

Rapid maxillary expansion in young adults: comparison of tooth-borne and bone-borne appliances, a cohort study.

Expansión rápida maxilar en pacientes adultos jóvenes: comparación de aparatos dentosoportados y esquelétalmente soportados. Estudio de cohorte.

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Abstract: Introduction: Maxillary constrictions are one of the most frequent abnormalities, regardless of the type of dentition studied. They can be treated either with tooth-borne or bone-borne expander appliances, depending on the biological maturation of the patient. Treatment during prepubertal stages has been shown to be successful, but there is evidence of an open suture even in late adolescence stages. The aim of this study is to compare the effects of a rapid expansion bone-borne device to a tooth-borne device in young adults suffering from maxillary constriction, by means of Cone-Beam Computed Tomography. Materials and methods: A retrospective observational study was conducted in nine patients (three males, six females) with a mean age of 18±5.5 years, who attended the Dentistry Service of Universidad de Chile during 2014-2015. Six patients were treated with tooth-borne appliances (Hyrax type) and three patients with bone-borne appliances (MARPE). Linear measurements of the anterior and posterior transverse dimension and angular measurements of the inclination of molars and incisors were obtained through CBCT for each group in T1 and T2. Results: A significant increase in the posterior transverse dimensions in both groups was observed. Radiolucency of the suture was observed in all patients treated with miniscrews and in half of the patients treated with Hyrax. Greater angulation of molars was shown in the tooth-borne group in comparison with the bone-borne group. Conclusion: Both appliances caused an increase in the posterior transverse dimension, but bone anchored appliances achieved a more parallel and skeletal expansion. Randomized clinical trials with a larger sample and follow-up are needed.

Keywords: Palatal expansion technique; cone-beam computed tomography; orthodontic appliances; orthodontic anchorage procedures; young adult.

Resumen: Introducción: Las compresiones maxilares son una de las anomalías más frecuentes, independiente del tipo de dentición que se esté estudiando. Su tratamiento se puede realizar con un aparato expansor ya sea dentosoportado o esquelétalmente soportado, dependiendo de las consideraciones de maduración biológica del paciente. Se ha demostrado éxito en el tratamiento en etapas prepuberales, sin embargo, existe evidencia de una sutura abierta aún en etapas post adolescencia. El objetivo de este estudio es comparar, mediante Cone Beam CT, los efectos de un dispositivo de expansión rápida maxilar esquelétalmente soportado, en relación a los dentosoportados, en adultos jóvenes con compresión maxilar. Material y método: Se realizó un estudio de tipo observacional retrospectivo, donde se evaluaron nueve pacientes (tres hombres y seis mujeres) con un promedio de edad de 18±5,5 años, que asistieron al Servicio de Ortodoncia de la Universidad de Chile, durante los años 2014-2015. Seis pacientes fueron tratados con aparatos dentalmente soportados (tipo Hyrax) y tres pacientes con aparatos esquelétalmente soportados (MARPE). A través de CBCT se

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tomaron medidas lineares de la dimensión transversal anterior y posterior, y medidas angulares de la inclinación de molares e incisivos para cada grupo en T1 y T2. Resultados: Hubo un aumento significativo en la dimensión transversal posterior de ambos grupos. Se presentó radiolucidez de la sutura en un 100% de los pacientes tratados con microtornillos y 50% de los pacientes tratados con hyrax. Hubo mayor angulación de molares en el grupo dentosoportado en comparación al grupo

esqueletalmente soportado. Conclusiones: Ambos aparatos lograron un aumento de la dimensión transversal posterior, sin embargo, los de anclaje esqueletal lograron una expansión más paralela y esqueletal. Hacen falta ensayos clínicos aleatorizados con mayor muestra y seguimiento.

Palabras Clave: Técnica de expansión palatina; tomografía computarizada de haz cónico; aparatos ortodóncicos; métodos de anclaje en ortodoncia; adulto joven.

