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ORIGINAL ARTICLE

Dentoalveolar Effects Following Maxillary Expansion: Comparison Between Dental and Skeletal Anchorage

Francesca Cremonini[1], Patrizia Pieralli[1], Paolo Albertini[1], Mario Palone[1]

[1]Department of Orthodontics, University of Ferrara, Ferrara, Italy.

Correspondence: Francesca Cremonini, Assistant Research Department of Orthodontics, University of Ferrara, Ferrara, Italy. 44121 Ferrara, Italy. **E-mail:** dr.ssafrancescacremonini@gmail.com

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ABSTRACT

Objective: To compare the dento-alveolar effects between dental and skeletal anchored expansion devices to achieve maxillary expansion in different groups of patients: pure dental anchorage was used in growing patients and skeletal anchorage in adult patients. Linear, angular and volumetric parameters have been analysed. **Material and Methods:** 22 patients has been selected from the total archive of patients treated in the Orthodontics Department of the University of Ferrara, Italy, divided into 3 groups according to the appliance used to obtain the transversal maxillary correction. Digital files of the upper arch were obtained from scans performed using an intro-oral scanner before treatment (T0) and at the end of expansion (T1). Therefore, linear, angular and volumetric measurements have been performed. **Results:** There is a highly significant statistic variation of the 3-3, 4-4 and 6-6 diameter as a function of time. There was a statistically significant variation of the palatal vault angle and of the 6-6 distance at the cusp level as a function of time. Moreover, it appears that these parameters are reduced in the group with skeletal anchored expander. No tooth considered have encountered a statistically significant change in tip and torque values, no matter the type of RPE and the treatment time. For all patients, we have recorded the superimposition of the maxillary dental cast before and after treatment. **Conclusion:** In all patients, we obtained a resolution of the maxillary transverse deficit. Patients treated by pure skeletal anchored devices have recorded a less variations of palatal vault angle and the distance between first molar cusps, as if the expansion was gained more parallel. The expansion obtained showed reduced dental side effects, as tip and torque values haven't changed in a statistically significant way.

Keywords: Orthodontics; Malocclusion; Palatal Expansion Technique.

Introduction

Transverse maxillary deficit represents a widespread skeletal problem of the craniofacial complex. It is a malocclusion that should be diagnosed, intercepted and corrected as soon as possible because early therapy in these cases is simple and effective, with good stability over time. The resolution of the deficit restores the balance between the skeletal and dental components to guarantee harmonious growth [1,2].

Maxillary expansion greatly improves smile aesthetics by reducing the dark vestibular corridors and making the smile wider and more attractive [3,4], implements the arch perimeter [5] and is indicated in patients at high risk of canine inclusion [6]. The best time to perform rapid palatal expansion is immediately following the onset of the eruption of the first permanent molars, possibly before the eruption of the permanent lateral incisors. At this development stage, the deciduous molars offer an excellent anchorage and the permanent molars also undergo expansion, going to erupt physiologically in the correct position [7].

Following rapid palatal expansion nasal cavity, oropharynx, maxillary sinus gets expanded [8], the total airway volume increases [9] and the palatal volume increases with insignificant relapse [10,11]. In growing patients, the sutures are malleable, so the skeletal resolution of maxillary transverse deficiency is possible with dental anchorage devices [12].

If the treatment is postponed [13], the effects would be more dental rather skeletal [14,15]. To overcome this problem, researchers have demonstrated that it is possible to obtain a valid skeletal expansion using micro-implants anchorage [16-18]. Palate is a tried and trusted site for mini-screws insertion, the anterior region is the thickest part of the palate, but the bone thickness in the posterior region is also suitable for screws of appropriate diameter and length [19]. Lee et al. [20] recommend a bicortical insertion of the palatal mini-screws to have greater stability of the anchor because the orthopaedic forces are high, and a lower risk of deformation and fracture of the mini-screws [20,21]. To achieve more predictable results, a safe and customized guide based on CBCT and STL file matching is recommended [22].

This study aimed to compare the dento-alveolar effects between dental and skeletal anchored expansion devices to achieve maxillary expansion in different groups of patients: pure dental anchorage was used in growing patients and skeletal anchorage in adult patients. Linear, angular and volumetric parameters have been analysed.

Material and Methods

Study Design and Sample

In this retrospective study, a sample of 22 patients has been selected from the total archive of patients treated in the Orthodontics Department of the University of Ferrara, Italy, according to the following inclusion criteria: 1) Skeletal transverse maxillary deficiency, defined by the presence of mono- or bilateral crossbite and pronounced Wilson Curve; 2) Aged between 7 and 25 years; 3) Digital scans at the start of treatment and at the end of the expansion.

