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Retrospective Observational Study

Cephalometric variation of vertical dimension in patients treated with hyrax-type and McNamara-type rapid palatal expander. Study on latero-lateral teleradiography

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ABSTRACT

To analyze changes in the vertical dimension of the lower third of the face studied on teleradiograph in L-L following rapid palatal expansion achieved by four-band Hyrax-type rapid palatal expander (RPE) and by acrylic-bonded McNamara RPE to identify the most appropriate therapeutic choice based on the patient's facial growth pattern. 30 patients were selected, of whom 20 (9 males and 11 females with a mean age of 8.285 ± 1.216) were treated using McNamara RPE (Group D), and 10 (6 males and 4 females with a mean age of 8.562 ± 1.152) were treated with Hyrax RPE (Group B), for an average treatment time T0-T1 of 0.96 ± 0.501 years. According to Tweed and Ricketts, Cephalometric tracings obtained from lateral cephalograms at T0 and T1 were analyzed to study changes in the vertical dimension of the lower third of the face. For this purpose, 6 cephalometric landmarks were considered: convexity (distance of point A to the NPg plane), Ricketts' total face height (angle between the NBa plane and Xi-Pm plane), lower face height (angle between the ANS and Xi-Pm planes), facial axis (angle between the NaBa plane and PtGn plane), ANB angle, and FMA angle. No statistically significant differences were found between the measurements at T0 and T1 for any of the 6 cephalometric measurements considered, neither within the single groups nor when comparing the two. However, a greater increasing trend was found for some variables between the two groups, such as Ricketts' total facial height, lower facial height, and FMA angle, although not statistically significant. Hyrax and McNamara's RPEs have provided minimal changes in the vertical component during palatal expansion treatment, thus demonstrating their ability to preserve the vertical dimension of the face. Therefore, there are no contraindications for using either appliance for patients with dolichofacial growth patterns.

INTRODUCTION

Rapid palatal expansion is a treatment option commonly used in orthodontics to increase the maxilla's transverse deficit and correct skeletal crossbites (1). The rapid palatal expander (RPE) on resin splints and the RPE on bands are two appliances used for maxillary expansion, which determine skeletal effects on the maxillofacial complex through the opening of the median palatine suture through a dental anchorage. The rapid expansion aims to solve the transverse discrepancy of the bone bases by increasing the width of the upper arch while limiting the orthodontic effect on the anchoring teeth as much as possible (2).

Numerous skeletal and dental effects obtained following palatal expansion mediated by a RPE anchored on bands and/or resin splints are reported in the literature. Some authors have reported that, in addition to the opening of the median palatine suture, the rapid palatal expansion obtained with an RPE appliance anchored on bands determines the antero-inferior dislocation of the maxilla, the vestibular inclination of the alveolar process and the extrusion and vestibular inclination of the posterior teeth (3-5).

These effects result into a posterior-inferior rotation of the mandible, with a consequent increase in the vertical dimension of the face (6-8). Over time, this phenomenon has promoted the use of alternative rapid palatal expansion appliances, such as the RPE anchored on resin splints, with the belief that it could guarantee greater control of the anterior facial height of the face compared to what happens with appliances anchored on bands (4, 5, 9, 10).

According to other authors, both RPEs on splints and bands have been considered capable of minimizing vertical changes as a consequence of the expansion (2,11-14), a fundamental feature for those patients who have an increased anterior facial height and/or mandibular plane angle before the orthodontic treatment, with a hyperdivergent growth trend.

The RPE on bands promotes a distal rotation and a vestibular expansion of the molar region, which is also transmitted to the elements of the premolar and anterior region thanks to the extension of the steel arms. However, the mechanism of action of this appliance determines an extrusive migration and a vestibular-inclination of the lateral-posterior dental elements (15), a posterior-rotation of the bispinal plane, and an increase in the craniomandibular angle, negative effects if patients with an increased anterior vertical dimension of the face are considered (16).

The RPE on resin splints promotes a vestibular expansion of the posterior elements included in the resin splints, which perform a "bite-block" function: thanks to the intrusive occlusal force directed at the posterior elements, they minimize their extrusion (2), and consequently, the backward and downward movement of the mandible is limited (4, 17). According to this theory, the greater control of the vertical dimension is due to the advancement of the mandible, which is no longer in a constrained position due to maxillary hypoplasia, and it will tend to rotate upwards and forwards (10, 18).

The skeletal effects and increases in width on the transverse plane, as a result of distraction of the midpalatine suture, have been widely discussed and confirmed in the literature (19), while there is less concordance of results compared to effects of palatal expansion on the variation of the vertical dimension. It is known, in fact, that an increase in the transverse width of the maxilla is also accompanied by changes in the vertical and sagittal direction, where the rotation of the mandible has been recognized as one of the most frequent effects (20).