INTRODUCTION.

Maxillary constriction is one of the most frequent abnormalities of the dental arches. It can often be accompanied by posterior crossbite and dental crowding. It is a progressive abnormality that tends to increase in young people and can be permanent in adults.¹

Most of these transverse deficiencies are treated with rapid maxillary expansion (RME) using either a tooth-borne or a bone-borne expander.² Treatment in patients before the pubertal growth peak has been shown to be successful; however, RME efficacy in adults is still a matter of debate. The fusion of the palatine suture in late adolescence would make orthodontic disjunction almost impossible in young adults, making surgical treatment necessary.³ This surgical procedure, however, requires patient hospitalization and implies a set of morbidity risks that can affect the patient's quality of life.

It has been shown that the fusion of the palatine suture depends on the patient, and that the chronological age is not a reliable method to determine the stage of the suture's fusion during growth. Cone-Beam Computed Tomography (CBCT) has been used to classify the morphology of the suture into five stages according to the maturation stage to decide on RME.³⁻⁶

Angelieri *et al.*⁵ classify the sutures into:

Stage A: straight high-density sutural line, with no or little interdigitation;

Stage B: scalloped appearance of the high-density sutural line;

Stage C: two parallel, scalloped, high-density lines that lie close to each other, separated in some areas by small low-density spaces; Stage D: fusion of the suture at the palatine bone level, with separation in the maxillary portion; Stage E: complete fusion of the palatine suture.

Grünheid *et al.*,⁷ on the other hand, propose the

use of CBCT to assess the density of the suture as a reliable predictor of RME outcomes, regardless of the chronological age.

Bone-borne RME began to be used when temporary anchorage devices were introduced. Nevertheless, there is not much evidence of its effect in the treatment of adult patients. On the other hand, most of these studies only use 2D images to obtain data, with the disadvantage of the superposition of the soft tissues, or through the analysis of study models that only allow for the assessment of dental measurements.

Thanks to CBCT, it is now possible to acquire more reliable images, allowing clinicians and researchers to assess bone and dental quantitative changes in a three-dimensional way with minimum distortion and low doses of radiation.⁸

The aim of this study is to compare, by means of CBCT, the effects of a rapid expansion bone-borne device in relation to a tooth-borne device in young adults suffering from maxillary constriction.

MATERIALS AND METHODS.

Sample

A retrospective observational study was conducted in nine patients (three males, six females) with a mean age of 18±5.5 years (13 to 28 years range) (Table 1), who attended the Dentistry Service of Universidad de Chile during 2014-2015. All patients were healthy or received controlled medical treatment and gave informed consent. None of the patients had previously received orthodontic treatment.

Patients who were post pubertal peak were included according to the assessment using the Baccetti's cervical vertebral maturation method⁹ (three patients in stage CS4, two in stage CS5, and four in stage CS6), determined through lateral teleradiography. Maxillary

constriction diagnosis was made by tracing an outline on the frontal telerradiographs using Ricketts' method. The analysis was performed by locating two skeletal points in order to determine the width of the maxilla (JL-JR), and two additional points to establish the width of the jaw (AG-GA). The difference between maxillary and mandibular linear measurements was obtained and compared with the mean defined by Ricketts according to the age of the patient.¹⁰ Patients were treated with rapid maxillary expansion without surgical treatment. Six patients were treated with tooth-borne appliances (Hyrax type) and three patients with bone-borne appliances (MARPE) (Table 1).

Data collection: photographic records, posteroanterior and lateral telerradiographies and study models of each patient were used. Additionally, a CBCT was performed before the treatment (T1) and after the expansion (T2).

CBCT was performed using Pro Max 3D (Plan Meca) device with a field of view of 90mm x 90mm. The analysis of images was carried out using Plan Meca Romexis Viewer, Helsinki. Each subject was asked to remain seated vertically with the Frankfort horizontal plane parallel to the floor.