Then, it was divided into 3 groups according to the appliance used to obtain the transversal maxillary correction:

- Group 1: Nine subjects, 3 males and 6 females, of an average age of 8 years, treated using Haas-type expander anchored on deciduous second molars, with an expansion protocol of one round of activation per day (Figure 1);
- Group 2: Nine subjects, 4 males and 5 females of an average age of 11 years, treated using a hybrid expander (2 Spider Screw Regular Plus mini-screws and bands on first permanent molars). They

underwent an Alt-Ramec protocol, introduced by Liou in 2005 [23]: 1 mm of activation per day (4 rounds), alternating a week of expansion to a week of constriction, for a total period of 7-9 weeks (Figure 2).

- Group 3: Four patients, 2 males and 2 females of an average age of 19 years, treated using exclusively skeletal anchored expander (4 Spider Screw Regular Plus palatal screws) (Figure), with an expansion protocol of one round of activation per day.

The expansion was always overcorrected until the first upper molar palatal cusp comes into contact with the first lower molar vestibular cusp.

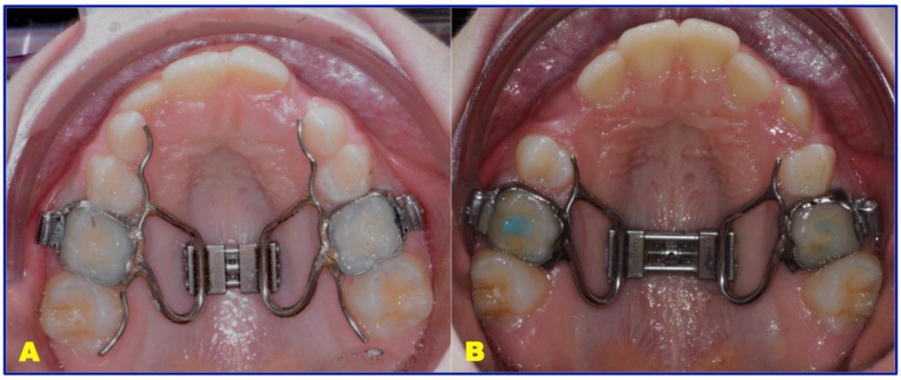

Figure 1. Occlusal upper photograph of the appliance used in group 1, at T0 - before treatment – (A) and T1 - after treatment (B).

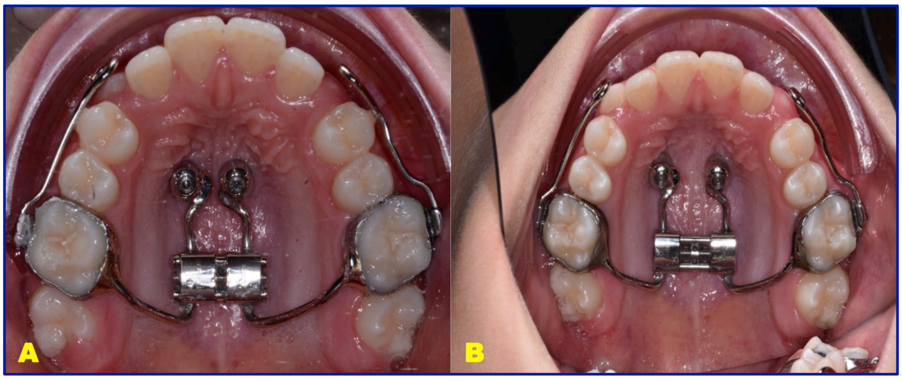

Figure 2. Occlusal upper photograph of the appliance used in group 2, at T0 (A) and T1 (B).

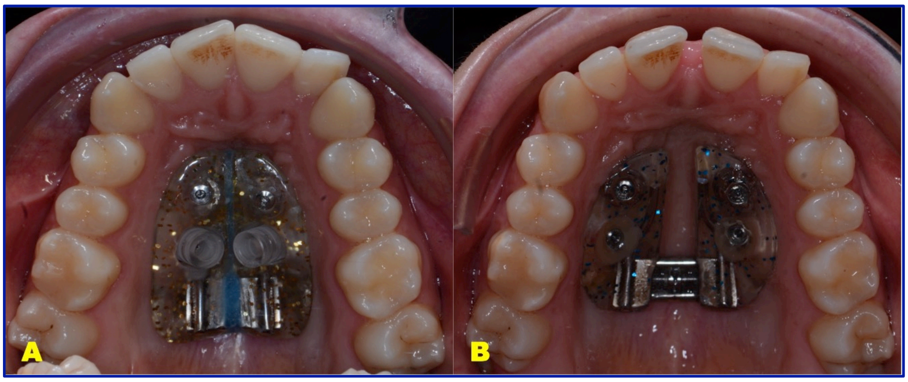

Figure 3. Occlusal upper photograph of the appliance used in group 3, at T0 (A) and T1 (B).