This aspect has a particular relevance in those patients who present a class II, in which a clockwise rotation of the mandible can lead to a worsening of the skeletal class on the sagittal plane, or in patients with increased anterior facial width, whose profile would be further worsened on the vertical plane, as a consequence of a posterior-inferior rotation of the mandible. The sagittal component is inverted for third class patients requiring palatal expansion (21)

As reported by several authors (10, 20), the most significant changes on the vertical plane are observed in the first phases of palatal expansion, in which there is a clockwise rotation and a retrusion of the mandible, probably correlated to the presence of pre-contacts of the overly expanded palatine cusps and the downwards and forwards displacement of the maxilla, caused by the V-shaped opening of the median palatine suture (3).

During the subsequent retention period, the tendency to increase the vertical component decreases, a phenomenon related to the anti-clockwise and upward rotation of the mandible due to the correction of the transverse deficit and the settling of the occlusal relationship (22). From these observations, it can be deduced how the vertical repositioning of the maxilla due to palatal expansion influences the movement of the mandible on the sagittal and vertical plane; this correlation is influenced by numerous factors, such as the observation of skeletal and dental effects, the facial type of the subject and the orthodontic appliance used, which justifies the absence of unanimity in the literature regarding the final effect on the vertical dimension.

The objective of the present study is to analyze the variations in the verticality of the lower third of the face through cephalometries performed on L-L teleradiographs, following rapid palatal expansion mediated by two different appliances, such as Hyrax and McNamara RPEs, to identify which one is the most suitable therapeutic choice in relation to the initial clinical conditions, or whether there are contraindications to the use of one or the other appliance in patients with a tendency to hyperdivergent facial growth who would benefit from a palatal expansion therapy.

MATERIALS AND METHODS

The present study compared the effects of the expansion of the maxillary arch using an RPE with dental anchoring through resin splints (McNamara type) and on bands (Hyrax type), analyzing the variations in the verticality of the lower third of the face in patients who presented transverse skeletal deficit.

Thirty patients with transverse deficiency of the maxilla were selected; 20 of them (9 males and 11 females with an average age of 8.3 ± 1.22) were treated with a McNamara RPE (Group D), and 10 (6 males and 4 females with an average age of 8.56 ± 1.15) were treated with a Hyrax RPE (Group B), for an average treatment time T0-T1 of 0.96 ± 0.50 years. The treated patients had a cervical vertebral maturation stage (CVMS), according to Baccetti and Franchi (21), lower than CS 3, therefore before the peak of pubertal growth.

At T0, 20% of patients had a bilateral posterior crossbite, while the remaining 80% had a unilateral posterior crossbite as shown (Fig. 1).

Fig. 1. *Unilateral posterior left crossbite.*

The choice of one or the other type of RPE occurred randomly, and all the appliances were manufactured by the same dental laboratory. The inclusion and exclusion criteria of the sample (23, 24) are shown in Table I.

Table I. *Inclusion and exclusion criteria of the sample.*

Inclusion criteria	Exclusion criteria
Skeletal class type I or II	Skeletal anomalies and/or craniofacial asymmetries
Transverse skeletal deficiency of the maxilla	Genetic diseases or endocrine pathologies that could interfere with the orthodontic treatment
Presence of mono or bilateral cross-bite	Previous orthodontic treatments
Transverse dental discrepancy between 5 and 6 mm	Dental anomalies
Complete radiographic documentation	Labiopalatoschisis
Pre-pubertal stage of maturation	Poor oral hygiene

	Periodontal defects of the anchoring teeth
	Oral pathologies
	Severe adenotonsillar hypertrophy
	Mouth breathing, obstructive sleep apnea syndrome and other respiratory disorders

The subjects were treated by the same orthodontist at the Orthodontics department of the Dentistry and Maxillofacial Surgery clinic of the G.B. Rossi Hospital in Verona. Before starting the orthodontic therapies, informed consent to treatment was requested and collected from the parents of the patients included in this study. All subjects were treated until the correct transverse widths of the dental arches were achieved (the vestibular cusps of the upper teeth were located in a more labial position to the antagonist tooth, and lingual cusps of the lower elements located at the level of the central fossa of the upper antagonist element), specific to the individual case. This study was approved by the Clinical Investigation Ethics Committee of Verona and Rovigo, Italy (protocol number 70252). The procedures were in accordance with the Helsinki Declaration of 1975, as revised in 2000.

Types of rapid palatal expanders

RPE on resin splints was introduced in the 1970s and perfected in its clinical management by McNamara (25) (Fig. 2). The appliance consists of a central expansion screw with lateral arms incorporated into grooves made of acrylic material that completely cover the palatal, occlusal and vestibular surfaces of the anchoring teeth (generally extending from C or D to the upper first or second molars).

