables. Levene's Test was applied to test the assumption for equality of error variance: depending on its results, a Tukey's Honest Significant Difference or a Games-Howell test was used for the post-hoc analysis.
After applying Bonferroni's correction for multiple testing, the first type error for the primary outcomes was set at 0.008. First type error for secondary outcomes was set at 0.05.

Results

Before the beginning of treatment, the three groups showed homogeneous data for all primary outcomes (Table 2). The descriptive statistic is shown in Table 3. *Post-hoc* evaluations are reported in Table 4 for primary outcomes. *Post-hoc* evaluations for secondary outcomes are reported in Table 5.
Both BJ and TB showed a statistically significant and clinically relevant reduction of the distance AO-BO (mm), compared to the control group.
In group 2 (TB), there was a total increase of Co-Gn from T1 to T2 significantly higher than in group 1 and in the control group; the *post-hoc* analysis showed the absence of differences between the group 1 and the control group. The increase of SNB angle from T1 to T2 resulted significantly higher in group 2 compared to control group and group 1. Consequently, considering that SNA angle showed the absence of significant variations among the groups, the decrease of ANB angle resulted significantly higher in group 2 compared to the control group.
Data about the Co-Go confirmed a higher increase of the distance Co-Go in the group 2, that resulted statistically significant compared with group 1 and the control group. The lower increase observed in the group 1 resulted not significantly different from the control group although the p-value was considerably close to the significance threshold.
Both the functional appliances were able to reduce the overjet from T1 to T2, with statistically significant variations respect to the control group. From a clinical point of view, the average overjet turned within normal values in group 1 and 2, while it remained pathological in the control group.
Regarding the error of the method, all measurements showed an ICC coefficient above 0.75 confirming an excellent reliability.

Discussion

This retrospective controlled clinical trial aimed to compare the dentoskeletal effects of the Bite-Jumping Appliance (BJ) and the Twin-Block Appliance (TB), compared with an untreated control group of subjects with the same malocclusion.
The null hypothesis was that there is no difference in the outcomes measurements between subjects treated with these two appliances, and

Table 2 - One-way ANOVA for comparison of primary and secondary outcomes at baseline (T1) among groups.

Variable	*Sum of squares*	*df*	*F*	*P*
Dependent variable: U1^ANS-PNS†				
Between groups	61.50	2	1.08	0.347
Dependent variable: L1^Go-Me†				
Between groups	18.13	2	0.18	0.837
Dependent variable: AO-BO†				
Between groups	8.84	2	0.56	0.575
Dependent variable: FMA†				
Between groups	74.37	2	1.69	0.194
Dependent variable: Co-Gn†				
Between groups	63.45	2	1.06	0.354
Dependent variable: SNA				
Between groups	20.83	2	1.05	0.356
Dependent variable: SNB				
Between groups	61.5	2	1.76	0.182
Dependent variable: ANB				
Between groups	1.90	2	0.39	0.680
Dependent variable: Overjet				
Between groups	18.10	2	2.84	0.068
Dependent variable: Overbite				
Between groups	15.29	2	2.45	0.097
Dependent variable: Go-Me^ANSPNS				
Between groups	36.06	2	0.77	0.469
Dependent variable: Co-Go				
Between groups	40.91	2	1.12	0.334
Dependent variable: Ar-Go^Go-Me				
Between groups	194.87	2	2.29	0.111

*P< 0.05; †primary outcome; U1^ANS-PNS, angle between the long axis of the upper central incisor and the plane passing through anterior and posterior nasal spine; L1^Go-Me, angle between the long axis of the lower central incisor and the mandibular plane; AO-BO, distance between the perpendicular projections to functional occlusal plane of A point and B point; FMA, angle between Frankfurt plane and mandibular plane; Co-Gn, distance between Condilion and Gnathion point; SNA, angle at Nasion between Sella and A point; SNB, angle at Nasion between Sella and B point; ANB, angle at Nasion between A and B point; Go-Me^ANS-PNS, angle between mandibular plane and the plane passing through anterior and posterior nasal spine; Co-Go, distance between Condilion and Gonion; Ar-Go^Go-Me, gonial angle between the plane passing through Articulare and Gonion and the plane passing through Gonion and Menton.

untreated control patients. The present results rejected the null hypothesis.
The TB appliance induced a significant elongation of the mandible (Co-Gn in mm) over the BJ appliance (+ 4.18 mm) and the controls (+ 4.12 mm); while the BJ group showed not significantly differences when compared with the controls (- 0.07 mm). These results are in agreement with those reported by Cozza et al. in their systematic review (17) that confirmed a statistically significant increase in mandibular length (Co-Gn) induced by TB appliance when compared to

Table 3 - Descriptive statistics for cephalometric primary and secondary outcomes of the three groups (mean ± SD) and One-way ANOVA comparison of changes between T1 and T2.