Data Collection

The digital files of the upper arch were obtained from scans performed using an intra-oral scanner - TRIOS (3Shape A/S, Copenhagen, Denmark) or by scanning the plaster study scans before treatment (T0) and at the end of expansion (T1). Therefore, linear, angular and volumetric measurements have been performed.

In particular, first, second and third-order measurements of all the elements of the maxillary arch were performed using VAM software - VECTRA M3 3D Imaging System (Canfield Scientific, Fairfield, NJ, USA) with the acquisition method described by Huanca Ghislanzoni et al. [24] (Figure 4).

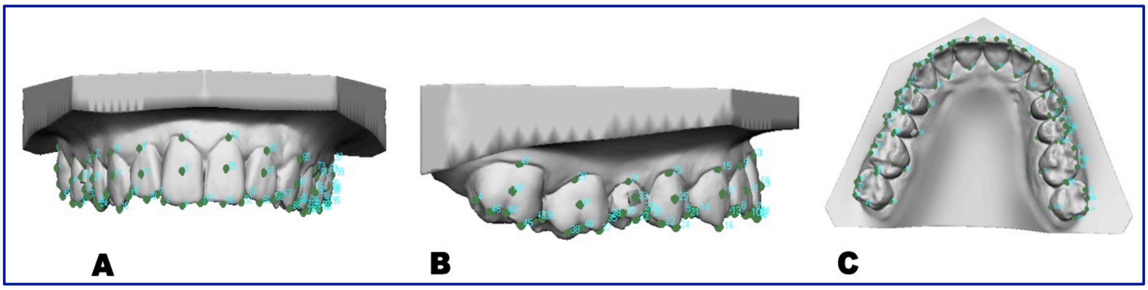

Figure 4. Points on incisors, canines, bicuspids and molars using VAM software.

Using 3 Shape Ortho Analyzer software (3Shape A/S, Copenhagen, Denmark), the STL file was oriented in the space planes and virtual basing and trimming of the digital scans was performed. The following linear measurements (Figure 5) were performed for each patient on the digital maxillary scan before and after treatment: 1) Distance 3-3: measured between the most lingual point of the margin of the gingiva on the canines; and 2) Distance 6-6: measured between the most lingual point of the margin of the gingiva on the first upper molars.

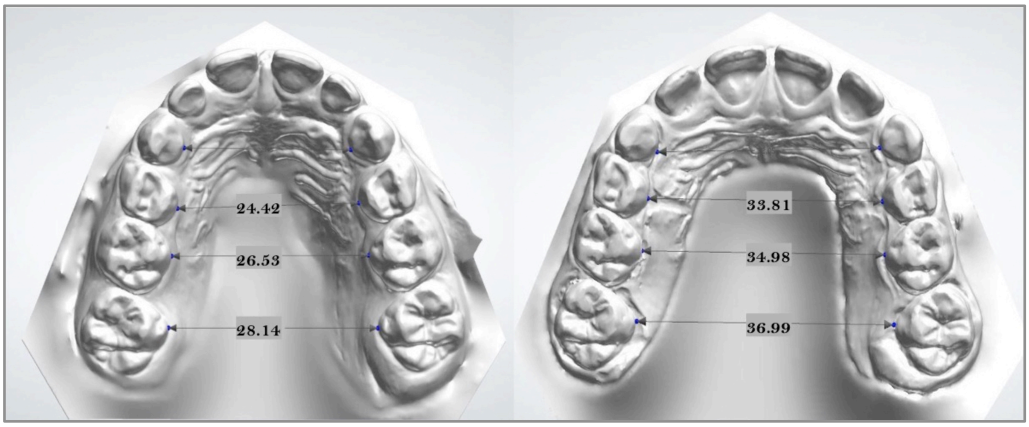

Figure 5. Diameter measurements from an occlusal view at T0 (A) and T1 (B).

Moreover, to assess the possible loss of epithelial attachment determined by the expansion, the heights of the clinical crowns of first molars and bicuspids were measured.

Then, the digital scans were cut using Rhinoceros 3D Software (Robert McNeel & Associates, Seattle, WA, USA) with a frontal plane that crosses the palatal grooves of the maxillary first molars (Figure 6), to perform linear and angular measurements (Figure 7).

