PAPER REF: 4043

RETROSPECTIVE EVALUATION OF THERAPEUTIC OUTCOMES OF FUNCTIONAL APPLIANCES COMBINED WITH HEADGEAR

Maria João Ponces[1(*)], José Pedro Tavares[2], Eugénio Martins[3], Paula Vaz[4], Afonso Pinhão Ferreira[5]

[1, 3, 5]Department of Orthodontics, Faculty of Dental Medicine (FMDUP), University of Porto, Porto, Portugal.
[2]Department of Civil Engineering, Transport Infrastructures Division, University of Porto, Portugal.
[4] Department of Medical and Orofacial Genetics, Faculty of Dental Medicine, University of Porto, Porto, Portugal.
[(*)]*Email:* mponces@fmd.up.pt.

ABSTRACT

The aim of this retrospective study was to investigate skeletal, dentoalveolar and tegumental effects of a modified Teuscher appliance in Class II division 1 malocclusion patients with mandibular retrognatism.

The treated subjects of study were gathered from a single practice and were all in the mixed dentition phase. They were divided in two groups: experimental group A comprised 16 patients (10 girls and 6 boys) with mean age of 9.6 ± 0.8 years all in stage II of skeletal maturation (CVMS) and the B control group, with 16 patients (10 girls and 6 boys) with mean age of 8.9 ± 0.7 years, all in stage II of CVMS.

Skeletal, dentoalveolar and tegumental changes were compared on the lateral cephalograms taken before the beginning of active treatment (T0) and 26.3 ± 3.5 months after T0, after treatment and a period varying from 4 to 9 months without appliance (T1). In B group T0 corresponds to the first orthodontic study of patients and T1 cephalogram was taken 30.0 ± 1.7 months later, after an observational period and before active treatment started.

Statistical analysis was undertaken with Wilcoxon's rank sum test for mean intragroup difference comparisons and with the Mann-Whitney test for differences between groups A and B, at a level of significance of $P < 0.05$.

Teuscher treatment in these growing patients resulted in an improvement of the skeletal Class II relationship (ANB: -1.9°, SD 0.7 and Ao-Bo: -1.68 mm SD 2,01), a restriction of maxillary growth (Nperp-A: -1.4 mm, SD 2.22), an increase in lower face height (ANS-Me: 6.01 mm SD 3.51), a correction of overjet (OJ: -3.87 mm, SD 2.71), a controlled displacement of anterior teeth (U1-SN: -6.62º, SD 7.43; U1-NA: -4.64º, SD 6.83 and IMPA: -0.14º SD 4.27) and correction of the dental Class II malocclusion. The soft tissue profile changes reflected an important lip retrusion.

The modified Teuscher appliance was effective in treating growing patients mainly at the expenses of dentoalveolar adaptations. There was a correction of Class II malocclusion combining skeletal, dentoalveolar and tegumental changes.

Results were not consistent with the significant contribution of mandibular advancement to the correction of skeletal Class II.

Keywords: activator, headgear, functional therapy, Class II, treatment outcome.

INTRODUCTION

The nature of Class II malocclusion is associated to craniofacial factors such as mandibular, maxillary and dentoalveolar growth patterns. Since the mandibular retrognatism is the major cause of Class II malocclusion, a therapy focused on mandibular growth improvement is the ideal choice (McNamara, 1981).

So, Class II treatment with functional appliances by means of a constructed bite aim to position the mandible anteriorly in order to increase mandibular growth (Moore, 1989). When there is a middle face excessive height, orthopaedic forces intending to inhibit the maxillary growth can be associated to the device (Pfeiffer, 1982; Lagerstrom, 1990; Dermaut, 1992; Ozturk, 1994; Cura, 1996; Weiland, 1997; Cozza, 2004a; Marsan, 2007).

There are several types of functional appliances resulting from modifications of Andresen-Haupl activator. (Schmuth, 1983) Their *modus operandi* is based on the activation of muscle activity that will interact with maxillomandibular craniofacial complex (Petrovic, 1979; (McNamara, 1979).

Teuscher (1978) proposed anchoring extraoral forces directly on the activator. Unlike the most common activators that induce isotonic contractions and transmit intermittent forces to teeth, this kind of device produces massive anterior displacement of mandible by developing isometric muscle activity (Pfeiffer, 1982). Few modifications, which are related to the torque loops, have been introduced to the original appliance design (de Pawn, 2006).

Despite the extensive information related to the effect of functional appliances and the obvious clinical advantage in the improvement of Class II malocclusion, the nature of modifications is still controversial. The same is true regarding the effect of combining extraoral forces to activators. Some authors point out the increase of mandibular growth as the great advantage of functional treatment option (Luder, 1982; McNamara, 1985). Some investigators consider the effects of functional treatment mainly dentoalveolar, not recognizing any difference in the amount of growth with or without this therapy (Harvold, 1971; Wieslander, 1979; Cura, 1996). However, some researchers consider the changes mainly skeletal (Cozza, 2004b) while others believe they are a mix of those two modifications (Pancherz, 1984; Marsan, 2007). Respecting posterior vertical control, the controversy can also be reported (Williams, 1982; Dermaut, 1992; Ozturk, 1994; Cura, 1996; Basciftci, 2003; Cozza, 2004a; Marsan, 2007) and the same applies to soft tissue changes. While a significant upper lip retrusion is reported by Gögen and Parlar (1989), Basciftci *et al.* (2003) found the opposite results. Other authors reported an improvement in soft tissue contour with flattened profile (Singh, 2003; Cozza, 2004a; Marsan, 2007).

This investigation aimed evaluating skeletal, dentoalveolar and tegumental factors before (T0) and after (T1) a treatment period with a modified Teuscher appliance through lateral cephalograms. In order to study the effective results of treatment, a matched control group of untreated Class II individuals was considered, formed by patients that refused orthodontic phase 1 treatment. In this second group, registers were taken in the equivalent two times, T0 corresponding to initial study of patients and T1 to the post period of control re-evaluation.

