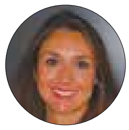
Maxillary "en masse" high-pull traction in Class II division 1 subjects: Which kind of skeletal outcomes does it produce?



F. Silvestrini-Biavati,
L. Lazzarotti, S. Bini,
M. Migliorati, A. Ugolini

*Department of Orthodontics,
University of Genoa, Genoa, Italy*

e-mail:
alessandro.ugolini@unige.it

DOI 10.23804/ejpd.2020.21.04.3

Abstract

Aim The aim of the present prospective study was to evaluate if the treatment performed using high-pull traction on a Stephenson plate had real orthopaedic outcomes in subjects with severe Class II Division 1 malocclusion due to maxillary protrusion.

Materials and methods Twenty-three growing patients showing Class II Division 1 malocclusion (Stephenson plate group, SPG) were treated and compared with an untreated Class II control group (CG – 21 subjects selected from the database of Bolton-Brush Growth Study). Lateral cephalograms at T0 and T1 for both groups were analysed using cephalometric tracing by Jarabak, Pancherz and Ghosh-Nanda.

Results Orthopaedic forces were applied in SPG. SPG group showed significantly greater decrease than CG group of SNA° (-1.4° vs +0.7°), ANB° (-1.3° vs +0°), WITS (-1° vs 0.6°), overjet (-4.1 mm vs +0.3 mm), molar relationships (–6.1° mm vs -0.1 mm) and upper incisors proclination (1/SpP, -10.3° vs -1°). The maxilla substantially maintained its position (A/OLp +0.3 mm, SNA° -1.4°) while the mandible slightly grew (Pg/OLp +1.7 mm; SNB° + 0.7°). Facial pattern and AFA/AFP ratio did not change.

Conclusions The high-pull traction on the Stephenson plate produced more dental than skeletal outcomes in growing subjects, despite of the application of orthopaedic forces.

KEYWORDS Class II malocclusion; Orthopaedic high-pull traction; Maxillary distal movement; Stephenson plate; Orthopaedic force.

Introduction

Class II Division 1 severe dento-skeletal malocclusions due to maxillary protrusion usually show an increased overjet, full Class II molar relationships and a sagittal discrepancy of maxillary and mandibular jaws; furthermore, there is the presence of transversal and vertical deficits [Grippaudo et al., 2020; Quinzi et al., 2018; Silvestrini et al., 2013, 2016]. It is known that extraoral forces applied to maxillary teeth may produce an orthopaedic effect [Cacciatore et al., 2019]; in this case, a skeletal distal movement of the entire maxilla is expected.

The advantages of an "en masse" maxillary distal movement are: Whole correction of both dental and skeletal features; shorter first treatment phase (until Class I molar relationship and a normal overjet are obtained); fast correction of overjet (that stops the lower lip sucking and the consequent worsening of malocclusion); use of a removable appliance in the distalisation phase (and shorter fixed treatment in the second phase); no bicuspids extractions (in hypo-normodivergent subjects); low costs of the removable appliance (important in social public units); reduced hygiene problems [Showkatbakhsh et al., 2013; Maspero et al., 2018; Goracci and Cacciatore, 2017; Monaco et al., 2013; Fabiani et al.,2017; Quinzi et al., 2020a, 2020b].

Stephenson plate with orthopaedic high-pull traction (SP) is a device about which only few references are available [Stephenson, 1968; Stephenson, 1974; Di Malta, 1979; Deshayes 1979]. It is similar to the "maxillary splint" [Thurow, 1975], "maxillary orthopaedic splint" [Joffe et al., 1979], "maxillary traction splint" [Caldwell et al., 1984], and "removable maxillary splint" [Fotis et al., 1984] found in literature. The use of SP, that joins all the maxillary teeth and pulls them backwards and upwards, should produce orthopaedic effects, when forces of 700–900 grams per side are applied on a head-cap. Since the forces delivered to the maxillary basal bone involve all the upper teeth rather than only the maxillary first molars and through the teeth reach the basal bone, the effect on the maxilla would be an "en masse" distal movement of both teeth and bone, and, moreover, may restrain its physiological downward and forward growth.

Between 1975 and 1992 some important authors studied the effects of maxillary splints with orthopaedic traction on human subjects [Thurow, 1975; Joffe et al., 1979; Caldwell et al., 1984; Fotis et al., 1984; Castanha Henriques et al., 1991; Orton et al., 1992], on monkeys [Droschl, 1973; Droschl, 1975; Brandt et al., 1979] and on dry skulls [Kragt et al., 1982; Duterloo et al., 1985]; all the results were very positive. The experimental researches on monkeys, using continuous forces application, showed dramatic changes of occlusion (until Class III dental relationships) and of skeletal structures (auditory canal and pterygo-maxillary fissure) [Brandt et al., 1979]. After 1992 only five articles were published on this topic [Duterloo et al., 1985; Uner et al., 1996; Martins et al., 2008; Garbui et al., 2010; Thurman et al., 2011; Jacob et al., 2013]. None of the previous studies on similar "en masse" appliances analysed the outcomes in pre-pubertal subjects using the cephalometric analysis by Pancherz [1982] and by Ghosh-Nanda [1996].