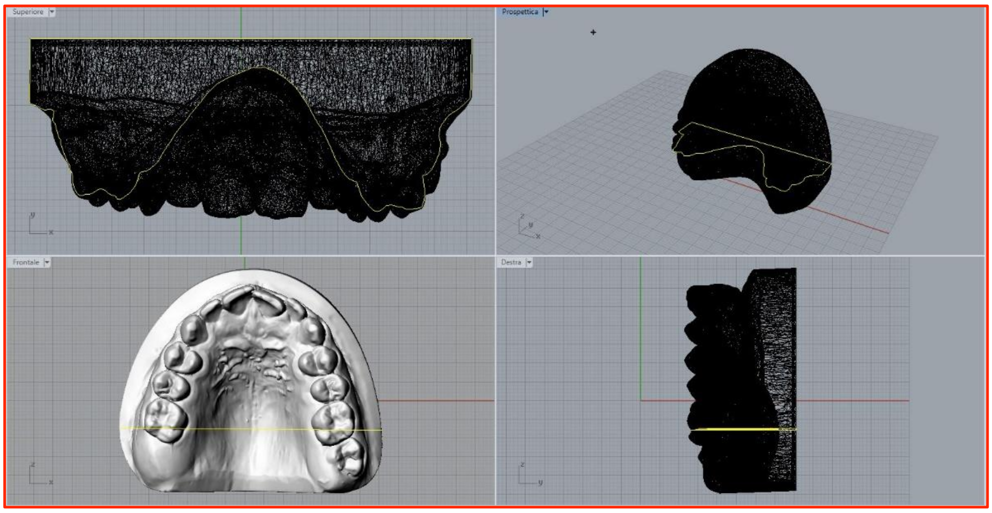

Figure 6. Representation of the frontal plane and the polyline on which the measurements were performed.

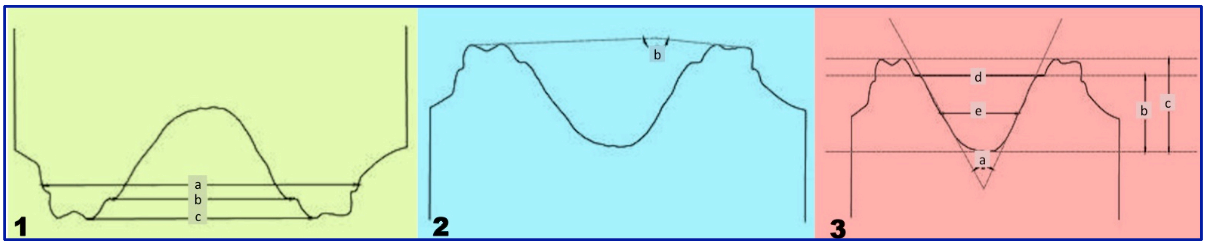

Figure 7. (1) a. Linear measure from the most prominent buccal bulge; b. Linear measure from the palatal gingival margin; c. Linear measure from the mesial-palatal cusp. (2) Maxillary first molar angulation. (3) a. Palatal vault angle; b. Palatal depth from gingival height; c. Palatal depth from molar cusp; d. palatal width at gingival height; e. Palatal width at mid-palate.

Statistical Analysis

The statistical analysis aimed to assess how different expansion protocol and devices impacted on linear and angular measurements made on dental casts before and after treatment. Repeated measures analysis has been carried on using the mixed effect modelling approach. The R Statistical software (R Foundation for Statistical Computing, Vienna, Austria) has been used to perform statistical analysis. Statistical significance has been assessed using the following thresholds: 1-50% weak, standard 5%-1%, strong < 1%. The analysis of the variables was carried out based on time, type of expander, and the interaction between the two. For each parameter, a graph shows the progress of the results. A value of p-value <0.001 is considered to be very significant, significant a value of 0.005-0.001, weakly significant from 0.10 to 0.05.

Results

Below we report the outcomes with a statistically significant variation before and after expansion treatment, considering the three different study groups. First of all, there is a highly significant statistic variation of the 3-3, 4-4 and 6-6 diameter as a function of time (T0-T1) (Table 1 and Figures 8 and 9). Depending on the appliance in all groups, there is a statistically significant variation of the 3-3 diameter (Figure 8).

Distance between 15 and 25 has changed over time in a statistically weakly significant manner based on the type of expander (from the figure it seems that the dental anchoring one behaves differently) (Figure 9).

Table 1. Descriptive statistics of the outcome 3-3, 4-4, 5-5 and 6-6 diameter.