SUBJECTS AND METHODS

The subjects of the study were gathered from a single practice (Guimarães, Portugal) except two cases from the control group that were provided by another orthodontic practice. The criteria selection were: Caucasian population, no previous orthodontic treatment, between 9 and 11 years old, stage II of Cervical Maturation Method Stage (CVMS) (Baccetti, 2002), overjet more than 5 mm, Class II molar relationship of at least 3,5 mm, skeletal Class II malocclusion with ANB more than 5º and retrognatic mandible with SNB less than 78º.

The selected patients were divided in 2 groups. The experimental group A consisted of 16 subjects (10 girls and 6 boys) with a mean age of 9.6 ± 0.8 years, all in the stage II of CVMS. This group underwent treatment with a modified Teuscher appliance. The B control group, with 16 subjects (10 girls and 6 boys) with a mean age of 8.9 ± 0.7 years and all in stage II of CVMS, were evaluated and studied but they rejected the immediate treatment.

Groups A and B were matched according to initial assessment age, maturation stage, malocclusion and period of treatment or interval of observation. All patients' parents allowed the study by signing an informed consent.

The modified Teuscher appliance is a monobloc attached to the upper jaw by the acrylic edentations and by a facebow fitted into tubes that are placed in the region of second bicuspid or second deciduous molar (figure 1). A highpull headgear is attached to the outer facebow.

Figure 1. The modified Teuscher appliance.

The outer arch of the facebow is placed in order to allow the extraoral force passing as close as possible through the center of resistance of the maxilla. The extraoral force intends not only to redirect vertical growth of the maxilla but also to avoid the tipping of palatal and occlusal plans while it stabilizes the activator in place (figure 2).

Figure 2. Teuscher appliance in place.

In the presence of an upper dentoalveolar compression, a quad-helix was prescribed for a maximum period of 6 months, immediately before the use of the functional appliance (Kolf, 1991). The activator was designed to avoid unwanted anterior teeth movements. However, in order to prevent anterior tipping, a 2 mm cap of acrylic covered labial surface of upper and lower incisors. Posterior-inferiorly, lower lingual extended flanges were introduced in order to produce mandibular mucosal contact. Vestibular vertical spurs were placed facing labial surface of upper incisors to assure retention and a controlled displacement of teeth, when desired (figure 1).

A wax bite reproducing the mandibular anterior positioning was prepared in order to manufacture the appliance. The mandible was positioned in Class I relationship, corresponding to 2 or 3 mm of sagittal advance. Nevertheless, if the forward movement for Class I relationship is very extensive, the process is done in 2 stages (Kolf, 1991; Hagg, 2008). So, a second laboratorial adaptation of the appliance is needed. This last procedure of treatment was not required in any of these study cases. Relating to vertical activation, the height of the wax should exceed the freeway space by 2 or 3 mm. During treatment and in the transition of teeth, acrylic was trimmed to promote the teeth shift. Acrylic around posterior-inferior teeth was also shaped and grounded in order to promote mesial eruption. Concerning vertical dimension, the acrylic was not relieved in the regions where eruption should be inhibited. The active treatment was started in stage II of CVMS. This means that treatment began before pubertal growth spurt, in order to maximize growth increment (Pfeiffer, 1982; Kolf, 1991). The patient was instructed to use the appliance 8 to 12 hours a day, during night period, with 400-500 grams of force per side for around 18 months. Then, after the appliance removal and during a period varying from 4 to 9 months, an eventual relapse period was monitored in order to identify the real effectiveness of functional phase treatment. The aim of this step was to unmask the neuromuscular memory effect related to dental relationship. So, this transitional phase intended to reduce or eliminate factors of misdiagnosis, allowing to establish a more precise second phase treatment plan.

The skeletal, dentoalveolar and tegumental changes that occurred were assessed through 29 analytical factors on two lateral cephalograms. In group A, the first radiograph was obtained before treatment (T0) and the second one (T1) after 26.3 ± 3.5 months and immediately before the beginning of the second phase treatment. This period included not only treatment phase but also a transitory period 4 to 9 months without any device, where eventual relapse could have happened. In the control group cephalograms were taken with around the same interval, 30.0 ± 1.7 months. All the radiographs were taken in maximum intercuspation with the lips in a relaxed position.

A cephalometric analysis (figures 3 and table 1) was performed to evaluate initial pattern of individuals from the two groups, as well as the alterations related to treatment and growth in group A or only growth in group B. The assessed factors intended to evaluate not only sagittal and vertical skeletal patterns, but also dentoalveolar and soft tissue relationships.

The two cephalograms, T0 and T1, corresponding to each case were traced in a row and measured manually twice by the same examiner (MJP), in two different occasions with an interval of 10 days. Then, the mean values were considered.

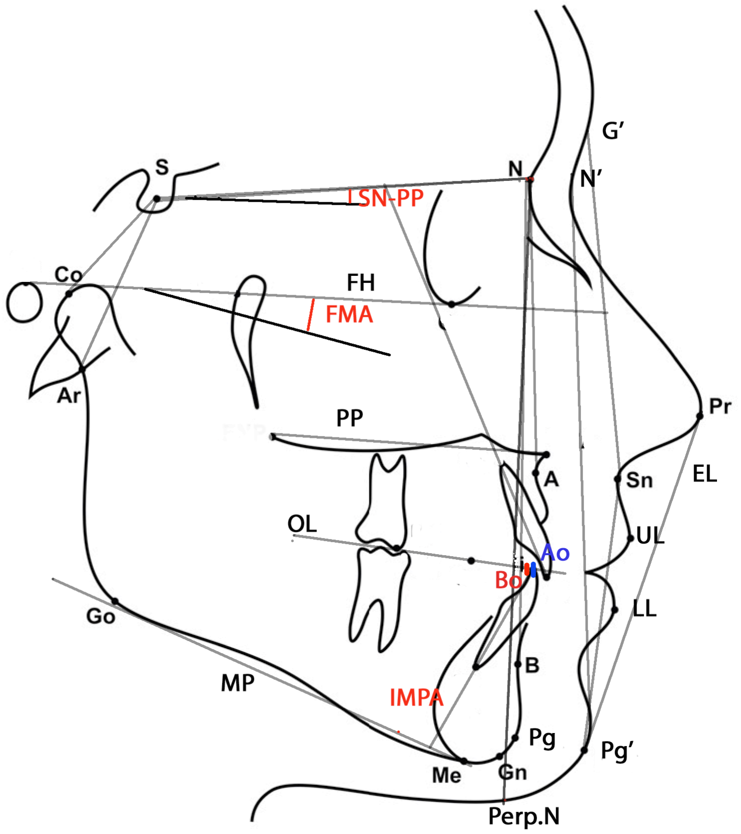


Figure 3 Reference points. Skeletal and dentoalveolar points: S – sella; N – nasion; A – A point; B – B point; Pg – pogonion; Co – condylion; Ar – articulare; Go – gonion; Me – menton; U1 – upper incisor; L1 – lower incisor; tegumental points: G' – soft tissue glabella; Pn – pronasale; Sn – subnasale; UL – upper lip; LL – lower lip; Pg' – soft tissue pogonion; Me' – soft tissue menton.