In a previous article [Silvestrini Biavati et al., 2019], the treatment outcomes were reported, focusing on overjet correction and timing. The aim of the present prospective study was to evaluate if the treatment with high-pull traction on Stephenson plate in CS1-3 selected subjects having Class II Division 1 malocclusion due to maxillary protrusion produced really orthopaedic effects.

Subjects and methods

Study design

This study was performed in the Department of Orthodontics, School of Dentistry, University of Genoa, Italy. All subjects were in vertebral stages CS1-3 [Baccetti et al., 2002] and had Class II Division 1 malocclusion; none underwent extraction or had agenesis and craniofacial syndromes. For sample collection, the inclusion criteria were the following.

- Mixed dentition, Class II molar relationship with at least 1/2 cusp distal relation.
- Lateral cephalograms and ortopantomographies available at the beginning (T0) and at the end (T1) of treatment.
- having at least two of the following parameters in cephalometric tracing:
    - ANB > 4.5°,
    - Overjet ≥ 5 mm,
    - Wits ≥ 3 mm,
    - SNA > 83°.

This clinical research was approved by the "Department of Surgical and Diagnostic Sciences" of University of Genoa, Italy (No. 734 bis). All the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000. The Stephenson plate [Stephenson, 1968; Stephenson, 1974] (SP) is an acrylic plate, anchored with Adams' clasps on upper first permanent molars, bicuspids or deciduous molars; the plate has tubes for extraoral traction soldered upon Adams' clasps, between first and second deciduous molars or bicuspids, where the extraoral bow is applied; an transversal expansion screw is used only for greater stability; the labial arch is surrounded with acrylic. The elastic force (700–900 g per side) is tied to the head-cap, choosing a vector passing through the maxillary center of resistance (Fig. 1, 2). The plate was applied on patient checking its stability; then an head-cap was adapted to the patient and high-pull orthopaedic heavy safe-modules (American Orthodontics, Sheboygan, WI, USA) were applied to the extraoral arch and measured with a dynamometer (Correx Haag-Streit, Bern, Switzerland) (traction of 700–900 g per side). All patients were instructed on the insertion of the device and on daily duration of application (at least 14 h per day). All subjects were treated consecutively by the same operator until reaching, after this orthopaedic phase, at least Class I molar relationship and a significant overjet improvement. Once a month the subjects were controlled, checking the traction force, the molar relationships and the position of the upper incisors. Treated patients had a good compliance (peremptory in these cases) and tolerated this headgear on Stephenson plate well.

Twenty-three growing subjects (14 females and 9 males) were included in the treated group (SPG). At baseline (T0), the mean age was 10.4 ± 1.9 years (CS 1-3). The mean duration of the SPG active phase was 1 year ± 0.8; in the retention period the appliance was worn only by night. At the end of retention treatment (T1), the mean age was 12.0 ± 2.0 years (observation interval T1-T0 1.6 ± 0.8 years).

As a control group a sample of 35 subjects (14 girls and 16 boys) was selected from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection (http://www.aaoflegacycollection.org, Database of Bolton-Brush Growth Study Center of Case Western Reserve University, Cleveland, Ohio). The control subjects were selected according to the same criteria at T0 as for the SPG group and were matched for age, sex, and skeletal maturity. Fourteen cases were excluded for difficult calibration. Nine males and 12 females composed the final control group (CG), with a mean age of 9.5 ± 0.7 years at T0 and 11.2 ± 0.6 years at T1, and the duration of the T0–T1 observation interval was 1.7 ± 0.7 years.

Cephalometric analysis

Lateral cephalograms (corrected to match a 0% enlargement factor) were taken at T0 and T1 for both the SPG and CG. Measurements were carried out with a customised cephalometric software (Orisceph Rx3, Orisline, Vimodrone, Milan, Italy).

Method error

As previously reported [Silvestrini Biavati et al., 2019] 10 lateral cephalograms at T0 and T1 of ten randomly selected patients were retraced and redigitised by a second examiner and a combined error of landmark location, tracing, measurement was determined. Intraclass correlation coefficients (ICC) were calculated for comparison. Within-subjects and between-subjects variability were obtained by intraclass correlation coefficients (ICC). ICC for linear measurement were 0.3 mm ± 0.7 mm and for angular measurements were 0.5° ± 0.6°. To calculate the inter-rater reliability, cephalograms were retraced by a second examiner and a k-Cohen-Fleiss coefficient of .92 was found. Overall, the method error was considered negligible.