Fig. 2. *Example of McNamara-type RPE with resin splints extending from the first molars to the deciduous canines.*

The expansion screw used has a thread pitch of 0.8 mm, corresponding to four activations (a single activation is therefore 1/4 of a turn, i.e. 0.2 mm), and it is positioned at the level of the medial palate at approximately 2 mm from the palatine mucosa and as distal as possible, so as to bring it closer to the center of resistance of the upper jaw located at the base of the two zygomatic processes.

Hyrax RPE

The Hyrax® RPE (OIS Orthodontics, Aston, PA, USA) (14) is composed of a metal structure that has four orthodontic bands, two positioned on the permanent maxillary first molars and/or premolars (alternatively, on the E elements), and two arms in contact with the palatal surfaces that extend from the banded elements up to the C and/or upper second molars (26). It is equipped with a midline screw with characteristics and position similar to the McNamara expansion appliance described previously (Fig. 3).

Fig. 3. *Example of Hyrax RPE with two bands cemented on the first molars and two on the first premolars.*

Therapeutic protocol

For each treated patient, a case study was initially performed to diagnose and formulate the treatment plan. During the first visit, alginate impressions were taken for the study models, and an orthopantomography and a teleradiography with lateral-lateral projection (L-L) at the start of treatment (T0) were prescribed and taken. A cephalometric tracing was performed according to Ricketts and Tweed, and the maturation stage of the cervical vertebrae was analyzed according to the system by Baccetti and Franchi (27).

The degree of transverse discrepancy (TD) was determined by measurements on the models of the dental arches using a fine-point caliper with a precision of 0.1 mm, calculating the difference between the mesio-palatal cusp of the right and left upper first molars and the central fossa of the right and left mandibular first molars. Furthermore, the Wilson curve was analyzed using the study models to identify the posterior crossbite's skeletal or dental nature and the palatal vault's width.

The amount of correction necessary to achieve a correct transverse relationship was calculated based on the millimetric measurement of the TD; moreover, an overcorrection was added (28) to obtain the vestibular aspects of the palatal cusps of the upper molars in proximity to the lingual sides of the buccal cusps of the lower molars.

During the second visit, for Group D (subjects treated with McNamara RPE), new alginate impressions were taken to construct the orthodontic appliance. In contrast, for Group B treated with Hyrax's RPE, adequate bands were selected, and then an alginate impression with bands on the teeth was taken to create the appliance.

On the third appointment, the RPE was cemented with self-photo-polymerizable dual-type glass ionomer cement (GC Fuji PLUS® Radiopaque Reinforced Glass Ionomer Luting Cement). After removing all the excess cement, light curing was performed for 120 seconds on each side.

Patients underwent a standardized expansion protocol involving 4 activations at the time of cementation and, subsequently, 3 daily activations (two in the morning and one in the evening) until the desired correction was obtained. Each activation of the appliance requires 1/4 turn of the screw (equivalent to 0.2 mm), which corresponds to 1 mm of expansion every 5 activations.

Indications on home oral hygiene, correct nutrition (29-31), the maintenance of the appliance, and the use of a key to carry out the activations were given to the parents, who were also warned of the physiological appearance of the inter-incisor diastema after a few days, a sign that the palatal expansion had occurred (32) (Fig. 4).

Fig 4. *Frontal intra-oral photography at the end of the activations.*

During the treatment, the patients were checked after a week. At the end of the activations, and once the desired expansion was achieved, the screw was blocked with a metal ligature with a diameter of 0.01 inch and flowable composite.

During the following 6 months, the appliance was kept in place as retention, and it was removed at the end of that phase; therefore, a further nocturnal retention appliance was created and carried at night for further 6 months for the patients in the group D if the McNamara RPE remained intact after decementation, it was used for this aim, otherwise in all the other cases, and for patients in group B, a custom made Hawley plate was manufactured. At the end of the nocturnal retention period, during which the patients were seen for control every 4-6 weeks, one end-of-treatment L-L projection teleradiography (T1) was performed for each patient.

Radiological Protocol

Two teleradiographs with L-L projection were prescribed and performed for each patient in the study:

- Initial L-L teleradiography (T0) carried out between 0 and 14 days before the positioning of the appliance.
- Final L-L teleradiography (T1) carried out at the end of the nocturnal retention.

All X-rays were performed by a single radiologist at the Radiology department of the G.B. Polyclinic Rossi in Verona. To carry out the X-ray, each patient was asked to assume an upright position to reproduce the natural position of the head (NHP), with the chin supported by an adjustable platform and the Frankfurt plane parallel to the floor.