Outcome variable	*Group 1 (n= 23) (BJ)*			*Group 2 (n= 23) (TB)*			*Group 3 (n= 15)*			*One-way ANOVA*
	T1	*T2*	*T2-T1*	*T1*	*T2*	*T2-T1*	*T1*	*T2*	*T2-T1*	*T2-T1*
U1^ANS-PNS (°)†	113.76 ± 6.19	108.84 ± 6.77	-4.91 ± 8.09	111.26 ± 3.30	108.68 ± 5.56	-2.58 ± 3.95	112.33 ± 6.13	111.58 ± 6.5	-0.74 ± 2.55	ns
L1^Go-Me (°)†	95.64 ± 8.01	98.35 ± 7.46	2.71 ± 2.63	96.38 ± 5.16	96.58 ± 4.18	0.20 ± 3.51	97.09 ± 7.99	98.5 ± 7.58	1.42 ± 2.12	ns
AO-BO (mm)†	2.38 ± 3.03	-0.11 ± 2.60	-2.50 ±2.77	3.34 ± 2.61	0.49 ± 3.19	-2.85 ± 1.89	2.89 ± 2.76	3.28 ± 3.17	0.4 ± 2.03	F=9.83 *P*<0.001
FMA (°)†	24.40 ± 5.54	24.24 ± 5.20	-0.16 ± 2.52	24.70 ± 3.32	24.02 ± 3.43	-0.66 ± 1.51	21.94 ± 4.91	21.16 ± 5.09	-0.8 ± 1.03	Ns
Co-Gn (mm)†	99.98 ± 5.23	104.49 ± 5.56	4.5 ± 2.87	97.51 ± 5.74	106.2 ± 5.57	8.69 ± 2.32	99.39 ± 5.42	103.97 ± 6.04	4.57 ± 1.22	F=19.77 *P*<0.001
SNA (°)	81.86 ± 3.93	81.46 ± 4.01	-0.4 ± 1.75	80.40 ± 2.55	80.69 ± 2.97	0.28 ± 1.24	81.23 ± 2.59	80.71 ± 3.15	-0.53 ± 1.52	ns
SNB (°)	76.17 ± 3.10	77.10 ± 3.31	0.78 ± 2.01	74.40 ± 2.91	76,64 ± 2.89	2.23 ± 0.87	75.11 ± 2.79	75.47 ± 3.4	0.35 ± 1.07	F=8.17 *P*=0.001
ANB (°)	5.69 ± 1.95	4.36 ± 1.66	-1.33 ± 1.46	6.04 ± 0.95	4.07 ± 0.73	-1.96 ± 1.12	6.13 ± 1.6	5.26 ± 1.71	-0.89 ± 1.13	F=3.15 *P*=0.05
Overjet (mm)	7.58 ± 1.93	4.21 ± 1.10	-3.37± 2.07	6.96 ± 0.93	3.24 ± 0.89	-3.70 ± 1.01	6.13 ± 2.34	5.85 ± 2.31	-0.25 ± 0.79	F=27.61 *P*<0.001
Overbite (mm)	2.49 ± 1.90	1.92 ± 1.16	-0.57 ± 2.06	3.74 ± 1.82	2.63 ± 1.31	-1.10 ± 1.50	3.13 ± 1.49	3.35 ± 1.37	0.21 ± 1.07	ns
Go-Me^ANS-PNS (°)	26.66 ± 5.11	25.64 ± 5.26	-1.01 ± 1.87	26.32 ± 4.02	25.52 ± 3.93	-0.81 ± 1.63	24.69 ± 5.53	23.71 ± 5.63	-0.97 ± 1.13	ns
Co-Go (mm)	46.77 ± 4.79	50.07 ± 5.59	3.30 ± 3.41	47.04 ± 3.73	52.43 ± 3.97	5.40 ± 1.66	48.83 ± 4.16	51.07 ± 4.5	2.24 ± 1.85	F=7.19 *P*=0.002
Ar-Go^Go-Me (°)	126.02 ± 6.39	125.86 ± 6.74	-0.16 ± 3.14	124.12 ± 6.80	123.94 ± 6.60	-0.21 ± 2.36	121.26 ± 6.3	119.51 ± 6.81	-1.77 ± 1.95	ns