ERROR METHOD

Twenty-six cephalograms were randomly selected, traced and measured. The same examiner re-traced and re-measured the radiographs 10 days after. Student paired t test was used to evaluate the systematic error, for $P < 0.05$. Random errors were calculated according to Dahlberg's formula (Houston, 1983):

$$SE = \sqrt{\Sigma d^2 / 2n},$$

d is the difference between a pair of repeated measurements;

n is the number of double measurements (table 2).

According to Houston (1983), the final linear and angular Dahlberg values higher than 1 mm and 1.5 degrees respectively are considered causal errors (Galvão, 2012).

Table 1 Cephalometric factors.

Sagittal skeletal analysis	SNA (º)	Angle made by sella, nasion and A point
	SNB (º)	Angle made by sella, nasion and B point
	ANB (º)	Angle made by A point, nasion and B point
	Ao-Bo (mm)	Orthogonal projection of A and B points on functional occlusion line
	Nperp-A (mm)	Distance from A point to nasion perpendicular line
	NSCo (º)	Angle made by nasion, sella and condylion
	NSAr (º)	Angle made by nasion, sella and articulare
	GoMe (mm)	Line joining gonion and menton
	FH-NA (º)	Angle made by Frankfurt horizontal and nasion and A point line
	FH-NPg (º)	Angle made by Frankfurt horizontal and nasion and pogonion line
Vertical skeletal analysis	FMA (º)	Angle made by Frankfurt horizontal and mandibular plan joining gonion and menton
	FH-OL (º)	Angle made by Frankfurt horizontal and functional occlusal line
	SN-PP (º)	Angle made by sella and nasion plan and palatal plan
	PP-GoMe (º)	Angle made by palatal plan and mandibular plan
	N-ANS (mm)	Distance between orthogonal projection of nasion and anterior nasal spine on nasion perpendicular line
	ANS-Me (mm)	Distance between orthogonal projection of anterior nasal spine and menton on nasion perpendicular line
Dentoalveolar analysis	U1-FH (º)	Angle made by maxillary long axis incisor and Frankfurt horizontal
	IMPA (º)	Angle made by mandibular long axis incisor and mandibular plan
	U1-L1 (º)	Angle made by maxillary and mandibular incisors long axis
	OJ (mm)	Overjet: distance from incisal edge of L1 to incisal edge of U1 measured parallel to OL
	OB (mm)	Overbite: distance from incisal edge of L1 to incisal edge U1 measured perpendicular to the OL
	L1-OL (mm)	Distance from incisal edge of L1 to OL
Tegumental analysis	N'Pg'-FH (º)	Angle made by tegumental nasion, tegumental pogonion and Frankfurt horizontal
	G'SnPg' (º)	Angle made by glabella, subnasal and tegumental pogonion
	UL-EL (mm)	Distance between anterior contour of upper lip and esthetic line
	LL-EL (mm)	Distance between anterior contour of lower lip and esthetic line

Table 2 Method errors.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			

DF: Dahlberg's formula, *P < 0.05, **P < 0.01, ***P < 0.001, ns: non-significant.

STATISTICAL METHOD

The analysis consisted of mean and standard deviation (SD) descriptive data. For the mean intragroup differences between T0 and T1 the Paired Sample Test was employed and when variables where not normally distributed the Wilcoxon's Signed Ranks Test was applied. To assess the mean differences between A and B groups, Independent Samples Test was used and for the non-normally distributed variables Independent-Samples Mann-Whitney U Test was the one selected. $P < 0.05$ was the level of significance used in the analysis.

RESULTS

In T0, all patients were in the pre-peak stage of growth development (stage II of CVMS) and had similar malocclusion conditions: Class II molar relationship, skeletal Class II with retrognatic mandible and increased overjet. In T0, between groups A and B, there were no significant differences for all the studied variables, except for interincisal angle (U1-L1), which comparatively was increased in the control group (table 3). Alterations observed between T0 and T1 in groups A and B are shown in tables 4 and 5. The tables present the averages and standard deviations (SD) for each cephalometric variable studied before (T0) and after (T1) the treatment (table 4) or the observational period (table 5).

Table 3 Groups A (n = 16) and B (n = 16): average and standard deviations (SD) at T0.