Dentoskeletal changes were determined using cephalometric analysis by Jarabak and Pancherz (Fig. 3); some new measurements were added, in order to control maxillary movements (modified Pancherz) (Fig. 4); moreover the analysis by Ghosh-Nanda was traced in order to determine after treatment upper teeth tipping with respect to S-N Plane.

Statistical analysis

Shapiro-Wilk's test showed that data in both groups were normally distributed, and thus parametric statistics were applied. For all variables within and between group analysis were carried out using Student's t tests. Probabilities of less than 0.05 were accepted as significant in all statistical analyses. Sample size was calculated a priori to obtain a statistical power of the study greater than 0.85 at alpha of 0.05, using the mean values and standard deviations of SNA correction after removable headgear splint therapy found by Martins et al. [2008].

Results

Cephalometric measurements and p-value of the two groups at T0 and T1 are reported in Tables 1-3. The statistical comparison on the T0-T1 cephalometric changes showed

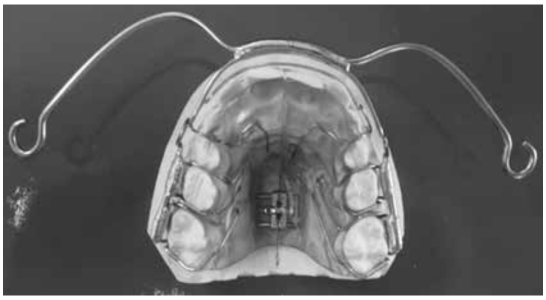


FIG. 1 Stephenson plate, with the extraoral bow.

FIG. 2 High-pull traction.

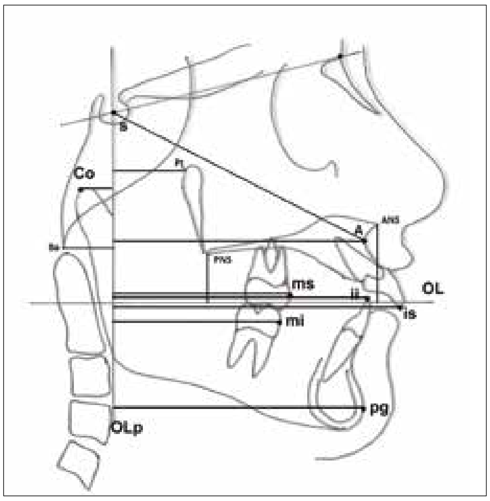


FIG. 3 Cephalometric analysis by Pancherz.

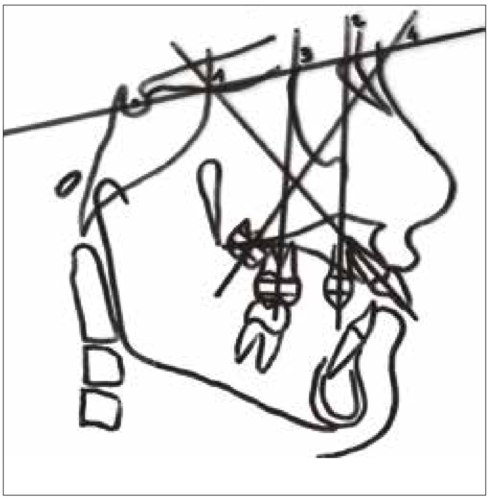


FIG. 4 Ghosh-Nanda analysis: the vertical axes of central incisor, 1st premolar, first-second molars were measured with respect to S-N plane [Ghosh and Nanda, 1996].

statistically significant differences both in the skeletal and dental variables.

Dentoalveolar changes

From Jarabak' analysis, at T1 the SPG group showed a significant reduction in the overjet (-4.1 mm vs +0.3 mm in CG; p<0.01), in the molar relationships (-6.1 mm vs -0.1 mm in CG; p<0.01), in the upper incisors proinclination (1/PP -10.3° vs -1.6 in CG; p<0.01). The lower incisors showed a back movement in the SPG (-3.1°) while maintained their position in CG (Table 1). After treatment, the upper incisors, the bicuspids and the first molars resulted back-tipped (Table 2) respectively 11.8°, 5.7° and 6.1° with respect to the S-N Plane. Pancherz' analysis showed significant changes in the position of the central incisor within the maxilla (-3.8 vs + 0.1 mm; p<0.01) and of the first molar within the maxilla (-2.8 vs +0.5 mm; p<0.01), together with overjet (-4.1 vs +0.3 mm; p<0.01) and molar relationships (-6.1 vs -0.1 mm; p<0.01) changes.