Anchorage	Outcome	Period	N	Mean	SD
Hybrid	3-3 diameter	T0	9	24.9	3.76
		T1	9	30.7	3.93
	4-4 diameter	T0	9	25.8	2.68
		T1	9	30.4	2.69
	5-5 diameter	T0	9	29.5	2.92
		T1	9	34.3	2.36
	6-6 diameter	T0	9	32.9	3.57
		T1	9	39.5	5.45
Skeletal	3-3 diameter	T0	4	21.9	2.28
		T1	4	25.0	1.53
	4-4 diameter	T0	4	23.2	2.39
		T1	4	27.2	1.39
	5-5 diameter	T0	4	27.8	2.96
		T1	4	31.4	2.50
	6-6 diameter	T0	4	28.9	2.47
		T1	4	32.4	2.37
Dental	3-3 diameter	T0	9	24.5	1.86
		T1	9	29.9	1.77
	4-4 diameter	T0	9	25.7	2.46
		T1	9	32.1	2.68
	5-5 diameter	T0	9	28.1	2.19
		T1	9	34.4	2.04
	6-6 diameter	T0	9	30.4	2.36
		T1	9	36.1	2.23

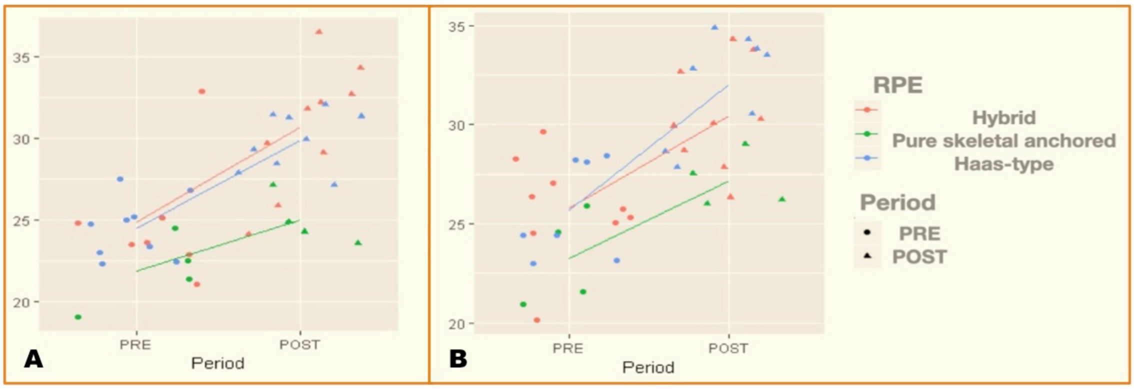

Figure 8. Trend over time: (A) Parameter "3-3 diameter"; (B) Parameter "4-4 diameter".

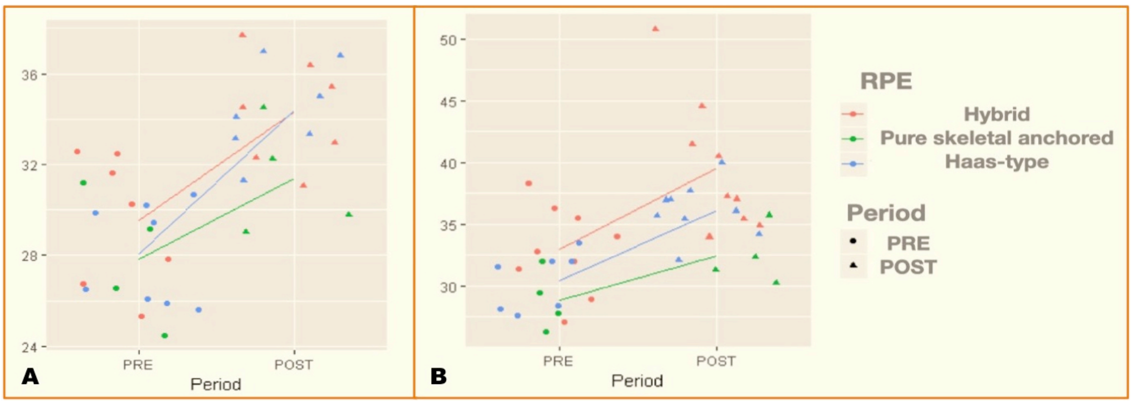

Figure 9. Trend over time: (A) Parameter "5-5 diameter"; (B) Parameter "6-6 diameter".

Palatal width at first molar gingival height and at mid-palate increased in a statistically very significant way from T0 to T1 (Table 2 and Figure 10), but there was no difference between groups (Figure 11).

Table 2. Descriptive statistics of the outcome palatal width at mid-palate, palatal width at gingival height 6-6, palatal vault angle.