Variables	T0 - group A	SD	T0 - group B	SD	P	
SNA (º)	82.09	3.32	80.16	2.1	0.149	ns
SNB (º)	74.56	3.5	73.71	1.66	0.59	ns
ANB (º)	7.54	1.77	6.89	1.43	0.258	ns
Ao-Bo (mm)	3.23	2.4	3.07	1.95	0.838	ns
Nperp-A (mm)	0.52	2.46	-0.7	3.38	0.25	ns
Nperp-Pg (mm)	11.92	3.43	-12.75	5.61	0.616	ns
NSCo (º)	136.56	4.5	135.06	5.12	0.27	ns
NSAr (º)	126.36	4.35	125.14	4.03	0.418	ns
Go-Me (mm)	64.07	3.63	61.89	3.16	0.102	ns
FH-NA (º)	90.59	2.4	89.59	3.46	0.35	ns
FH-NPg (º)	83.48	1.9	83.12	3.42	0.716	ns
FMA (º)	28.32	4.45	29.11	6.15	0.867	ns
FH-OL (º)	12.58	3.16	12.53	2.62	0.964	ns
SN-PP (º)	9.09	2.9	8.78	2.72	0.756	ns
PP-Go Me (º)	29.05	4.42	29.36	5.34	0.858	ns
N-ANS (mm)	49.9	3.57	50.42	2.63	0.64	ns
ANS-Me (mm)	61.78	3.99	60.19	2.91	0.102	ns
U1-FH (º)	116.02	5.14	111.53	4.63	0.012	*
U1-SN (º)	107.6	6.02	101.22	5.13	0.003	**
IMPA (º)	96.19	5.73	94.09	6.16	0.328	ns
U1-NA (º)	24.08	5.69	22	5.01	0.282	ns
U1-L1 (º)	120.4	6.08	125.78	7.25	0.03	*
overjet (mm)	7.71	2.88	6.86	2.13	0.491	ns
overbite (mm)	3.33	1.81	3.56	2.12	0.746	ns
L1-OL (mm)	2.72	1.53	2.37	1.33	0.49	ns
N'Pg'-FH (º)	85.22	2.25	85.06	3.19	0.956	ns
G'SnPg' (º)	159.2	5.15	157.4	2.81	0.224	ns
UL-EL (mm)	2.65	1.74	0.26	1.69	0	***
LL-EL (mm)	3.17	2.35	1.38	1.66	0.018	*

*$P < 0.05$, **$P < 0.01$, ***$P < 0,001$, ns: non-significant.

Table 4 Group A (experimental) (n = 16): average and standard deviations (SD) before (T0) and after (T1) treatment.

[illegible]

*P < 0.05, **P < 0.01, ***P < 0,001, ns: non-significant.

Table 5 Group B (control) (n = 16): average and standard deviations (SD) before (T0) and after (T1) observational period.

Variables	T0	SD	T1	SD	Mean	SD	P	
SNA (º)	80.16	2.1	79.76	2.47	-0.39	0.92	0.104	ns
SNB (º)	73.72	1.66	74.31	1.66	0.59	4.13	0.62	ns
ANB (º)	6.89	1.42	6.66	1.49	-0.23	1	0.366	ns
Ao-Bo (mm)	3.06	1.95	3.15	2.21	0.08	0.97	0.748	ns
Nperp-A (mm)	-0.7	3.38	-0.02	3.33	0.68	0.96	0.024	*
Nperp-Pg (mm)	-12.75	5.6	-11.7	6.7	1.07	2.49	0.106	ns
NSCo (º)	135.06	5.12	134.8	5.15	-0.25	1.55	0.515	ns
NSAr (º)	125.14	4.03	125.3	4.13	0.2	1.55	0.608	ns
Go-Me (mm)	61.89	3.16	67.07	3.97	3.18	2.09	0.001	**
FH-NA (º)	89.59	3.46	90.03	3.56	0.44	1.35	0.214	ns
FH-NPg (º)	83.12	3.42	84.16	3.72	1.03	1.29	0.002	**
FMA (º)	29.11	6.15	28.5	6.73	-0.61	1.94	0.196	ns
FH-OL (º)	12.53	2.62	11.28	2.57	-1.25	1.97	0.014	*
SN-PP (º)	8.78	2.72	9.06	2.75	0.28	2.47	0.435	ns
PP-Go Me (º)	29.36	5.34	29.91	5.34	0.55	1.87	0.39	ns
N-ANS (mm)	50.42	2.63	53.65	2.34	3.23	2.89	0	***
ANS-Me (mm)	60.19	2.91	63.45	3.6	3.26	2.71	0.001	**
U1-FH (º)	111.53	4.63	115.2	8.28	3.69	4.85	0.007	**
U1-SN (º)	101.21	5.12	104.6	7.42	3.41	4.58	0.01	*
IMPA (º)	94.09	6.16	94	6.44	-0.09	5	0.861	ns
U1-NA (º)	22	5.01	25.78	7.76	3.78	4.63	0.005	**
U1-L1 (º)	125.78	7.24	123.5	8.03	-2.28	3.74	0.028	*
overjet (mm)	6.86	2.13	7.86	2.81	1	1.79	0.038	*
overbite (mm)	3.56	2.12	4.51	1.74	0.95	1.22	0.007	**
L1-OL (mm)	2.37	1.33	3.42	1.29	1.06	0.93	0.001	**
N'Pg'-FH (º)	85.06	3.19	86.16	3.68	1.09	1.64	0.011	*
G'SnPg' (º)	157.41	2.81	158.2	3.14	0.75	2.46	0.269	ns
UL-EL (mm)	0.26	1.69	-0.07	2.04	-0.33	1.27	0.32	ns
LL-EL (mm)	1.37	1.66	1.45	2.5	0.07	1.25	0.812	ns

*P < 0.05, **P < 0.01, ***P < 0,001, ns: non-significant.

Sagittal analysis

The radiographic values before (T0) and after (T1) treatment showed a significant improvement in sagittal jaw relationship. In experimental group, ANB was reduced by an average of 1.9 degrees (SD 0.7, $P < 0.001$) while in control group the decrease was of 0.23 degrees (SD 1.0, ns).

In group A the relative sagittal position of jaws evaluated in relation to OL (Ao-Bo) reflected an average decrease of 1.68 mm (SD 2.01, $P < 0.01$), while in group B it increased 0.08 mm (SD 0.97, ns).

Considering middle face development, the results show an anterior maxillary growth restriction in treated group. In fact, with regard to SNA, both groups exhibited an average non-significant decrease, in group A of 1.39 degrees (SD 3.98) and in group B of 0.39 (SD 0.92). For FH-NA, group A displayed an average decrease of 0.78 degrees (SD 2.03, ns), while group B had a non-significant increase of 0.44 degrees (SD 1.35). In addition, the evaluation of Nperp-A in treated group presented an average decrease of 1.14 mm (SD 2.22, $P = 0.057$) while in control group the same distance increased on average 0.68 mm (SD 0.96, $P < 0.05$).