Median palatine suture was assessed by measuring the anterior and posterior transverse dimension at fixed bone and dental points. Incisor and molar inclinations were assessed with angular measurements in the maxillary axial plane (Figure 1). All measurements were obtained at T1 and T2.

Anterior Transverse Dimension

A line between the inflection points of the vestibular cortical bone of both sides was traced, having as anteroposterior reference the interradicular space between the second premolar and the first upper molar.

Posterior Transverse Dimension

Once the line had been traced, in the same zone of the cut, a line was traced between the vestibular cortical, tangential to the palatal root of both first molars.

Molar inclination

In the coronal plane, the angle formed by two points and the horizontal reference of the software. The palatine point located at the center of the width of the palate at the level of the palatine floor, and the dental point located in the middle of the palatine apex of the

first right and left molar.

The angle of molar inclination (right and left) is formed by a lower line going from the cusp reference over the horizontal reference of the software, and an upper line traced from the dental reference to the middle palatine point.

Incisor inclination

An angle was obtained for each incisor, whose sides were: a vertical line from the distal amelocemental junction of the incisor to the root apex of the same tooth, and a horizontal line to the apex the contralateral incisor. The internal angle of each tooth was measured.

Clinical Protocol

The Type 2 bone-borne expander described by Lee et al.¹¹ was used. It has four miniscrews, two between the canines and the first premolars, and two between the second premolars and the first molars. The miniscrews are connected to the expander through an acrylic resin coverage.¹¹ Four self-drilling and self-tapping M.O.S.A.S, Dewimed, Gac miniscrews (Figure 2) 10mm long and 1.6mm in diameter with a transmucosal collar and soft tissue platform were used.

The tooth-borne Hyrax-type expander was used; it has four wire tags, two in the first premolars and two in the first permanent upper molars, with a Hyrax type central expansion screw of 11mm of expansion placed near the palatine contour (Figure 2).

All appliances were manufactured by the same dental laboratory technician.

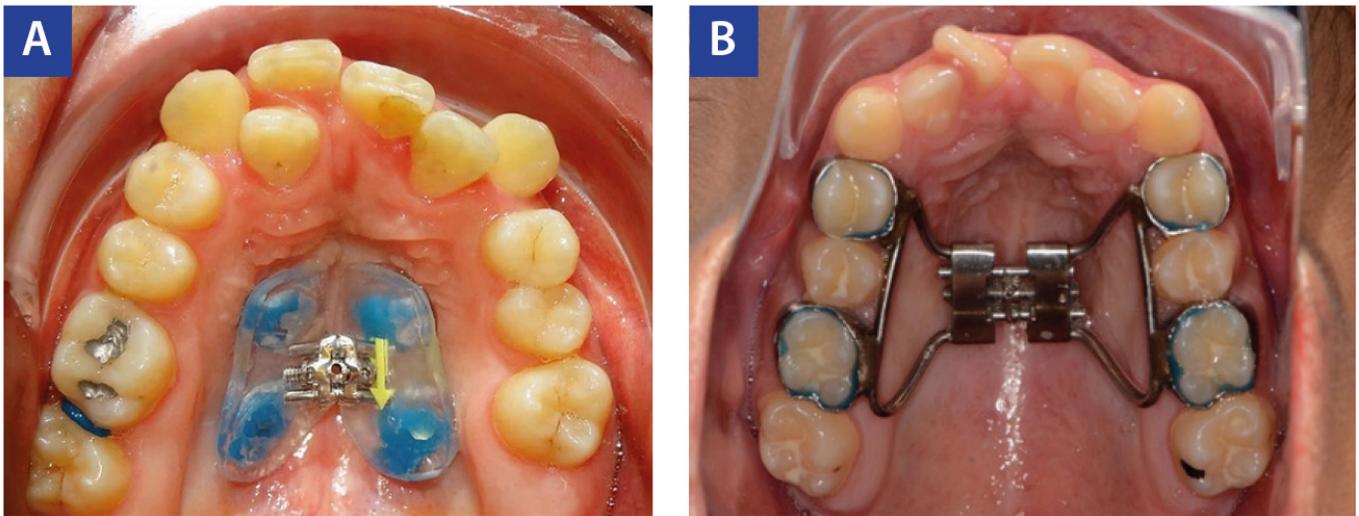
The activation protocol for both software packages was used twice a day (two quarters turn in the morning and two quarters turn in the night). The duration was calculated according to the expansion required for each patient. Patients were told to stop expansion in case of experiencing any pain or tissue inflammation. The same expander or transpalatal bar was used as containment for 5 months.