Anchorage	Outcome	Period	N	Mean	SD
Hybrid	Palatal Width at Mid-Palate	T0	9	22.5	2.44
		T1	9	26.1	5.10
	Palatal Width at Gingival Height 6-6	T0	9	34.1	3.53
		T1	9	40.9	5.42
	Palatal Vault Angle	T0	9	80.2	11.73
		T1	9	81.9	15.41
Skeletal	Palatal Width at Mid-Palate	T0	4	21.7	2.72
		T1	4	24.2	2.03
	Palatal Width at Gingival Height 6-6	T0	4	31.9	3.15
		T1	4	34.4	2.63
	Palatal Vault Angle	T0	4	65.7	10.07
		T1	4	56.0	10.44
Dental	Palatal Width at Mid-Palate	T0	9	21.5	2.77
		T1	9	22.6	2.90
	Palatal Width at Gingival Height 6-6	T0	9	31.9	2.83
		T1	9	36.2	2.80
	Palatal Vault Angle	T0	9	81.6	7.47
		T1	9	92.0	11.65

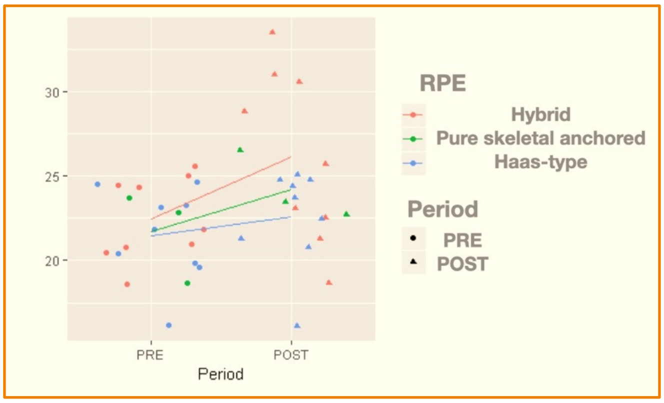

Figure 10. Trend over time of the parameter "Palatal width at mid-palate".

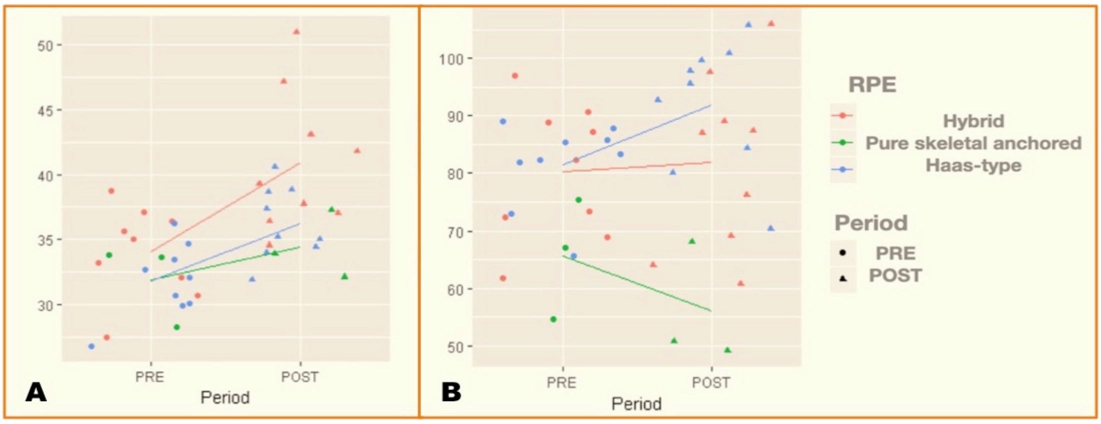

Figure 11. Trend over time: (A) Parameter "Palatal width at gingival height 6-6"; (B) Parameter "Palatal vault angle".

There was a statistically significant variation of the palatal vault angle and of the 6-6 distance at the cusp level as a function of time (Table 3 and Figure 12). Moreover, it appears that these parameters are reduced in the group with skeletal anchored expander (Table 3 and Figures 11 and 12).

Distance between 16 and 26 at gingival level and at the most prominent buccal bulge of the superior alveolus increased significantly from T0 to T1 (Table 3). Moreover, in the group with hybrid ERP this distance increases more (Figures 13 and 14).

Table 3. Descriptive statistics of the parameter Cusp 6-6, Trans alveolar 6-6, Trans 6-6.