Data collection and analysis

The L-L teleradiographs at T0 and T1 were loaded onto the Delta-Dent CE Outside Format software, and cephalometric tracing was performed on them according to Ricketts and Tweed (Fig. 5, 6). Each cephalometric tracing was performed by a single operator and was subsequently remeasured 10 days later according to the same protocol to minimize the possibility of mistakes in the identification of the reference points and to guarantee the highest accuracy for each cephalometric tracing.

Fig. 5. *Example of cephalometric tracing according to Ricketts and Tweed.*

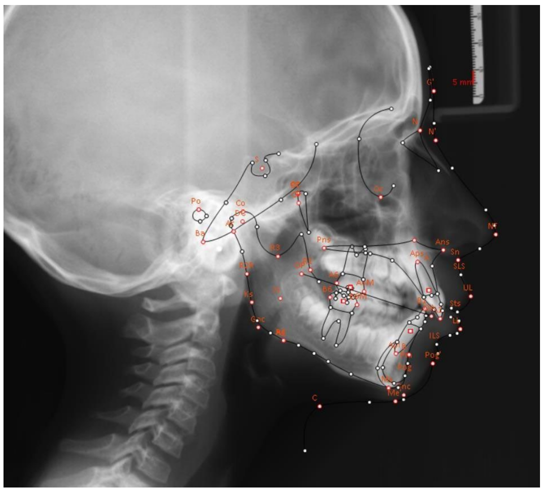

Fig. 6. *Example of Ricketts and Tweed cephalometric tracing on latero-lateral cephalometry.*

Subsequently, it was verified that there were no statistically significant differences between the two values obtained using the Student t-test for paired samples. On both occasions, the operator was unaware whether the X-rays analyzed were taken at T1 or T0. An average between the two values obtained for each measurement was used for statistical investigations.

The evaluation of the changes in the vertical dimension was made on the basis of the following six cephalometric references: convexity (distance of point A with respect to NPg plane), total height of the face according to Ricketts (angle between NBa plane and Xi-Pm plane), lower height of the face (angle between the anterior nasal spine ANS and Xi-Pm plane), facial axis (angle between NaBa plane and PtGn plane), ANB angle and FMA angle (angle between the Frankfurt plane and the mandibular plane).

Statistical analysis

Descriptive statistics, including means and standard deviations, were calculated for each of the six cephalometric measurements. To analyze the differences between the groups before treatment (T0), the independent sample parametric statistical test t-Student was used. The comparison of the changes between T0-

T1 between group B and group D was also carried out using the Student t-test. In contrast, the Student t-test for paired samples was used to evaluate whether there was a mean difference statistically significant between time points T0 and T1 within each treatment group. Exploratory statistical analyses were conducted to evaluate the distribution (Shapiro Wilk test) and variance (Sd-Test) of the six cephalometric measures. Statistical significance was tested for $P < 0.05$.

RESULTS

Since the sample examined was not equally balanced both by sex (6 males and 4 females for group B; 9 males and 11 females for group D) and by subjects belonging to each group (10 subjects belonging to group B; 20 subjects belonging to group D), the Fisher-test statistical verification test (or Fisher-Yates test) was carried out, which demonstrated that these differences are not statistically significant (p-value > 0.05); therefore the sample is to be considered suitable for comparison.

From the exploratory statistical analyses conducted, it was highlighted that all the variables were normally distributed (Shapiro-Wilk test) and had similar variances (Sd-Test). The means and standard deviations for the cephalometric variables measured before orthodontic treatment (T0) relating to the two groups are shown in Table II.

Table II. *Mean values ± standard deviation and median of group B and D. Results of T-Student test of T0 values (p-value>0.05).*

GROUPS AT T0	Bands (Group B) T0		Splints (Group D) T0		P-VALUE T0
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.34±3.66	53.85	55.00±3.72	55.45	0.817
Lower Face Height (Degrees)	40.92±3.67	39.95	42.28±2.87	41.75	0.274
Facial Axis (Degrees)	91.18±1.62	91.20	91.18±0.92	91.25	0.991
Convexity (mm)	2.32±1.48	2.00	2.32±1.35	2.30	0.993
ANB (Degrees)	3.61±1.74	4.15	3.12±1.72	3.10	0.465
FMA (Degrees)	28.51±4.60	27.65	28.77±3.65	29.30	0.990

There were no statistically significant differences between the baseline measurements among the two groups, which allows us to assert that the measurements are to be considered homogeneous at T0; therefore, samples from each group are suitable for comparison.

The descriptive statistics for the changes that occurred during the treatment and the comparison between T0 and T1 of groups B and D are reported in Tables III and IV. The statistical results of the comparison between the two groups of the changes obtained between T0 and T1 are reported in Table V.