Statistical Analysis: The type of distribution of the sample was analyzed using the Shapiro-Wilk test ($\alpha > 0.05$). Unpaired t-test was used to compare the results. Paired t-test was used to compare pre and post treatment results between patients in the same group. Significance level was fixed at $p \leq 0.05$, statistical analysis was performed with Stata software version 14.

Figure 1. Angular and linear measurements.



Figure 2. Rapid maxillary expander appliance .



A: Bone-borne rapid maxillary expander appliance. **B:** Tooth-borne rapid maxillary expander appliance

Figure 3. Box plot Anterior and Posterior Transverse Dimension.

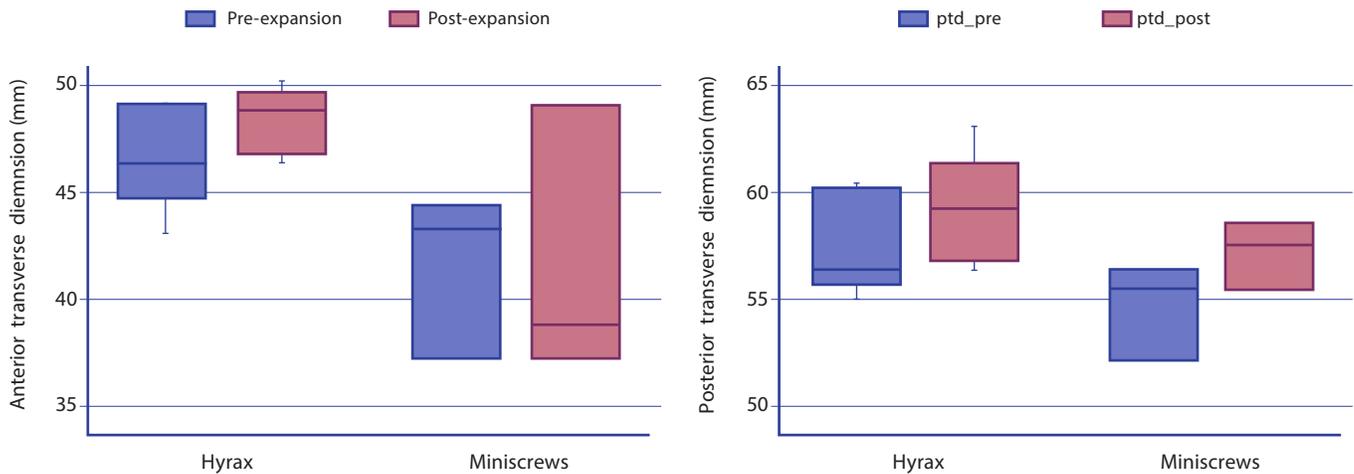


Table 1. Sample data.

Expander Appliance	Age (years) $\bar{x} \pm SD / \text{range}$	Activation (mm) $\bar{x} \pm SD$	Activation Time (days) $\bar{x} \pm SD$	Containment Time (days) $\bar{x} \pm SD$	Baccetti's Vertebral Maturation		
					CS4	CS5	CS6
MARPE (n=3)	17 \pm 1.7/15-18	7.33 \pm 1.52	7.33 \pm 1.52	9.67 \pm 4.04	1	0	2
HYRAX (n=6)	18 \pm 5.5/13-28	8.25 \pm 3.22	8.17 \pm 3.43	6.83 \pm 1.83	2	2	2

Table 2. Results of the comparison between Pre and Post expansion states with Hyrax appliance and Miniscrews (Paired t-test).