Skeletal changes

In the sagittal plane the SPG and CG groups respectively showed decreases of SNA° (-1.4° vs +0.3°; p=0.02), ANB (-1.3° vs 0°; p=0.01) and WITS (-1.0° vs +0.9°; p<0.01) values, while SNB° remained the same (Table 3). S-N distance was stable in the two groups, while Go-Me grew more in SPG (+3.3 mm vs 1.3 mm; p=0.01). In the vertical plane, facial pattern (∑) remained the same in both groups, as well as AFA/AFP relation (%). The data achieved using the modified Pancherz' analysis showed that S-A distance at T1 was shorter in SPG (1.1 mm vs 2 mm; p=0.04), as well as PTV/OLp (0.1 vs 1.1 mm; p=0.05), focusing a reduced maxillary descent. The modifications of the distances PNS/OL (0.2 vs 1 mm; p=0.05) and ANS/OL (-1.1 vs 0.6 mm; p=0.01) put in evidence a limited maxillary rotation and restraint.

Discussion

About bones, sutures and orthopaedic maxillary distal movements, we do not know exactly what can we reach without surgery, because it depends both from the skeletal age of the subject (and synostosis degree of involved sutures), and from the compliance of the patient.

The most important skeletal effect was essentially a restraint: the position of the maxillary base remained the same (A/OL_P 0.3 mm in SPG with respect to untreated control subjects that worsened 1.5 mm). SNA° had a reduction (-1.4° after SPG vs +0.7° in GC) as well as Wits (-1.0 mm in SPG vs +0.6 mm in GC). The minor improvement of S-A distance (+1 mm in SPG vs +2.4 mm in GC), together with the SNA, ANB, WITS, PTV/OLp, PNS/OLp, PNS/OL and ANS/OL modifications confirmed that maxilla was not able to come down and was partially restraint. The very significant dental outcomes, in the maxilla, showed an important distal movement of the upper molars (ms/OL_P -2.6 mm in SPG vs 1.9 mm in GC), a net reduction of overjet (-4.1 mm in SPG vs 0.2 mm in GC; is/OL_P -3.4 mm in SPG vs 1.6 mm in GC;), and of upper incisor inclination (1/SPP -10.3° in SPG vs -1.0° in GC). The net molar

Dental	Stephenson				Bolton				Stephenson		Bolton		T0 vs T0	Stephenson T1-T0	Bolton T1-T0	Steph vs Bolton Net difference
	T0 Mean	T0 SD	T1 Mean	T1 SD	T0 Mean	T0 SD	T1 Mean	T1 SD	Net Mean	Net SD	Net Mean	Net SD	P-value	P-value	P-value	P-value
+1/PP°	114,9	6,1	104,7	6,9	112	9,4	110,4	9,9	-10,3	8,7	-1,6	4,5	0,17	<0,01*	0,12	<0,01*
-1/MP°	98,1	7,4	95	6,2	98,8	8,7	99	10,3	-3,1	5,1	0,1	3,7	0,72	0,01*	0,86	0,02*
1. Overjet is/OLp (d) minus ii/OLp (d)	7,8	2,2	3,7	1,7	5	2,4	5,3	2,2	-4,1	2	0,3	1,1	<0,01*	<0,01	0,35	<0,01*
2. Molar relation ms/OLp (d) minus mi/OLp (d)	2,7	1	-3,5	1,7	2	1,3	1,9	1,1	-6,1	1,6	-0,1	1,5	0,92	<0,01*	0,8	<0,01*
Position of the maxill. centr incisor is/Olp (d)	81,4	5,1	77,9	5,7	77,1	3,6	78,4	3,8	-3,4	3	1,3	1,6	<0,01*	<0,01*	<0,01*	<0,01*
Position of the mand. centr incisor	73,7	6	74,3	5	72,1	3,9	73,1	3,8	0,5	3,3	1	2,2	0,27	0,46	0,03*	0,49
Position of the maxill. permanent 1st molar ms/OLp (d)	49,8	4,8	47,3	5,2	47,7	3,6	49,6	3,7	-2,5	4,2	1,9	2,7	0,11	0,01*	<0,01*	<0,01*
Position of the mand. permanent 1st molar mi/OLp (d)	47,1	5,1	50,7	5,2	45,7	4	48	3,9	3,6	4,1	2,2	2,5	0,32	<0,01*	<0,01*	0,18
Change in posit. cent incis within max is/OLp (d) minus A/OLp (d)	8,4	1,9	4,5	2,6	4,6	1,6	4,6	2,1	-3,8	2	0,1	1,3	0,00*	<0,01*	0,92	<0,01*
Change in position centr incis within mand. ii/OLp (d) minus Pg/OLp (d)	2,5	3,6	1,2	3,1	1,6	2,2	1,5	2,6	-1,1	1,8	-0,1	1,8	0,33	<0,01*	0,83	0,05*
Change in posit. perm. 1st molar within the max. ms/OLp (d) minus A/OLp (d)	-24,8	2,4	-27,6	3,7	-19,6	2,4	-19,2	1,7	-2,8	3,3	0,5	3,1	0,00*	<0,01*	0,51	<0,01*
Change in posit. of perm. 1st molar within mandib. mi/OLp (d) minus Pg/OLp (d)	-25,3	4,2	-23,4	4,4	-20,2	2,9	-19,7	2,7	1,9	2,6	0,6	3,1	0,00*	<0,01*	0,26	0,27