Table III. *A comparison between T0 and T1 of group B and the p-value of each variable was taken into consideration.*

Groups	RPE on bands (Group B)				
	T0		T1		P-Value
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.34 ± 3.66	53.85	55.27 ± 4.38	54.90	0.9620
Lower Face Height (Degrees)	40.92 ± 3.67	39.95	41.22 ± 3.20	41.50	0.7131
Facial Axis (Degrees)	91.18 ± 1.62	91.20	91.50 ± 1.95	91.45	0.5949
Convexity (mm)	2.32 ± 1.48	2.00	1.91 ± 1.36	1.80	0.3998
ANB (Degrees)	3.61 ± 1.73	4.15	2.81 ± 1.49	3.05	0.7409
FMA (Degrees)	28.51 ± 4.60	27.65	27.88 ± 3.34	27.35	0.6153

Table IV. *A comparison between T0 and T1 of group D and the p-value of each variable was taken into consideration.*

Groups	RPE on resin splints (Group D)				
	T0		T1		P-Value
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Total Face Height (Degrees)	55.00 ± 3.72	55.45	55.86 ± 3.49	54.85	0.163
Lower Face Height (Degrees)	42.28 ± 2.87	41.75	41.96 ± 3.82	41.20	0.549
Facial Axis (Degrees)	91.18 ± 0.91	91.25	91.12 ± 1.02	91.30	0.771
Convexity (mm)	2.32 ± 1.35	2.30	2.39 ± 1.38	2.15	0.818
ANB (Degrees)	3.11 ± 1.72	3.10	2.99 ± 1.61	3.05	0.138
FMA (Degrees)	38.77 ± 3.65	29.30	27.86 ± 4.56	27.55	0.144

Table V. *P-value of the differences between T0 and T1 of groups B and D: there are no statistically significant differences between the two groups B and D.*

Groups	**P-Value (Group B e Group D)**
Total Face Height (Degrees)	**0.376**
Lower Face Height (Degrees)	**0.548**
Facial Axis (Degrees)	**0.776**
Convexity (mm)	**0.744**
ANB (Degrees)	**0.243**
FMA (Degrees)	**0.153**

There were no statistically significant differences between T0 and T1 for any of the six measurements within each group B and D; the comparison between the groups also showed no statistically significant differences between T0 and T1. Analyzing the variations in measurements between T0 and T1, although there are no significant differences, a tendency towards an increase in the total facial height of the face (NBa-XiPm) is observed, more represented in group B compared to group D (respectively, in 70% of the cases in group B and 55% of the cases in group D), as well as the FMA angle, the increase of which appears to be significantly higher in group B (50% of the cases) compared to group D (25% of the cases). The lower face height (ANS-XiPm) increased in slightly different proportions for group B (30%) and group D (40%); as for the other measurements, they had a similar increase in proportion for the two groups B and D.

DISCUSSION

This study aimed to evaluate whether there are significant changes in terms of verticality after the palatal mediated by two different appliances, such as the Hyraxe and McNamara RPEs. According to our results, in agreement with other studies in the literature, no statistically significant differences were recorded for any of the variables considered, demonstrating the fact that the transverse expansion of the maxilla does not significantly influence the vertical dimensions of the face (11-14, 18) while providing adequate width augmentation not obtainable with other appliances (33).

The patients treated in our study with the Hyrax appliance (group B) did not record statistically significant changes between T0 and T1 for any variable considered. A tendency for an increase in the facial axis and facial convexity was found in 50% of cases, and an increase in the ANB angle in 30% of cases. Similarly, patients treated with the McNamara appliance (group D) did not record statistically significant changes between T0 and T1 for any variable considered. A tendency for an increase in the facial axis was found in 50% of cases and an increase in convexity in 45% of cases; the ANB angle increased in 30% of cases.

Although no statistically significant changes were recorded, observing the measurements at T0 and T1 compared between the two groups, it is possible to identify a different trend of change for some of the variables considered: the measurement that recorded the most differences between the two groups is the FMA angle, which increased in only 25% of cases in group D compared to an increase of 50% of cases in group B; there was also an increase in total facial height equal to 55% of cases in group D compared to an increase equal to 70% of cases for group B; the lower facial height recorded an increase of 40% of cases in group D and 30% in group B. Table VI reports the average variations recorded for each variable belonging to the two groups between T0 and T1.