†primary outcome; U1^ANS-PNS, angle between the long axis of the upper central incisor and the plane passing through anterior and posterior nasal spine; L1^Go-Me, angle between the long axis of the lower central incisor and the mandibular plane; AO-BO, distance between the perpendicular projections to functional occlusal plane of A point and B point; FMA, angle between Frankfurt plane and mandibular plane; Co-Gn, distance between Condilion and Gnathion point; SNA, angle at Nasion between Sella and A point; SNB, angle at Nasion between Sella and B point; ANB, angle at Nasion between A and B point; Go-Me^ANS-PNS, angle between mandibular plane and the plane passing through anterior and posterior nasal spine; Co-Go, distance between Condilion and Gonion; Ar-Go^Go-Me, gonial angle between the plane passing through Articulare and Gonion and the plane passing through Gonion and Menton.

untreated controls. Conversely, Santamaría-Villegas et al. in a systematic review and meta-analysis (18) came to a different conclusion: the increase in mandibular length (Co-Gn) was greatest with the BJ (3.4 mm CI 95% 1.69-5.11), followed by TB (1.8 mm CI 95% 0.87-2.73). However, the main limitation to compare the measurements of mandibular length among the different studies, is that there is not consistency of measurement.

The same trend observed for the Co-Gn value was found for the mandibular ramus height (Co-Go). This variable showed a statistically significant difference between TB group when com-

Table 4 - *Post-hoc* test for primary outcome changes (T2-T1) between groups.

Dependent variable	*(I) Group*	*(II) Group*	*Mean difference (I-II)*	*SE*	*P*	*99.2% Confidence Interval*	
						Lower bound	*Upper bound*
U1^ANS-PNS (°)‡	1	2	-2.33	2.01	0.490	-7.34	2.02
	1	3	-4.17	1.92	0.098	-8,98	0.47
	2	3	-1.84	1.12	0.245	-4.60	2.85
L1^Go-Me (°)†	1	2	2.51	0.91	0.023	0.29	4.72
	1	3	1.29	0.97	0.390	-1.07	3.65
	2	3	-1.22	0.98	0.438	-3.60	1.16
AO-BO (mm)†	1	2	0.35	0.73	0.881	-1.42	2.12
	1	3	-2.90*	0.78	0.002	-4.79	-1.01
	2	3	-3.25*	0.79	<0.001	-5.16	-1.34
FMA (°)‡	1	2	0.50	0.59	0.682	-0.94	1.93
	1	3	0.64	0.63	0.575	-0.89	2.17
	2	3	0.14	0.64	0.973	-1.41	1.69
Co-Gn (mm)‡	1	2	-4.18*	0.84	<0.001	-6.22	-2.15
	1	3	-0.07	0.71	0.995	-1.84	1.70
	2	3	4.12*	0.62	<0.001	2.58	5.65

*P< 0.008; †Tukey HSD test; ‡Games-Howell test; U1^ANS-PNS, angle between the long axis of the upper central incisor and the plane passing through anterior and posterior nasal spine; L1^Go-Me, angle between the long axis of the lower central incisor and the mandibular plane; AO-BO, distance between the perpendicular projections to functional occlusal plane of A point and B point; FMA, angle between Frankfurt plane and mandibular plane; Co-Gn, distance between Condilion and Gnathion point.

pared to BJ group (+2.10 mm) and control group (+3.16 mm). Similar effects of the TB appliance on the Co-Go value were reported by other Authors (21).

The functional appliances were effective in improving the skeletal sagittal intermaxillary relationship with a reduction of approximately 3.5 mm both in the Wits appraisal (2). From a clinical and statistical point of view, TB and BJ appliances were able to return the AO-BO distance to the normal range of values, while in the control group the same variable remained in the range of pathology. Specifically, the AO-BO distance at T2 resulted -0.11 mm in BJ group, and 0.49 mm in TB group, while it remained pathological in the control untreated group (3.28 mm) with statistically significant differences.

In the current study, both functional appliances were effective in reducing the overjet (-3.37 mm for the BJ group and -3.70 mm for the TB group), compared with the control group (-0.25 mm). In accordance with our results Martina et al. (7) found that BJ appliance determined an improvement of sagittal dental relationships as compared to controls, by producing a significant overjet reduction (5.3 mm; 95% CI 6.7-4.1 mm), while Illing et al. (22) reported similar results for the TB appliance of an overjet reduction from 10.2 mm to 4.5 mm.

Regarding incisors position, Illing et al. (22) reported a statistically significant retraction of upper incisor (U1^ANS-PNS: -9.1°) and a moderate proclination of the lower incisor (L1^Go-Me: +2.0°) as a consequence of TB treatment. Similarly, Martina et al. (7) observed comparable significant changes in incisors position for the BJ with a minor proclination of the lower incisor (L1^Go-Me: +3.0°) and a retraction of upper incisor (U1^SN: -5.4°). In the present study a proclination of the lower incisors was ob-

Table 5 - Post-hoc test for secondary outcome changes (T2-T1) between groups.