TABLE 1 cephalometric measurements for dental variables at T0 and T1; differences T1-T0 and statistical significance (*= p<0.05).

correction was -6.1 mm in SPG vs -0.1 mm in GC.

All the upper teeth moved back, with partial crown tipping (6-11.8° excluding second and third molars), probably due to the single point of application of orthopaedic intermittent forces on anchorage teeth crowns. The net overjet (4.1 mm) correction occurred for the complementary action of incisors distal movement with some tipping, maxillary restraint (that maintained A point) and mandibular growth (Go-Me +2 mm in the treated group); the fast overjet correction stopped the lower lip sucking. The upper molar distalisation (4.7 mm) mainly contributed to the net molar correction: the lower molars maintained their position within the mandible, that grew bringing them about 2 mm mesially.

These results are somewhat unexpected. When we apply orthopaedic forces, we are accustomed to think that the result will be a real skeletal distal movement. The outcomes of the present study do not confirm this argument, as a matter of fact we obtained a mainly dento-alveolar correction joined to some skeletal modifications. The ratio of dental to skeletal change for the active phase was 2 (dental) to 1 (skeletal) as happened in Macaca Fascicularis monkeys' experiments [Brandt et al., 1979].

In growing subjects, the maxillary descent is physiological: to be able to avoid or limit this descent is already a great success. Moreover, the maxilla has a real posterior wall, shown at the contouring of the pterygo-palatine fissure, that it is not possible to move back but only to squeeze (some results on primates noted a shrinking of the pterygo-palatine fissure) [Brandt et al., 1979], confirmed in this research by the reduction of PTV/OLp measure. These considerations and results let reasonable to think that is possible to maintain the maxilla where it is or restrain it, while the mandible is growing, but not to move the maxilla back at all. At the same time, while maxilla is maintained, both molars and incisors had a real distal movement within the maxilla, that is a dento-alveolar correction. This more dental than skeletal correction lead to fast occlusal modifications both in the posterior and in the anterior part of the dental arch, improving dental relationships and, consequently, muscular balance, lip closure and profile. On the other hand, the untreated CG subjects had instead a worsening (overjet +0.3 mm; ms/OLp + 1.9; A/OLp +1.3mm; Pg/OL_p +1.2; is/OL_p +1.3; ii/OL_p +1.0).

Present study outcomes didn't show a real "en masse" movement as was expected, and focused on the need to find

Dental - Gosh	Stephenson						T1-T0
	T0 Mean	T0 SD	T1 Mean	T1 SD	Net Mean	Net SD	P-value
Incisor angle (°)	108,1	5,1	96,3	6,8	-11,8	7,7	<0,01*
Premolar angle (°)	79,4	7,2	73,6	7,4	-5,7	8,6	<0,01*
First molar angle (°)	62,8	5,4	56,7	7,2	-6,1	8,6	<0,01*
Second molar angle (°)	46,3	6,3	43,3	7,4	-3,0	8,2	0,09
Third molar angle (°)	32,0	10,7	35,8	8,5	5,7	13,1	0,16

TABLE 2 cephalometric measurements for dental inclination at T0 and T1; differences T1-T0 and statistical significance (*= p<0.05)