Table VI. *Average changes in T1-T0 difference for each of the six variables expressed as an absolute number.*

Differences T1 – T0 (mean)	**BANDS (Group B) T0**	**SPLINTS (Group D) T0**
Total Face Height (Degrees)	0.07	0.86
Lower Face Height (Degrees)	0.30	0.32
Facial Axis (Degrees)	0.32	0.06
Convexity (mm)	0.41	0.07
ANB (Degrees)	0.80	0.12
FMA (Degrees)	0.63	0.91

An increase in the FMA angle describes a clockwise (posterior-inferior) rotation of the mandibular body. At the same time, its reduction indicates an anti-clockwise (anterior-superior) rotation (34); an increase in the FMA angle with a greater frequency in patients treated with the Hyrax RPE compared to the McNamara one shows that in the first case, there is a greater tendency for posterior-inferior rotation of the mandible. In contrast, in the second case, there is a greater tendency for its rotation to be in an antero-superior direction.

From the data analysis, it can be deduced that there is a greater preservation of the total height of the face after the expansion obtained using the McNamara RPE compared to the Hyrax one.

The explanation for this phenomenon can be attributed to the different characteristics of the two appliances, where the resin in the McNamara RPE performs its function as a "bite-block" on the teeth, limiting their extrusion (4, 10, 17). Furthermore, as the resin includes the occlusal table of the dental elements, it allows the elimination of pre-contacts of the palatine cusps in the expansion phase, which has been recognized as one of the main factors promoting an anti-clockwise rotation of the mandible (20, 22). The increase in the FMA angle with greater frequency in the group treated with Hyrax RPE is likely to be correlated to the dento-alveolar effects determined by the mechanics of the appliance, whose dental anchoring through the bands and the extension of the steel arms to the premolar region determines a vestibular-inclination of the lateral-posterior sectors (15).

The lower height of the face is a parameter that reflects the tendency to have an open or skeletal deep bite; therefore, its value must be kept within a normal range to obtain an ideal skeletal bite (2). In this study, no statistically significant differences in lower facial height were found, neither considering the inter-group changes between T0 and T1 nor comparing groups B and D, demonstrating that both appliances can guarantee the maintenance of a correct skeletal bite.

There are no uniform results in the literature regarding the changes in the vertical and sagittal planes that follow rapid palatal expansion. The variability in the results may be attributable to the timing in which the measurements were recorded during the orthodontic expansion treatment.

The rapid palatal expansion can be temporally divided into an active phase and a subsequent retention phase of variable duration, in which different movements of the maxillary and mandibular bone bases are observed: immediately after the active phase, there is a downward and forward movement of the maxilla due to the effect of the expansion on the craniofacial structures, associated with an increase in the vertical dimension as a consequence of mandibular postero-rotation (6, 19).

However, during the subsequent retention phase, long-term observations demonstrate a tendency towards a progressive return towards the initial position: during this phase, there is, therefore, only the preservation of the transverse component (16), whereas the changes on the vertical and sagittal plane are not significant (12, 14), in agreement with the present study.

The theory that the palatal expansion mediated by the two RPEs could influence the vertical and sagittal dimensions differently raised the hypothesis that choosing between one appliance or appliance was necessary depending on the patient's facial growth model. It is known that patients with dolichofacial growth patterns present a greater predisposition to an increase in the vertical component of the face compared to the brachyfacial one (34); therefore, greater control of verticality is essential to avoid a possible worsening of the facial profile following expansion orthodontic treatment.

The present study reports results in contrast with other authors in the literature, according to which the vertical dimension would be better controlled through the use of the RPE equipped with resin splints thanks to its "bite-block" action, therefore recommending its use in those patients with dolichofacial growth tendency (4, 10).

Considering the results of this study, the use of both appliances may be valid regardless of the patient's vertical conditions or facial growth pattern since the two appliances did not promote significant vertical cephalometric alterations, in agreement with other studies in the literature (11, 12).

The analysis of vertical changes in the present study was carried out on L-L teleradiographs, which involve intrinsic limiting factors such as magnification, overlap of anatomical structures, and distortion caused by the position of the head. The use of CBCT would have allowed the obtaining of a three-dimensional image on which to carry out more realistic measurements of skeletal changes without the limiting factors of magnification and distortion (3); however, CBCT does not provide additional clinical benefits for patients undergoing rapid palatal expansion orthodontic treatment alone, exposing such individuals to higher doses of ionizing radiation, and the related risks.

Another limitation of the present study is represented by the absence of a control group, which would have allowed us to determine the extent of the skeletal changes attributable to the effect of the orthodontic appliance or, otherwise, to the natural growth of the subject. However, the choice to include a control group would have resulted in unjustified exposure to ionizing radiation so that patients could obtain radiographic documentation at time T1 without having performed any treatment. However, since no statistically significant differences were found in the vertical changes of the patients, the absence of a control group is of relative importance.