Variables	Pre Expansion (T1)		Post Expansion (T2)		$\bar{x} \pm SD$		Changes t-test	p-value
	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD		
tooth-borne appliance								
Anterior TD	46.6	2.3	48.6	1.5	1.9	2.2	2.135	0.0860
Posterior TD	57.4	2.2	59.3	2.7	1.9	1.4	3.336	0.0206*
IM Tooth 3	49.1	3.2	47.5	4.3	3.4	2.5	3.335	0.0207*
IM Tooth 14	49.1	1.9	46.4	2.9	2.8	2.6	2.5944	0.0486*
II Tooth 8	104.2	5.8	100.6	5.3	3.6	4.8	1.8499	0.1236
II Tooth 9	104.6	5.4	106.7	3.2	2.0	5.2	0.9498	0.3858
Bone-borne Appliance								
Anterior TD	42.0	3.7	44.1	6.2	0.07	4.5	0.0269	0.9810
Posterior TD	54.6	2.1	57.0	1.5	2.4	0.7	6.133	0.0256*
IM Tooth 3	44.2	4.0	39.9	4.5	4.2	3.9	1.9165	0.1954
IM Tooth 14	46.3	2.5	43.7	1.1	2.7	1.4	3.1179	0.8930
II Tooth 8	103.7	2.0	105.2	4.9	1.4	3.3	0.7531	0.5300
II Tooth 9	104.6	4.3	98.0	8.0	5.4	9.4	1.2298	0.3438

*: Statistically significant (p -value ≤ 0.05).

Table 3. T1-T2 differences, Hyrax appliances y Miniscrews (Unpaired t-test).

Variables	Hyrax		Miniscrews		\bar{x}	Difference	
	\bar{x}	SD	\bar{x}	SD		t-test	p-value
ATD	1.93	2.21	3	2.6	1.06	0.6464	0.5386
PTD	1.94	1.42	2.41	0.7	0.47	0.5298	0.6126
IM Tooth 3	3.43	2.52	4.29	3.88	0.86	0.4086	0.6950
IM Tooth 14	3.13	2.08	2.59	1.43	0.54	0.4017	0.6999
II Tooth 8	3.89	4.52	2.74	1.56	1.15	0.4159	0.6899
II Tooth 9	3.71	3.99	7.98	7.64	4.28	1.1420	0.2910

RESULTS.

When evaluating the analyzed variables by CBCT, in terms of linear measurements, it is possible to observe a rise in anterior transverse dimension (ATD) in 78% of patients, while posterior transverse dimension (PTD) increased in all patients, regardless of the appliance used. The ATD in the tooth-borne group showed a mean rise of $1.93\text{mm} \pm 2.21\text{mm}$, while in the bone-borne with miniscrews group the mean rise was $2.1\text{mm} \pm 2.6\text{mm}$. The PTD in the Hyrax group showed a mean rise of $1.94\text{mm} \pm 1.42\text{mm}$, while for the miniscrews group the mean rise was $2.41\text{mm} \pm 0.68\text{mm}$.