Skeletal	STEPHENSON				BOLTON				STEPHENSON		BOLTON		T0 vs T0	Stephenson T1-T0	Bolton T1-T0	Steph vs Bolton Net difference
	T0 Mean	T0 SD	T1 Mean	T1 SD	T0 Mean	T0 SD	T1 Mean	T1 SD	Net Mean	Net SD	Net Mean	Net SD	P-value	P-value	P-value	P-value
Summa Σ °	395,5	7	395,9	6,3	391,9	4,9	391	5,6	0,5	4	-0,9	4,6	0,05*	0,59	0,38	0,24
AFA (mm)	107,9	8,5	112,5	9,6	104,6	5	107,4	6,3	4,6	3,2	2,8	3	0,12	<0,01*	<0,01*	0,07
AFP (mm)	67,5	6,4	71	6,7	68,1	4,5	69,8	4,4	3,6	2,4	1,67	2,6	0,72	<0,01*	0,01*	0,02*
AFP/AFA%	62,6	4,1	63,2	4,4	64,8	3,8	65,1	4	0,6	3,4	0,3	2,6	0,33	0,26	0,58	0,59
Go-Me (mm)	62,3	5,2	65,7	5,5	62,9	3,8	64,2	3,7	3,3	2,5	1,3	2,5	0,64	<0,01*	0,02*	0,01*
S-N (mm)	66,1	3,4	67,7	3,9	66,9	2,9	68,6	3,4	1,6	1,2	1,7	1,5	0,45	<0,01*	<0,01*	0,79
N-S-Ar°	123	4,2	123,3	3,8	122,8	5	123	4,5	0,4	3,3	0,2	3,9	0,94	0,6	0,78	0,62
SN/Go-Me°	37,6	5,5	36,6	6,5	33,5	4,4	33,1	4,8	-0,2	2,6	-0,3	2,8	0,03*	0,75	0,62	0,9
Ar-Go-Me°	127,4	7,6	126,4	7,1	123,4	6,1	123,6	7	-1,2	3,6	0,2	4,4	0,06	0,19	0,79	0,35
Ar-Go-N°	52,4	5	51,4	4,4	52,4	4,9	52,7	4,6	-1,1	2,5	0,3	2,8	0.99	0,08	0,65	0,19
N-Go-Me°	75,1	4,9	75,3	4,8	71	3,3	71,2	3,8	0,2	2,1	0,2	2,2	<0,01*	0,92	0,96	0,93
SNA°	81,9	3,5	80,5	3,7	79,4	3,1	79,7	3,6	-1,4	2,1	0,3	2,7	0,02*	0,01*	0,6	0,02*
SNB°	75	2,9	75,2	2,9	74,3	2,7	74,5	3,2	0,2	2	0,2	1,5	0,31	0,96	0,61	0,61
ANB°	6,9	1,9	5,6	2,2	5,3	1,8	5,3	2,1	-1,3	1,6	0	1,4	0,01*	<0,01*	0,94	0,01*
WITS (mm)	4,2	2,2	3,3	1,7	3,1	2,1	3,9	2,3	-0,9	2,1	0,9	1,7	0,08	0,05*	0.03*	0,01*
Maxillary base A/Olp (d)	73,5	4,2	73,9	4,3	71,5	3,1	72,8	0,4	3,1	1,3	1,3	1,8	0,28	0,35	0,42	0,11
Mandibular base Pg/OLp (d)	71,2	5,9	72,9	4,6	70,1	3,6	71,3	4,2	1,7	3,4	1,2	2,5	0,44	0,03*	0,04*	0,56
Ba/OLp (mm)	14,2	3,5	14,4	3	14,8	3,6	16,7	3,5	0,1	2,0	1,6	2,8	0,59	0,76	0,02*	0,04*
PNS/OLp (mm)	26,6	3,3	26,5	2,7	26	3,5	25,9	3,3	-0,1	2,0	-0,1	1,9	0,55	0,82	0,82	0,94
PTV/OLp (mm)	19,7	2,4	19,9	1,7	19,1	2,5	20,4	2,6	0,1	1,7	1,1	1,8	0,42	0,58	0,01*	0,05*
S-A (mm)	80,5	4	81,5	4,6	77,8	2,9	80,2	2,9	1,1	1,6	2,0	1,4	0,01*	0,02*	<0,01*	0,04*
PNS-OL (mm)	15,2	2,8	15,3	2,9	15	2,2	16,2	2,5	0,2	1,7	1,0	1,1	0,81	0,74	<0,01*	0,05*
ANS/OL (mm)	25,5	3,6	24,1	3,8	23	2,6	23,8	2,6	-1,1	2,8	0,6	1,4	0,01*	0,01*	0,05*	0,01*

TABLE 3 cephalometric measurements for skeletal variables at T0 and T1; differences T1-T0 and statistical significance (*= p<0.05).

a different definition and distinction between orthodontic and orthopaedic forces, as Gianelly wrote: "heavy forces, intermittently applied, may be capable of moving teeth, indicating that the distinction between the orthopedic and orthodontic components of the applied force may not be so clear" [Giannelly and Valentini, 1978]. It may be argued that heavy forces have always both orthopaedic and orthodontic components, that may depend on the skeletal age of patient and related sutures status, from appliance application time, from constancy of compliance, from obstacles of structures that cannot move. This assertion does not mean that the SP outcomes were not significant, but it underlines that probably any "orthopaedic appliance" will produce different combinations of orthodontic/orthopaedic results, related essentially to the anatomical structures that might/might not be modified and to the direction of traction. The posteriorly directed maxillary skeletal movement was substantially impossible, the maxilla indeed maintained its sagittal and vertical position; the upper alveolar processes moved back together with the upper teeth, substantially sliding and tipping back within the maxillary skeleton; the resultant maxillary movement was different from the expected one, but concurred to the global correction of the malocclusion, together with a concomitant mandibular displacement or growth.