A further limitation of the study is the choice to include only one operator who carried out the cephalometric tracings and related measurements. This methodological limit could have been reduced if the cephalometric tracings had been performed by independent operators, which is different from those involved in the study.

However, to overcome this limitation and achieve the highest possible degree of accuracy, the measurements were repeated 10 days later without the operator knowing the timing of the analyzed teleradiographs. In the coming years, better algorithms and new, fully automated methods of 3D comparison will probably be developed, making these measurements even more precise and dependable (35).

Finally, another limitation of the study is the small sample size. The search and selection of patients with relatively complete radiographic documentation significantly restricted the pool of suitable subjects who could be included in the present study. For a future study, it would therefore be desirable to include more subjects so that it can be considered more representative; furthermore, if a statistically significant difference in the increase in verticality is found immediately after the end of the expansion, it is advisable to carry out a follow-up at the end of the growth to evaluate the stability of the results in the long term. In patients undergoing palatal expansion, pre and post-endoscopic and polysomnographic evaluation would be interesting (36).

CONCLUSIONS

Based on the results of this clinical study, the conclusions are:

- Both the subjects treated with Hyrax and the McNamara RPEs showed a minimal increase in the vertical component.
- A trend, although not statistically significant, was recorded for greater maintenance of the verticality of the lower third of the face by the McNamara RPE compared to the Hyrax one.
- None of the 6 variables considered (Ricketts total facial height, lower facial height, facial axis, convexity, ANB angle, and FMA angle) showed statistically significant changes, both considering the variation of the measurements in T0 and T1 within each group and by comparing them between the two groups.

REFERENCES

1. Faccioni P, Sacchetto L, Sinigaglia S, et al. An improvement of upper airway flow in patients treated with rapid maxillary expansion: a Cone Beam Computed Tomography study. J Appl Cosmetol. 2023; 41(1 Supplement 1):99/106.
2. Conroy-Piskai C, Galang-Boquiren MTS, Obrez A, Viana MGC, Oppermann N, Sanchez F, Edgren B, Kusnoto B. Assessment of vertical changes during maxillary expansion using quad helix or bonded rapid maxillary expander. Angle Orthod. 2016; 86(6):925-33.
3. Habeeb M, Boucher N, Chung CH. Effects of rapid palatal expansion on the sagittal and vertical dimensions of the maxilla: a study on cephalograms derived from cone-beam computed tomography. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2013; 144(3):398-403.
4. Rozzi M, Alesi G, Mucedero M, Cozza P. Dentoskeletal effects of rapid maxillary expander therapy in early mixed dentition patients with different vertical growing patterns without posterior crossbite: A retrospective study. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2023; 163(3):319-27.
5. Asanza S, Cisneros GJ, Nieberg LG. Comparison of Hyrax and bonded expansion appliances. Angle Orthod. 1997; 67(1):15-22.
6. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2004; 126(5):569-75.
7. Akkaya S, Lorenzon S, Uçem TT. A comparison of sagittal and vertical effects between bonded rapid and slow