Related to mandibular sagittal position in both groups, although non-significantly, there was an increase in SNB, in the group A on average 0.92 degrees (SD 4.01, ns) while in the group B the increment was 0.59 degrees (SD 4.13, ns). With regard to the assessment related to the pogonion, NperpPg presented also a non-significant increase, registering 1.19 mm (SD 3.59) and 1.07 mm (SD 2.49) respectively in groups A and B. In addition, and also for both two groups FH-NPg showed a significant average increase, with 1.68 degrees (SD 1.82, $P < 0.01$) in the experimental group and 1.03 degrees (SD 1.29, $P < 0.01$) in control group.

The factors that provide information about temporomandibular articulation position, NSCo and NSAr, registered an average non-significant decrease in group A (0.82º, SD 3.37 and 0.81º, SD 1.65) while in group B, the NSCo decreased 0.25 (SD 1.55, ns) and the NSAr increased 0.2 (SD 1.55, ns). Finally, the mandibular structure assessed on GoMe showed an average significant increase of 4.99 mm (SD 2.35, $P < 0.001$) in experimental group and 3.18 mm (SD 2.09, $P < 0.01$) in control group.

Vertical analysis

A significant increase in both groups was noticed in the factors that assess vertical development. Concerning middle face, N-ANS showed an average increase of 3.23 mm (SD 3.33, $P = 0.001$) in experimental group and 3.23 mm (SD 2.89, $P < 0.001$) in control group. Related to lower anterior face height, ANS-Me presented in both groups an average increase, respectively of 6.01 mm (SD 3.51, $P < 0.001$) in group A and 3.26 mm (SD 2.71, $P = 0.001$) in group B.

FMA and FH-OL decreased in both groups (group A: FMA -0.062º, SD 2.17, ns and FH-OL -1.01º, SD 3.48, ns; group B, FMA -0.61º, SD 1.94, ns and FH-OL -1.25º, SD 1.97, $P < 0.05$). Palatal plane inclination (SN-PP) exhibited in experimental group a non-significant average decrease of 0.02 degrees (SD 1.45) while a slight increase happened in group B (0.28, SD 2.47, ns). Mandibular plane inclination related to maxillary structure (PP-GoMe) presented non-significant opposite variations in the two groups (group A: -0.94º, SD 2.27; group B: 0.55º, SD 1.87).

Dental analysis

Modified Teuscher appliance therapy presented an important effect on the upper anterior incisors position. In fact, maxillary incisors moved palatally with a significant average reduction of their inclination related to Frankfurt Horizontal Plan (U1-FH: -6.17º, SD 8.99, P < 0.05), to Sella-Nasion Plan (U1-SN: -6.62º, SD 7.43, P < 0.01) and to Nasion-A point Plan (U1-NA: -4.64º, SD 6.83, P = 0.016). It was also found a significant average reduction of overjet (-3.87 mm, SD 2.71, P < 0.001). Contrasting to group A findings, all the four factors presented a significant increase in the control group (U1-FH: 3.69º, SD 4.85, P < 0.05; U1-SN: 3.41º, SD 4.58, P = 0.01; U1-NA: 3.78º, SD 4.63, P < 0.01; overjet: 1.0 mm, SD 1.79, P < 0.05).

Concerning lower incisors, both groups registered a non-significant trend to retro-inclination evaluated by the decrease of IMPA (group A: -0.14º, SD 4.27 and group B: -0.09º, SD 5).

With regard to interincisal angle, overbite and L1-OL, in group A the variations were according to data previously described. Therefore, U1-L1 increased on average 5.21º (SD 8.62, P < 0.05), the overbite increased but non-significantly (0.14º, SD 1.3, ns) and the relation of lower incisor to occlusal plan (L1-OL) decreased also non-significantly (0.32 mm, SD 1.03). However, in control group, U1-L1 decreased (2.28º, SD 3.74, P < 0.05) and both overbite and L1-OL increased significantly (overbite: 0.95 mm, SD 1.22, P < 0.01; L1-OL: 1.06 mm, SD 0.93, P = 0.001).

Aesthetic analysis

Profile tegumental effects of treatment were accompanied by an average significant increase in G'SnPg' (1.79º, SD 3.11, P < 0.01) and in N'Pg'- FH (1.15º, SD 2.11, P = 0.05) while in control group the average increase showed different results (G'SnPg': 0.75º, SD 2.46, ns; N'Pg'- FH: 1.09º, SD 1.64, P < 0.05). Concerning lip position and relating it to Ricketts Aesthetic Line, the variations displayed by group A reflected an average significant upper and lower lip retrusion (UL-EL: -3.11 mm, SD 2.06, P < 0.001; LL-EL: -1.52 mm, SD 1.81, P < 0.01) contrasting with the non-significant variations presented by control group (UL-EL: -0.33 mm, SD 1.27, ns; LL-EL: 0.07 mm, SD 1.25, ns).

Table 6 intends to present the differences between experimental and control groups.