Anchorage	Outcome	Period	N	Mean	SD
Hybrid	Cusp 6-6	T0	9	41.0	4.27
		T1	9	47.3	4.32
	Trans Alveolar 6-6	T0	9	56.5	4.78
		T1	9	62.8	5.03
	Trans 6-6	T0	9	34.1	3.53
		T1	9	41.1	5.28
Skeletal	Cusp 6-6	T0	4	39.1	4.71
		T1	4	40.0	1.87
	Trans Alveolar 6-6	T0	4	53.1	3.87
		T1	4	55.9	2.68
	Trans 6-6	T0	4	31.9	3.15
		T1	4	34.4	2.63
Dental	Cusp 6-6	T0	9	37.9	3.80
		T1	9	43.2	3.25
	Trans Alveolar 6-6	T0	9	53.7	3.45
		T1	9	57.6	4.42
	Trans 6-6	T0	9	33.1	1.99
		T1	9	36.2	2.82

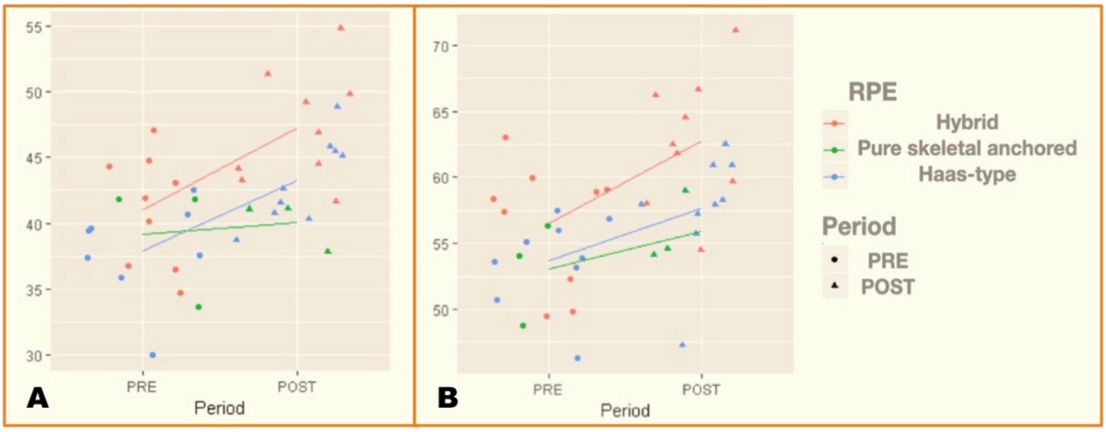

Figure 12. Trend over time: (A) Parameter "cusp 6-6"; (B) Parameter "trans alveolar 6-6".

If the other outcomes are considered, there is no statistically significant difference in the variation of clinical crown height of 16, maxillary molar axial angulation and palatal depth from molar cusp and gingival margin. Moreover, no tooth considered have encountered a statistically significant change in tip and torque values, no matter the type of RPE and the treatment time.

For all patients, we have recorded the superimposition of the maxillary dental cast before and after treatment (Figure 14). It was made by superimposing the straight line passing through the central palatal wrinkles and a vertical line connecting the anterior interdental papilla and the posterior part of the midsagittal line.

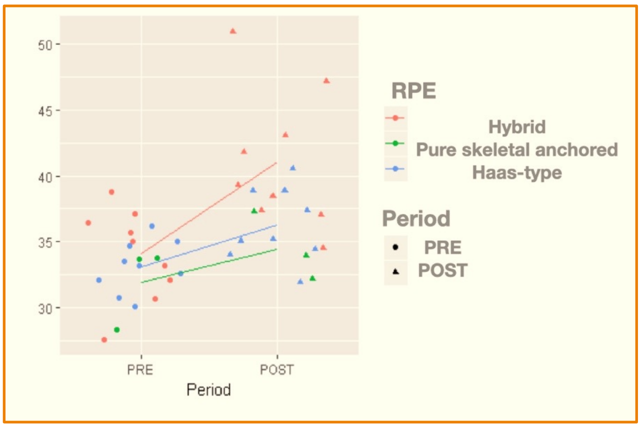

Figure 13. Trend over time of the parameter "trans 6-6".

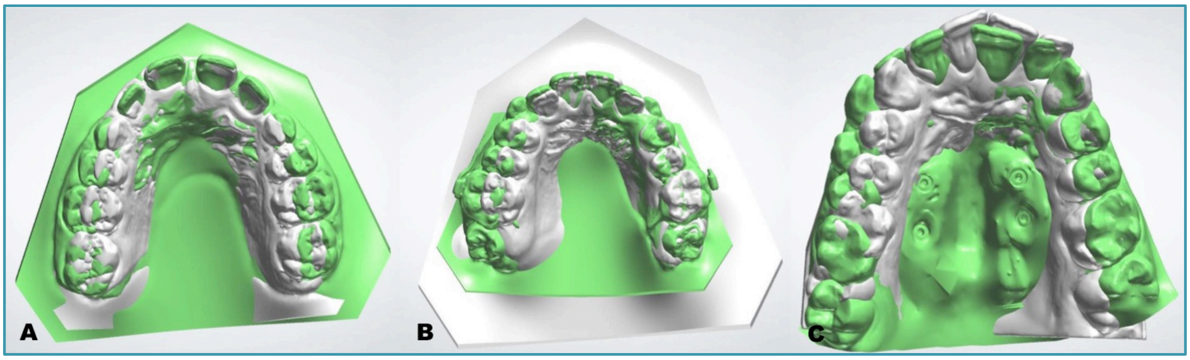

Figure 14. (A) Group 1 - Female, 8 years old; (B) Group 2 – Female, 14 years old; (C) Group 3 – Female, 24 years old.