The observed tipping of the upper teeth, particularly of the first molars, did not produce second and third molars impaction; however it should underline to control the molars position during treatment or suggest to extract third molars before starting the "en mass" treatment, in order not to compromise the retromolar space and limit the possibility to create molars impaction [Miclotte et al., 2017].

Limitations of the study

The main limitation of the study is the use of a control group selected form the Bolton-Brush growth study, since for ethical reasons it was not possible to create a prospective untreated control group. As reported by Papageorgiou and coauthors [2017] and Antoun and coauthors [2015] the use of historical control groups was associated with deflation of treatment effects. To overcome this selection bias, we have included as many patients as possible from the Bolton-Brush Collection, matching study and control groups with a precise and restricted criteria for Class II definition. This process allowed to reduce the impact of the selection bias.

Conclusions

The results of the present study suggest that the high-pull traction on Stephenson plate was efficient in growing subjects in the treatment of severe Class II dentoskeletal malocclusions due to maxillary protrusion but, despite of the use of orthopaedic forces, the outcomes were more dental than skeletal; the maxilla maintained its sagittal position and its descent was reduced, while the mandible slightly grew.

These conclusions underline also that when a gross back movement of maxilla is needed, only the maxillo-facial surgery will be having the chance to reach a real correction. Further mid-term studies will better explain if the subsequent growth of the maxilla may be affected.

Funding

This study was not supported by any internal or external funding.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