Dependent variable	*(I) Group*	*(II) Group*	*Mean difference (I-II)*	*SE*	*P*	*95% Confidence Interval Lower bound*	*95% Confidence Interval Upper bound*
SNB (°)†	1	2	-1.44*	0.492	0.018	-2.66	-0.22
	1	3	0.43	0.528	0.696	-0.87	1.73
	2	3	1.87*	0.341	<0.001	1.02	2.72
ANB (°)†	1	2	0.63	0.404	0.269	-0.34	1.61
	1	3	-0.44	0.431	0.562	-1.48	0.60
	2	3	-1.07*	0.436	0.044	-2.13	-0.02
Overjet (mm)‡	1	2	0.33	0.518	0.795	-0.95	1.62
	1	3	-3.12*	0.506	<0.001	-4.37	-1.86
	2	3	-3.45*	0.308	<0.001	-4.21	-2.69
Co-Go (mm)†	1	2	-2.10*	0.852	0.049	-4.21	0.01
	1	3	1.06	0.900	0.476	-1.16	3.28
	2	3	3.16*	0.612	<0.001	1.65	4.67

*P< 0.008; †Tukey HSD test; ‡Games-Howell test; SNB, angle at Nasion between Sella and B point; ANB, angle at Nasion between A and B point; Co-Go, distance between Condilion and Gonion

served in the BJ group compared to the TB appliance, that showed a better control of incisors position, however this result was not statistically significant. This finding suggests that there was no dentoalveolar compensation in the skeletal correction of Class II malocclusion. Consequently, the absence of the coverage of the lower incisors did not affect significantly their inclination.

The TB group revealed statistically significant differences in SNB angle when compared with the BJ (+1.44 degrees) and in SNB and ANB values with the control group (respectively +1.87 degrees and -1.07 degrees).

Instead patients treated with BJ device, at end-of-treatment, showed an ANB value not significantly different from the control group. In addition, concerning the ANB angle, the predictability of the BJ effects was lower than for TB, as underlined by the standard deviation of ANB angle at T2, which was 1.66 for the BJ group, and 0.73 for the TB group. In agreement with our study Illing et al. (22) found a statistically significant reduction in ANB angle using the TB appliance, whereas they observed no significant differences in SNB values. No data were found in literature for the BJ appliance.

As for the vertical skeletal effects, functional appliance treatment did not induce any significant change either in the inclination of the palatal plane to the Frankfort horizontal or in the inclination of the mandibular plane to the Frankfort horizontal and to the palatal plane (2). No differences were found in our study between BJ, TB, and control group for the variables regarding the vertical plane (FMA°, Go-Me-ANS-PNS). These results are in accordance with those reported by Martina et al. (7) that found no clockwise mandibular rotation during treatment with the BJ. On the contrary Illing et al. (22) observed a small reduction in the Go-Me-ANS-PNS (-1.5°) with the use of TB appliance.

Considering the present cephalometric findings, it can be argued that both the BJ and TB appliances are effective in treating class II malocclusion (reaching AO-BO distance normalization, and overjet reduction). However, TB appears more effective respect to the BJ appliance in increasing the mandibular length, the SNB angle, mandibular ramus height, and in reducing the

ANB angle. From a clinical point of view, the changes observed in Co-Gn, SNB, ANB, Co-Gn in the BJ group were all in the direction of a Class II correction, and reached the correction of the AO-BO distance, resulting in a clinical correction. But some changes registered with BJ were not statistically relevant, respect to the control group. Therefore, it can be argued that the TB appears to be particularly effective in Class II cases for which the mandibular hypoplasia component prevails, while BJ can be routinely used in class II with mixed components.

In contrast to our findings, the only study (19) that it can be found in literature directly comparing the treatment outcomes of TB and BJ concluded that the two appliances produced similar changes in the sagittal plane, including significant increase in SNB angle and no significant changes in the maxilla, the only difference was observed in the vertical plane because the BJ induced mandibular clockwise rotation, whereas the TB produced fewer changes in the vertical plane.

However, it must be underlined that the cited study did not include an untreated control group and this is the reason why those results are not directly comparable to the present study.

In conclusion, compared to untreated controls, TB and BJ caused a statistically significant reduction in the AO-BO distance with respect to the control group, leading to a clinical normalization of this cephalometric variable. Additionally, both TB and BJ devices were able to significantly reduce the overjet at the end of treatment, respect to the control group.

Both the two appliances, therefore, demonstrated a clinical efficacy in treating class II malocclusion.

However, TB was more effective than BJ in increasing the mandibular length (Co-Gn), and the ramus height (Co-Go), and therefore more reliable in reducing the ANB angle and changing the SNB angle. It seems therefore more indicated, respect to BJ, in class II cases with a predominant component of mandibular hypoplasia.

Conflict of interest

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