Discussion

Dental and dento-alveolar effects following the rapid palatal expansion with three different types of anchorage (dental- hybrid- skeletal) have been investigated. Different approaches are used in relation to the different skeletal maturation stages; in Group 3 a skeletal anchorage was used because the resistances encountered by the exclusively dental anchoring device could have been high.

The linear and angular measurements were carried out on digital models, pre-expansion (T0) and post-expansion (T1), and statistical analysis of the results obtained was performed in order to understand whether there were any significant differences between the groups. These results were examined and compared with studies previously published in literature with the purpose of compare various types of expander.

Handelman et al. [25] made the same measurements but using an analogic method, performing the section and these measurements directly on the plaster casts. The variation of the maxillary trans-arch widths from T0 to T1 was very significant in all groups. This increase allowed the resolution of the transverse skeletal deficit of patients of all groups and it is likely that the amount of expansion obtained was related to the severity of the original malocclusion. However, this variation is not statistically different between the three groups and does not vary according to the type of expander used. In relation to time, the variation of diameter between 55 and 65 was statistically significant in patients in mixed dentition where these elements were used as an expander anchorage. This could explain why dental side effects were greater, according to Mosleh et al. [26].

In other studies, it is suggested a frequent onset of gingival recessions caused by the expansion treatment, appreciated as an increase of the clinical vestibular crown length [27,28]. Handelman et al. [25] performed the measurements in an adult group of patients and found a maximum measured recession of 2 mm, also appreciated in the control sample. Our study hasn't found a significant increase in the clinical crown length, in agreement with Choi et al. [29] and Lagravere et al. [30]. On the other hand, we pointed out a very significant variation of the palatal width, at the gingival height and at mid-palate, from T0 to T1, with no appreciable difference between the different study groups.

According to Gracco et al. [10], the increase was comparable in the three groups, confirming that the purpose of orthopedic expansion has been achieved. Surely, to measure and evaluate the skeletal effect, it would be necessary to perform evaluations on 3D X-ray images [31,32].

There was no statistically significant variation of the maxillary first molar axial angulation from T0 to T1 among the groups. This result indicates that there has not been a statistically significant molar tipping in any of the three groups, with the minimum dental side effects [33].

It's interesting to highlight that the palatine vault angle and the distance between cusps 16-26 have changed in a statistically significant way in relation to the expander type. Indeed, in Group 3, there was a reduction of this angle and it seems that the diameter has been increased less than in the other groups. We can hypothesize that a pure skeletal expander gives the most parallel opening of the suture, as Cantarella et al. [34] state in their study done on 3D X-ray images.

This a pilot study, research in small-scale conducted in preparation for larger researches. It is desirable a numerical increase of the sample and a greater uniformity of the protocol. Moreover, it would be interesting to compare the results with the stage of suture maturation and provide more detailed results through a volumetric analysis made by CBCT.

Conclusion

In all patients, we obtained a resolution of the maxillary transverse deficit. From a dental casts digital analysis, the following differences were noticed: Statistically significant increase of the maxillary trans-arch widths, dentally more pronounced in patients that have been subjected to a dental anchored expander. The palatal vault angle and the distance between first molar cusps changed significantly in all groups from T0 to T1. However, patients treated by pure skeletal anchored devices have recorded a less variations of these two parameters, as if the expansion was gained more parallel. Trans-alveolar and trans-gingival distance between first molars increased more in hybrid anchorage group compared to others. The expansion obtained showed reduced dental side effects, as tip and torque values haven't changed in a statistically significant way.

Authors' Contributions

FC	https://orcid.org/0000-0002-4641-2196	Conceptualization, Methodology, Formal Analysis, Investigation, Writing - Original Draft and Writing - Review and Editing.
PP	---	Data Curation and Writing - Review and Editing.
PA	https://orcid.org/0000-0002-4020-5065	Formal Analysis and Writing - Review and Editing.
MP	https://orcid.org/0000-0001-6198-3053	Conceptualization and Writing - Review and Editing.
All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.		

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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