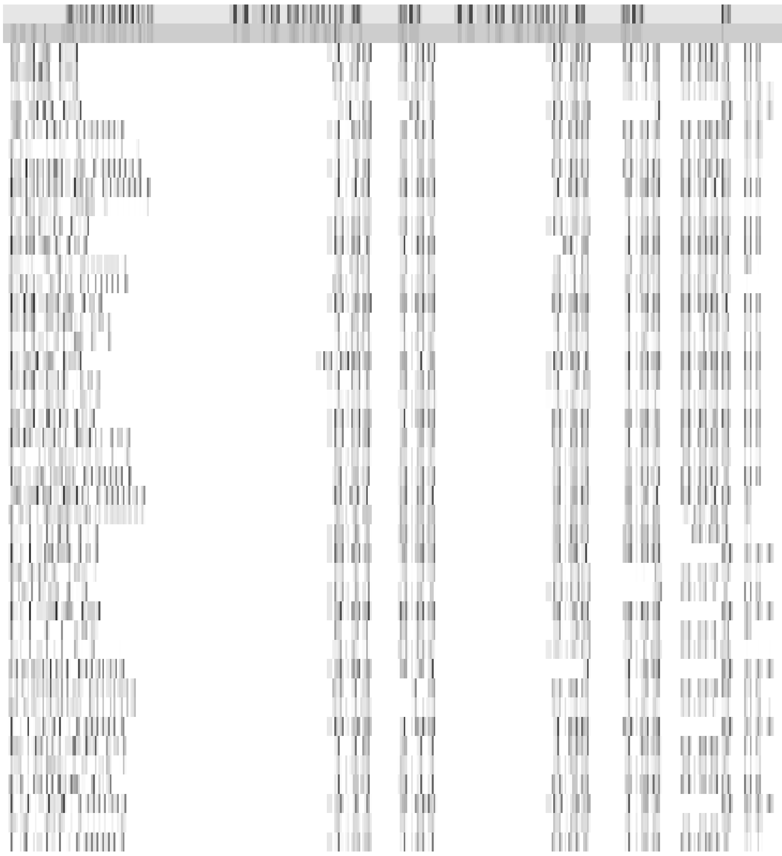
DISCUSSION

The controversy related to the effective orthodontic or orthopedic results of functional therapy in malocclusion Class II patients triggered the present study. The purpose of this investigation was to evaluate an experimental group treated with a modified Teuscher appliance before a second phase of treatment. This group was compared to a control group that was not submitted to treatment. Therefore, the deviations that happened beyond the perceived on the control group can be attributed to the effect of functional therapy. The use of this methodology intended to differentiate growth changes from treatment changes.

The design of this study and the interim period between T0 and T1 included active functional treatment phase and a relapse period. This stage was deliberately introduced in order to unmask neuromuscular positioning effects of functional treatment. In fact, the activator induces a clinically imposed mandibular position. If condylar growth and glenoid fossa adaptations are not enough to compensate the artificially induced positional gap, relapse will occur when the condyle relocates in the fossa. So, the introduction of a period with no device use was considered to be important in the evaluation of results for this therapeutic option

(Keeling, 1998). However, the majority of studies do not follow the same procedure, since they evaluate the patients exactly at the end of functional treatment (Dermaut, 1992; Basciftci, 2003; Cozza, 2004a; Janson, 2004; Turkkahraman , 2006; Marsan, 2007).

Table 6 – Alterations in groups A and B from before (T0) to after (T1) treatment or observational period.



$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0,001$, ns: non-significant.

Sagittal analysis

The results of this investigation are partly in agreement with most studies. An improvement in sagittal basal bone relationship was registered (van Beek, 1984; Pfeiffer, 1972; Lagerstrom, 1990; Ozturk, 1994; Cura, 1996; Singh, 2003; Cozza, 2004a,b; Janson, 2004; Marsan, 2007; Lerstol, 2010), with significant reductions of ANB and Ao-Bo in the experimental group. This effect was mostly related to a forward growth restriction in the maxillary complex once non-significant changes were shown in the sagittal position of mandible. Nevertheless, group A registered subtle tendencies for a decrease in SNA (Turkkahraman, 2006; Lerstol, 2010) and an increase in SNB (Janson, 2004). In relation to N, point A retracted 1.14 mm (SD 2.22, P = 0.057) in accordance to other previous studies (Pfeiffer, 1982; van Beek, 1984; Lagerstrom, 1990; Ozturk, 1994; Cura, 1996; Singh, 2003; Cozza et al., 2004a). Functional therapy has been pointed to inhibit maxillary growth (Pancherz, 1984; Moore, 1989) but it is important to highlight that in this evaluation the dentoalveolar effect on the remodelling of anterior maxillary contour should not be ignored (Wieslander, 1979). In fact, a significant palatal movement of upper incisors was disclosed in group A, representing a contribution to sagittal correction. However, the assessment in the experimental group was done after the period with no device use, where a rebound in the retracted teeth position could have already happened (Keeling, 1998).

The main controversy relies on mandibular growth. It has been stated by some investigators (Luder, 1982; McNamara, 1985) to be the crucial factor distinguishing functional therapy from other alternative treatments. While others think that mandibular length is unaltered (Harvold, 1971; Wieslander, 1979) and changes induced by functional treatment are similar to those produced by growth (Forsberg, 1981). In this study both SNB and FH-NPg did not show significant variations between groups A and B, although these factors tended to be slightly higher in the treated group. Janson (2004) reported precisely the same results in a study that intended to evaluate the stability of headgear-activator combination followed by a second phase treatment. Other authors found significant differences for SNB (Ozturk, 1994; Keeling, 1998; Singh, 2003; Cozza, 2004a; Marsan, 2007) and for FH-NPg (Cozza, 2004a; Marsan, 2007) . Despite this disparity among studies, the methodology of the present investigation introduced a non-existing variable in most quoted studies. In fact, an interim without the use of any appliance varying from 4 to 9 months intended to introduce the possibility of occurring mandibular joint repositioning, if global condyle compensatory growth had not occurred. In other words, the intention was displaying real growth treatment effects. Moreover, it is also important to notice that in this period of time, physiological growth also happened and influenced the registered results.

In addition, it is important to notice that according to a recent study of Franchi *et al.* (2013) functional treatment during the pubertal peak produces significantly greater increases in mandibular growth when compared with treatment before puberty. The present outcomes can be connected to the initial timing of treatment. In fact, all patients started treatment in the mixed dentition before pubertal growth spurt, in stage II of CVMS.

So, the study results show no significant differences in sagittal mandibular position influence produced by the modified Teuscher appliance. However, mandibular length (Co-Gn) increased significantly in experimental group when compared to control group (Ozturk, 1994; Turkkahraman , 2006; Marsan, 2007), while other investigations did not show the same results (Janson, 2004; Cozza, 2004a, b). In fact, the increase in lower anterior face height occurring in experimental group prevented the significant anterior mandibular prominence.

The sagittal results could have also been influenced by the position of the joint complex. Two factors were considered, NSCo and NSAr. The intention of considering those two factors seems redundant, but previous clinical studies suggested using substitutes for the condyle, like the point Ar, since conventional cephalometric methods do not allow precision in condyle assessment (Hagg, 2008). The results did not show differences between the two groups (Ozturk, 1994; Basciftci, 2003), although a higher decrease in experimental group could be detected. Other investigations estimated a significant decrease for NSCo (Cozza, 2004a; Marsan, 2007), connecting the relocation of glenoid fossa to sagittal correction.