With respect to angular measurements, the molar dental inclination angle decreases regardless of the expansion appliance used. Patients treated with a dental supported appliance showed a mean decrease of $3.43^\circ \pm 2.52^\circ$ for the first right molar and $2.78^\circ \pm 2.62^\circ$ for the first left molar, while for patients treated with a bone-borne appliance the mean decrease was $4.29^\circ \pm 3.8^\circ$ for the first right molar, and $2.59^\circ \pm 1.43^\circ$ for the first left molar. The angle of incisor inclination presented different results: in the Hyrax group, for the upper right incisor, it decreased $3.62^\circ \pm 4.79^\circ$, for the upper left incisor, it increased $2.02^\circ \pm 5.2^\circ$, while for the upper right incisor in the miniscrews group, it increased $1.42^\circ \pm 3.28^\circ$, and for the upper left incisor, it decreased $6.67^\circ \pm 9.39^\circ$. (Table 2)

A diastema was produced between incisors, following the maxillary expansion in the miniscrews group, with a separation between the crown of the central incisors of approximately 2.54mm.

According to the results of the paired t-test analysis, in the group of patients treated with the Hyrax appliance, statistically significant differences were found in the following studied variables: posterior transverse dimension, molar inclination of tooth 3 and molar inclination of tooth 14. In the group of patients treated with miniscrews, only in the posterior transverse dimension a statistically significant difference was found (Table 2). Distribution of data from anterior and posterior transverse dimension for both groups is show in boxplots (Figure 3).

When examining the presence of radiolucency of the midpalatal suture post disjunction and comparing the different appliances, all patients treated with miniscrews presented radiolucency, while only 50% of patients treated with Hyrax presented this radiolucent line. When

comparing the transverse dimensions between patients in whom suture radiolucency was achieved, the values of both transverse dimensions were higher in patients treated with Hyrax.

When analyzing the difference between T1 and T2 according to each appliance and comparing them between both groups: Hyrax and Miniscrews (non-paired t-test), statistically significant differences were not found (Table 3).

DISCUSSION.

The aim of this study was to compare two appliances of rapid maxillary expansion with CBCT in young adult patients. The maxillary disjunction is the treatment selected for teenagers and young adult patients to separate the palatal suture and induce significant changes in the maxilla. It has been demonstrated that clinically steady results are obtained in the subjacent structures.¹²

Similar studies have been conducted to observe rapid maxillary post-expansion changes; however, they are limited to the use of 2D images for data collection, with the inconvenient of the overlapping of soft tissues or through the analysis of study models; only allowing the analysis of dental measurements. The analysis of the effects of rapid maxillary expansion through CBCT has a higher accuracy of the diagnosis parameter measured and may soon become the routine checkup for those treatments.¹³

Of nine patients, three with miniscrews and six with Hyrax, radiolucency was achieved at the suture level in all patients treated with miniscrews and in 50% of patients treated with expansion through Hyrax. Both appliances produced a higher linear expansion at the coronal portion level of the first permanent molars than at their apical portion level, producing a vestibular inclination. Similar results were found for other studies.^{11,14,15}

When comparing the results between patients treated with Hyrax and miniscrews, in both groups, it was observed a rise in the anterior transverse dimension; however, in average, this was higher in the group of patients treated with miniscrews (3mm) *versus* Hyrax (1.9mm). It was also observed a higher rise of posterior transverse dimension in patients treated with

miniscrews 2.4mm, *versus* Hyrax 1.9mm. Nonetheless, when comparing transverse dimensions between patients in whom radiolucency of the suture was reached, values of both transverse dimensions were higher in patients treated with Hyrax. These results coincide with findings of Mosleh *et al.*,¹ and Lin *et al.*,¹⁶ but contrast with the results of Lagravere *et al.*,² who demonstrated significant and similar quantities of expansion at the level of the pulp chamber of the first permanent molars in both appliances, both skeletal and dental anchors.

In this study, both the group treated with Hyrax as the one treated with miniscrews showed statistically significant differences pre and post disjunction in the subsequent transverse diameter, as well as in other studies,^{2,17} which reported the highest expansion at the permanent first molar level.