References

- Antoun JS, Cameron C, Sew Hoy W, Herbison P, Farella M. Evidence of secular trends in a collection of historical craniofacial growth studies. Eur J Orthod. 2015 37:60-6.
- Baccetti T, Franchi L, Mc Namara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod. 2002;72:316-23.
- Brandt HC, Shapiro PA, Kokich VG. Experimental and post-experimental effects of posteriorly directed extraoral traction in adult Macaca Fascicularis. Am J Orthod. 1979;75:301-17.
- Cacciatore G, Ugolini A, Sforza C, Gbinigie O, Plüddemann A. Long-term effects of functional appliances in treated versus untreated patients with Class II malocclusion: A systematic review and meta-analysis. PLoS One. 2019;14(9):e0221624.
- Caldwell SF, Hymas TA, Timm TA. Maxillary traction splint: a cephalometric evaluation. Am J Orthod. 1984;85:376-84.
- Castanha Henriques JF, Rodrigues Martins D, de Araujo Almeida G, Ursi WJ. Modified maxillary splint for Class II, division 1 treatment. J Clin Orthod. 1991;25:239-45.
- Deshayes M.J. Crescita cranio-facciale e ortodonzia. Masson Editore. Milano 81-88, 1987.
- Di Malta E. A case of Class II division 1 treated with a Stephenson plate. Mondo Ortod. 1979;4:66-7.
- Droschl H. The effect of heavy orthopedic forces on the maxilla in the growing Saimiri Sciureus (squirrel monkey). Am J Orthod. 1973;63:449-61.
- Droschl H. The effect of heavy orthopedic forces on the sutures of the facial bones. Angle Orthod. 1975;45:26-33.
- Duterloo HS, Kragt G, Algra AM. Holographic and cephalometric study of the relationship between craniofacial morphology and the initial reactions to high-pull headgear traction. Am J Orthod. 1985;88:297-302.
- Fabiani G, Galván Galván J, Raucci G, et al. Pharyngeal airway changes in pre-pubertal children with Class II malocclusion after Fränkel-2 treatment. Eur J Paediatr Dent. 2017;18:291-295.
- Fotis V, Melsen B, Williams S, Droschl H. Vertical control as an important ingredient in the treatment of severe sagittal discrepancies. Am J Orthod. 1984;86:224-32.
- Garbui IU, Nouer PR, Nouer DF, Magnani MB, Pereira Neto JS. Cephalometric assessment of vertical control in the treatment of Class II malocclusion with a combined maxillary splint. Braz Oral Res. 2010;24:34-9.
- Ghosh J, Nanda RS. Evaluation of an Intraoral Maxillary Molar Distalization Technique. Am J Orthod Dentofacial Orthop. 1996;110:639-46.
- Gianelly AA, Valentini V. The role of "orthopedics" and orthodontics in the treatment of Class II, Division I malocclusions. Am J Orthod. 1978;69:668-78.
- Goracci C, Cacciatore G. Early treatment of a severe Class II malocclusion with the Forsus fatigue resistant device. Eur J Paediatr Dent. 2017;18(3):199-207.
- Grippaudo MM, Quinzi V, Manai A, Paolantonio EG, Valente F, La Torre G, Marzo G. Orthodontic treatment need and timing: Assessment of evolutive malocclusion conditions and associated risk factors. Eur J Paediatr Dent. 2020;21:203-208.
- Jacob HB, Buschang PH, Ddos Santos-Pinto A. Class II malocclusion treatment using high-pull headgear with a splint: a systematic review. Dental Press J Orthod. 2013;15:18:21.
- Joffe L, Jacobson A. The maxillary orthopedic splint. Am J Orthod. 1979;75:54-69.
- Kragt G, Duterloo HS, ten Bosch JJ. The initial reaction of a macerated human skull caused by orthodontic cervical traction determined by laser metrology. Am J Orthod. 1982;8:49-56.
- Martins RP, da Rosa Martins JC, Martins LP, Buschang PH. Skeletal and dental components of Class II correction with the Bionator and removable headgear splint appliances. Am J Orthod Dentofacial Orthop. 2008;134:732-41.
- Maspero C, Galbiati G, Giannini L, Guenza G, Farronato M. Class II division 1 malocclusions: comparisons between one- and two-step treatment. Eur J Paediatr Dent. 2018;19(4):295-299.
- Miclotte A, Grommen B, Lauwereins S, Cadenas de Llano-Pérula M, Alqerban A, Verdonck A, Fieuws S, Jacobs R Willems G. The effect of headgear on upper third molars: a retrospective longitudinal study Eur J Orthod. 2017;39:426-432.
- Monaco A, Petrucci A, Marzo G, Necozione S, Gatto R, Sgolastra F. Effects of correction of Class II malocclusion on the kinesiographic pattern of young adolescents: a case- control study. Eur J Paediatr Dent. 2013;14(2):131-134.
- Orton HS, Slattery DA, Orton S. The treatment of severe 'gummy' Class II division 1 malocclusion using the maxillary intrusion splint. Eur J Orthod. 1992;14:216-23.
- Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. Am J Orthod. 1982;82:104-13.
- Papageorgiou SN, Koretsi V, Jäger A. Bias from historical control groups used in orthodontic research: a meta-epidemiological study. Eur J Orthod. 2017;39:98-10.
- Quinzi V, Scibetta ET, Marchetti E, Mummolo S, Gianni AB, Romano M, Beltramini G, Marzo G. Analyze my face. J Biol Regul Homeost Agents. 2018:32:149-158.
- Quinzi V, Marchetti E, Guerriero L, Bosco F, Marzo G, Mummolo S. Dentoskeletal Class II Malocclusion: Maxillary Molar Distalization with No-Compliance Fixed Orthodontic Equipment. Dent J (Basel). 2020;18;8-26.
- Quinzi, V.; Tecco, S.; Nota, A.; Caggiati, E.; Mummolo, S.; Marzo, G. Mesial Rotation of the Upper First Molar: Association with Anterior Dental Crowding in Mixed and Permanent Dentition. Appl. Sci. 2020;10:5301. https://doi.org/10.3390/app10155301.
- Showkatbakhsh R, Castaldo MI, Jamilian A, et al. Treatment effects of R-appliance and Fränkel-2 in Class II division 1 malocclusions. Eur J Paediatr Dent. 2013;14:17-22.
- Silvestrini Biavati A, Fortini A, Silvestrini Biavati F, Ugolini A. Efficiency in the correction of Class II division 1 malocclusions with prominent upper incisors and increased overjet: a comparison between two methods. Minerva Stomatol. 2019;68:160-7.
- Silvestrini-Biavati A, Salamone S, Silvestrini-Biavati F, Agostino P, Ugolini A. Anterior open-bite and sucking habits in Italian preschool children. Eur J Paediatr Dent. 2016;17:43-6.
- Silvestrini-Biavati A, Angiero F, Gambino A, Ugolini A. Do changes in spheno-occipital synchondrosis after rapid maxillary expansion affect the maxillomandibular complex? Eur J Paediatr Dent. 2013;14:63-7.
- Stephenson JC. A "trouble-free" tube attachment for removable appliance extra-oral traction. Dent Pract Dent Rec. 1968;19:37-8.
- Stephenson JC. Extra-oral traction. Br J Orthod. 1974-;1:137-8.
- Thurman MM, King GJ, Ramsay DS, Wheeler TT, Phillips C. The effect of an anterior biteplate on dental and skeletal Class II correction using headgears: a cephalometric study. Orthod Craniofac Res. 2011;14:213-21.
- Thurow RC. Craniomaxillary orthopedic correction with en masse dental control. Am J Orthod. 1975;68:601-24.
- Uner O, Yucel-Eroglu E. Effects of a modified maxillary orthopaedic splint: a cephalometric evaluation. Eur J Orthod. 1996;18:269-286.