Dentoalveolar changes (Pancherz, 1984; Basciftci, 2003; Janson, 2004), particularly at the level of anterior maxillary incisors, have undoubtedly contributed to anteroposterior correction in experimental group. The same cannot be referred about the behavior of lower incisors. In fact, upper incisors registered an important palatal movement, resulting on the reduction of proclination and overjet (Ozturk, 1994; Cura, 1996; Weiland, 1997; Basciftci , 2003; Cozza, 2004a; Janson, 2004; Turkkahraman, 2006; Marsan, 2007; Lerstol, 2010). The activation of maxillary anterior spurs was effective in the correction of proclination (U1-NA: -4.64º, SD 6.83, P = 0.016). In fact, maxillary incisors were upright and retracted in basal bone since the inclination changes without any anterior positional displacement of incisal edge reflects effective root torque (Cura, 1996; Singh, 2003; Janson, 2004; Turkkahraman, 2006; de Pawn, 2006). Mandibular incisors, assessed by IMPA, showed a non-significant reduction in connection to an effective mandibular dentoalveolar anchorage established by teeth acrylic covering (Basciftci, 2003; Janson, 2004) and complemented by extended lower lingual flanges. However, other studies reported significant proclination of lower incisors despite capping (Pancherz, 1984; Weiland, 1997; Singh, 2003; Cozza, 2004a; Quintao, 2006; Marsan, 2007). So, a combined skeletal and dentoalveolar contribution was important in Class II correction.

The prescribed therapy intended not only to promote mandibular sagittal development but also to improve the retrognatic profile. Previous studies reported significant positive effects in tegumental profile with treatment (Forsberg, 1981; Singh, 2003; Cozza, 2004a; Marsan, 2007) but the present results registered non-significant improvement assessed by angular factors N'Pg'-FH and G'SnPg'. Lip position followed the main dentoalveolar results. In fact, both upper and lower lips retruded significantly with treatment (Gogen, 1989; Singh, 2003; Lerstol, 2010). Cozza *et al.* (2004a) and Marsan *et al.* (2007) registered non-significant lip retrusion with treatment, but Quintão *et al.* (2006) only registered significant retrusion for the upper lip.

Vertical analysis

Although functional approach is an alternative of orthodontic treatment philosophy, the understanding of the inner anatomic basis of correction is limited. Activator treatment can cause maxilla and mandible rotation in downward and backward direction, counteracting the Class I correction. The combination of high-pull headgear and activator intends to prevent the transfer of distally directed forces from the maxilla to the mandible (Teuscher, 1978). Some authors (Williams, 1982; Cozza, 2004a, b) have found that most of mandibular growth is expressed vertically because of its backward rotation. An increase in posterior dentoalveolar area disturbs vertical development balance, inducing a backward displacement of pogonion. So, there is an important interplay between vertical dimension of maxilla and sagittal discrepancy (Isaacson, 1977). In consonance with other studies, the present results expressed no significant alterations of vertical facial complex in experimental group when assessed by the angular factors FMA, FH-OL, PP-GoMe (Cozza, 2004a; Marsan, 2007) and SN-PP (Janson, 2004; Marsan, 2007). With regard to linear vertical assessment, N-ANS did not show significant modifications (Singh, 2003; Cozza, 2004a; Marsan, 2007) while ANS-Me registered a significant increase when compared to control group (Singh, 2003; Marsan, 2007). In opposition, Cozza *et al.* (2004a) found a significant increase in SN-PP in treated group and a non-significant increase in ANS-Me (Janson, 2004). Present results show that treatment did not introduce significant vertical relationship modifications, except for lower face height. This result can explain the reason for the unexpressed mandibular advancement, even though there has been a significant increase of Co-Gn linear measurement in treated group. In fact, lower anterior face height increase did not allow the intended significant mandibular advancement as a therapeutic result.

The vertical dental relation, assessed by overbite, did not increase in the same amount as happened in control group, although differences between the two groups are non-significant. In addition, the evaluation related to L1-OL showed a significant decrease in the experimental group (Cozza, 2004a). This resulted from the acrylic capping of anterior teeth that prevented the significant increase in overbite and the extrusion of lower incisors happening in the control group. Other studies (Cozza, 2004a; Janson, 2004; Marsan, 2007) reported a more effective control in overbite.

The overall final clinical effect of treatment reflected more important skeletal and dentoalveolar changes than those revealed by growth. There was an improvement in facial appearance due to a reduction in sagittal discrepancy and a more balanced lip position. However, results were not consistent with the mandibular advancement in order to improve maxillo-mandibular discrepancy. According to Franchi *et al.* (2013) functional treatment during the pubertal peak is more effective than treatment before puberty. The present outcomes can be related to the initial timing of treatment. In fact, all patients started treatment in the mixed dentition before pubertal growth spurt, in stage II of CVMS.

CONCLUSION

The results of the present investigation show that the modified Teuscher appliance is effective in the treatment of Class II div. 1 malocclusions in growing patients. The co-operation in treatment is determinant to successful results.

The outcomes of Class II div. 1 treatment were associated mainly with dentoalveolar changes, done by controlled displacement of anterior teeth, which improved lip position. An anterior restriction of the maxillary complex contributed to skeletal sagittal correction.

Results were not consistent with the mandibular advancement in order to improve maxillo-mandibular discrepancy.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Dr Inês Marques (University Hospitals Oftalmology Department) University of Coimbra, Portugal, for the statistical guidance and processing. We also wish to thank Dr Maria José Madureira (António Madureira Radiodiagnosis Center, Porto, Portugal) for providing records for the control group (group B).

REFERENCES

Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod, 2002, 72(4): 316-323.

Basciftci FA., Uysal T, Buyukerkmen A., Sari Z. The effects of activator treatment on the craniofacial structures of Class II division 1 patients. Eur J Orthod, 2003, 25(1): 87-93.

Cozza P, De Toffol L, Colagrossi S. Dentoskeletal effects and facial profile changes during activator therapy. Eur J Orthod, 2004a, 26(3): 293-302.

Cozza P, De Toffol L, Iacopini L. An analysis of the corrective contribution in activator treatment. Angle Orthod, 2004b, 74(6): 741-748.

Cura N, Sarac M, Ozturk Y, Surmeli N. Orthodontic and orthopedic effects of Activator, Activator-HG combination, and Bass appliances: a comparative study. Am J Orthod Dentofacial Orthop, 1996, 110(1): 36-45.

de Pawn GA, Dermaut L R. A modified Teuscher activator. Semin Orthod, 2006, 12(1): 34-40.