It has been reported that expansion happens because of a skeletal separation, with the remaining expansion being explained by the dental component of this. In this study, statistically significant changes are observed at a posterior transverse level between the use of Hyrax *versus* Miniscrew, and a greater tooth inclination at a molar level, which contributed greatly to solving the transverse problem. A higher inclination of patients treated with Hyrax was observed when comparing the dental inclination of the upper first molars between patients in whom suture radiolucency was reached. These results coincide with other studies.^{1,8,16}

In this study, a diastema between incisors was produced, subsequent to the maxillary expansion in the miniscrews group, with a distance of the central incisors crown of approximately 2.54mm, equivalent to 36% of expansion of the screw (7mm mean).

This percentage is smaller to the one observed by Hass *et al.*,¹⁸ in whose study postero-previous radiographs were used. However, there is agreement with observations reported by Hass, in which the roots of the central maxillary incisors diverged beyond the crowns after the active phase of rapid maxillary expansion.

Dental inclination that was produced in appliances anchored to the bone, as well as in those of dental support, should be taking into account during the treatment planning. Strategies to prevent undesirable dental inclinations, for example, giving negative torque

in the arch, should be considered in those patients who use expansion appliances anchored to miniscrews.

In this study it was expected that with expansion appliances anchored to miniscrews, there would be a more skeletal expansion and with less repercussions at dental level than those appliances on teeth. Effectively, greatest changes were observed in molar inclination in patients treated with Hyrax. The expansion of the root apex at molar level was smaller than the one at a coronary level, resulting in a coronary towards vestibular inclination. Similar results were found by Lin *et al.*,¹ who observed that skeletal expansion was significantly greater in the group treated with skeletal anchorage than those treated with dental anchorage, where greater vestibular inclination of molars was observed. The expanders with skeletal anchorage produce a higher orthopedic expansion in comparison to Hyrax and in a more parallel form.¹

Although having statistically significant differences for the changes in the subsequent transverse dimension and molar inclination, the results of this study would have a limited clinical relevance and not necessarily contribute to the decision of expanding with dental or skeletal supported appliances. However, it is important to underline that other studies have shown better results of expansion using a mixed appliance with bicorticals miniscrews and bands, that is to say both dental and bone-borne.¹⁹ The decision of using appliances with miniscrews which are anchored directly to the bone or those dental supported such as the Hyrax, in young adult patients, should be based on the dentist preferences and in the variables found in the patient (level of skeletal maturation, very high or narrow palate, hygiene, missing teeth, status of crowns, etc.). The expansion appliances with miniscrews can be very useful in patients who do not have some posterior teeth or to the health of engaged teeth. Moreover, the use of miniscrews allow the realization of orthodontic therapy at the same time than the expansion, thus shortening the treatment times.²

Limitations

As the size of the sample is very small, when applying the t-test many significant differences are not revealed; however, this does not mean that they do not exist.

The best study model to evaluate therapies is the randomized controlled clinical trial; however, this study was observational in nature of retrospective cohort, where the sample cannot be randomized, leading to a biased selection. Randomized clinical trials with a larger sample are needed to obtain conclusive results that can be extrapolated to the general population.

CONCLUSION.

In all the patients treated with bone-borne appliances there was an increase in transverse diameters and the presence of a radiolucent line. When comparing the skeletal and dental effects achieved with the bone-borne and tooth-borne devices, an increase in the posterior transverse dimension was observed with both; however, with skeletal anchorage, maxillary expansion was more parallel and with a more skeletal than dental movement.

Maxillary expansion in patients treated with miniscrews show results in the posterior transverse dimension, which are significantly greater than those of

the group treated with Hyrax.

Moreover, a smaller molar inclination in the group of skeletal anchorage was observed, being these results statistically significant. It is needed to conduct a controlled randomized clinical trial and a long-term follow-up to assess the stability of the expansion conducted in both appliances in young adults and with a larger sample.

Conflict of interests: There is no conflict of interest among the authors.

Ethics approval: All patients were healthy or received controlled medical treatment and gave informed consent. None of the patients had previously received orthodontic treatment.

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