maxillary expansion procedures. Eur J Orthod. 1999; 21(2):175-80.
8. Bertossi D, Albanese M, Nocini R, Mortellaro C, Kumar N, Nocini PF. Osteotomy in Genioplasty by Piezosurgery. J Craniofac Surg. 2021; 32(3):e317-21.
9. Sarver DM, Johnston MW. Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1989; 95(6):462-6.
10. Maspero C, Galbiati G, Giannini L. Disgiuntore con bande vs disgiuntore bondato: effetti nei tre piani dello spazio. Il Dent Mod. 2012;
11. Lineberger MW, McNamara JA, Baccetti T, Herberger T, Franchi L. Effects of rapid maxillary expansion in hyperdivergent patients. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2012; 142(1):60-9.
12. Garib DG, Henriques JFC, Carvalho PEG, Gomes SC. Longitudinal effects of rapid maxillary expansion. Angle Orthod. 2007; 77(3):442-8.
13. Guest SS, McNamara JA, Baccetti T, Franchi L. Improving Class II malocclusion as a side-effect of rapid maxillary expansion: a prospective clinical study. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2010; 138(5):582-91.
14. Reed N, Ghosh J, Nanda RS. Comparison of treatment outcomes with banded and bonded RPE appliances. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1999; 116(1):31-40.
15. Garib DG, Henriques JFC, Janson G, Freitas MR, Coelho RA. Rapid maxillary expansion--tooth tissue-borne versus tooth-borne expanders: a computed tomography evaluation of dentoskeletal effects. Angle Orthod. 2005; 75(4):548-57.
16. D'Amico C, Alboretti C. Espansione Rapida Palatale: Terapia Del Deficit Trasversale Scheletrico Del Mascellare Superiore - Salute33. Salute33; 2021.
17. Mucedero M, Fanelli S, Rozzi M, Cozza P. Dento-skeletal response to three different protocols of rapid maxillary expansion in hyperdivergent growing subjects: a longitudinal retrospective study. Eur J Orthod. 2022; 44(5):578-87.
18. Farronato G, Giannini L, Galbiati G, Maspero C. Sagittal and vertical effects of rapid maxillary expansion in Class I, II, and III occlusions. Angle Orthod. 2011; 81(2):298-303.
19. Haas AJ. Rapid Expansion Of The Maxillary Dental Arch And Nasal Cavity By Opening The Midpalatal Suture. Angle Orthod. 1961; 31(2):73-90.
20. Baratieri C, Alves M, Sant'anna EF, Nojima M da CG, Nojima LI. 3D mandibular positioning after rapid maxillary expansion in Class II malocclusion. Braz Dent J. 2011; 22(5):428-34.
21. Maggiordomo A, Farronato M, Tartaglia G, Tarini M. A method based on 3D affine alignment for the quantification of palatal expansion. PLoS One. 2022; 17(12):e0278301. doi:10.1371/journal.pone.0278301
22. Wendling LK, McNamara JA, Franchi L, Baccetti T. A prospective study of the short-term treatment effects of the acrylic-splint rapid maxillary expander combined with the lower Schwarz appliance. Angle Orthod. 2005; 75(1):7-14.
23. Faccioni P, Butera A, Bazzanella S, Albanese M, Gallo S, Pascadopoli M, Scribante A, Pardo A. 3D Evaluation of Upper Airway Morphological Changes in Growing Patients with Class II Malocclusion Using Sander Bite Jumping Appliance. Appl Sci (Internet). 2023; 13(6). Available from: https://www.mdpi.com/2076-3417/13/6/3908
24. Faccioni P, De Santis D, Sinigaglia S, et al. Effects of the sander bite jumping appliance in patients with class ii malocclusion before growth peak. J Biol Regul Homeost Agents. 2020; 34(6 Suppl. 2):1-7.
25. McNamara Jr J, Brudon W. Orthodontics and dentofacial orthopedics. Ann Arbor: Needham Press; 2001.
26. Farronato G, Giannini L, Galbiati G, Maspero C. Comparison of the dental and skeletal effects of two different rapid palatal expansion appliances for the correction of the maxillary asymmetric transverse discrepancies. Minerva

Stomatol. 2012; 61(3):45-55.
27. Franchi L, Baccetti T, McNamara JA. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2000; 118(3):335-40.
28. Bucci R, D’Antò V, Rongo R, Valletta R, Martina R, Michelotti A. Dental and skeletal effects of palatal expansion techniques: a systematic review of the current evidence from systematic reviews and meta-analyses. J Oral Rehabil. 2016; 43(7):543-64.
29. Arrigoni R, Cammarota F, Porro R, et al. Natural Bioactive Compounds against Oxidative Stress: Dietary Polyphenols Strike Back. Endocr Metab Immune Disord Drug Targets. 2023; 23(6):764-76.
30. Ludovichetti FS, Zuccon A, Lucchi P, et al. Mothers' Awareness of the Correlation between Their Own and Their Children's Oral Health. Int J Environ Res Public Health. 2022; 19(22):14967. doi:10.3390/ijerph192214967
31. Pardo A, Baccini F, Manzoni D, et al. Removal of bacterial biofilm in patients undergoing fixed orthodontic treatment: a literature review. JAC. 2023; 41(1 Supplement 1):1/12. doi:https://doi.org/10.56609/jac.v41i1.267
32. Manuelli M, Marcolina M, Nardi N, et al. Oral mucosal complications in orthodontic treatment. Minerva Stomatol. 2019; 68(2):84-8.
33. Lucchese A, Nocini R, Tacchino U, et al. Invisalign appliance: aesthetic and efficiency. Minerva Stomatol. 2020; 69(6):329-34.
34. Schudy FF. Vertical Growth Versus Anteroposterior Growth As Related To Function And Treatment. Angle Orthod. 1964; 34(2):75-93.
35. Cassoni A, Manganiello L, Barbera G, Priore P, Fadda MT, Pucci R, Valentini V. Three-Dimensional Comparison of the Maxillary Surfaces through ICP-Type Algorithm: Accuracy Evaluation of CAD/CAM Technologies in Orthognathic Surgery. Int J Environ Res Public Health. 2022; 19(18):11834.
36. Gasparini G, Saponaro G, Todaro M, et al. Functional Upper Airway Space Endoscopy: A Prognostic Indicator in Obstructive Sleep Apnea Treatment with Mandibular Advancement Devices. Int J Environ Res Public Health. 2021; 18(5):2393.