Dermaut L R, van den Eynde F, de Pauw G. Skeletal and dento-alveolar changes as a result of headgear activator therapy related to different vertical growth patterns. Eur J Orthod, 1992, 14(2): 140-146.

Forsberg, CM, Odenrick L. 1981 Skeletal and soft tissue response to activator treatment. Eur J Orthod, 3(4): 247-253.

Franchi L, Pavoni C, Faltin K.Jr, McNamara J AJr, Cozza P. Long-term skeletal and dental effects and treatment timing for functional appliances in Class II malocclusion. Angle Orthod, 2013, 83(2): 334-340.

Galvão MC , Sato JR, Coelho EC. Dahlberg formula: a novel approach for its evaluation Dental Press Journal of Orthodontics, 2012, 17 (1): 115-124

Gogen H, Parlar S. [Evaluation of facial profile changes in individuals with skeletal Class II anomaly treated with activator and activator + occipital headgear]. Turk Ortodonti Derg, 1989, 2(2): 299-306.

Hagg U, Rabie AB, Bendeus M, Wong R W, Wey MC, Du X, Peng J. Condylar growth and mandibular positioning with stepwise vs maximum advancement. Am J Orthod Dentofacial Orthop, 2008, 134(4): 525-536.

Harvold EP, Vargervik K. Morphogenetic response to activator treatment. Am J Orthod, 1971, 60(5): 478-490.

Houston W J. The analysis of errors in orthodontic measurements. Am J Orthod, 1983, 83(5): 382-390.

Isaacson RJ, Zapfel RJ, Worms F W, Bevis RR, Speidel TM. Some effects of mandibular growth on the dental occlusion and profile. Angle Orthod, 1977, 47(2): 97-106.

Janson G, Caffer DC, Henriques JF, de Freitas MR, Neves LS. Stability of Class II, division 1 treatment with the headgear-activator combination followed by the edgewise appliance. Angle Orthod, 2004, 74(5): 594-604.

Keeling SD, Wheeler TT, King GJ, Garvan CW, Cohen DA, Cabassa S, McGorray SP, Taylor MG. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. Am J Orthod Dentofacial Orthop, 1998, 113(1): 40-50.

Kolf, J. [Functional treatment of retrognathia]. Rev Orthop Dento Faciale, 1991, 25(4): 401-416.

Lagerstrom LO, Nielsen IL, Lee R, Isaacson RJ. Dental and skeletal contributions to occlusal correction in patients treated with the high-pull headgear-activator combination. Am J Orthod Dentofacial Orthop, 1990, 97(6): 495-504.

Lerstol M, Torget O, Vandevska-Radunovic V. Long-term stability of dentoalveolar and skeletal changes after activator-headgear treatment. Eur J Orthod, 2010, 32(1): 28-35.

Luder HU. Skeletal profile changes related to two patterns of activator effects. Am J Orthod, 1982, 81(5): 390-396.

Marsan G. Effects of activator and high-pull headgear combination therapy: skeletal, dentoalveolar, and soft tissue profile changes. Eur J Orthod, 2007, 29(2): 140-148.

McNamara JA Jr. Components of class II malocclusion in children 8-10 years of age. Angle Orthod, 1981, 51(3): 177-202.

McNamara JA Jr, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy on class II patients. Am J Orthod, 1985, 88(2): 91-110.

McNamara JA Jr, Carlson DS. Quantitative analysis of temporomandibular joint adaptations to protrusive function. Am J Orthod, 1979, 76(6): 593-611.

Moore RN, Igel KA, Boice PA. Vertical and horizontal components of functional appliance therapy. Am J Orthod Dentofacial Orthop, 1989, 96(5): 433-443.

Ozturk Y, Tankuter N. Class II: a comparison of activator and activator headgear combination appliances. Eur J Orthod, 1994, 16(2): 149-157.

Pancherz H. A cephalometric analysis of skeletal and dental changes contributing to Class II correction in activator treatment. Am J Orthod, 1984, 85(2): 125-134.

Petrovic A, Stutzmann J. [Control of postnatal growth of the facial skeleton. Experimental data and a cybernetic model]. Actual Odontostomatol (Paris) 1979, (128): 811-841.

Pfeiffer JP, Grobety D. Simultaneous use of cervical appliance and activator: an orthopedic approach to fixed appliance therapy. Am J Orthod, 1972, 61(4): 353-373.

Pfeiffer JP, Grobety D. A philosophy of combined orthopedic-orthodontic treatment. Am J Orthod, 1982, 81(3): 185-201.

Quintao C, Helena I, Brunharo VP, Menezes RC, Almeida MA. Soft tissue facial profile changes following functional appliance therapy. Eur J Orthod, 2006, 28(1): 35-41.
Schmuth GP. Milestones in the development and practical application of functional appliances. Am J Orthod, 1983, 84(1): 48-53.

Singh GD, Thind BS. Effects of the headgear-activator Teuscher appliance in the treatment of Class II Division 1 malocclusion: a geometric morphometric study. Orthod Craniofac Res, 2003, 6(2): 88-95.

Teuscher U. A growth-related concept for skeletal class II treatment. Am J Orthod, 1978, 74(3): 258-275.

Turkkahraman H, Sayin MO. Effects of activator and activator headgear treatment: comparison with untreated Class II subjects. Eur J Orthod, 2006, 28(1): 27-34.

van Beek H. Combination headgear-activator. J Clin Orthod, 1984, 18(3): 185-189.

Weiland FJ, Ingervall B, Bantleon HP, Droacht H. Initial effects of treatment of Class II malocclusion with the Herren activator, activator-headgear combination, and Jasper Jumper. Am J Orthod Dentofacial Orthop, 1997, 112(1): 19-27.

Wieslander L, Lagerstrom L. The effect of activator treatment on class II malocclusions. Am J Orthod, 1979, 75(1): 20-26.

Williams S, Melsen B. The interplay between sagittal and vertical growth factors. An implant study of activator treatment. Am J Orthod, 1982, 81(4): 327-332.