AJDS ALAZHAR
Al-Azhar Journal of Dental Science
Vol. 21- No. 1- 27:35- January 2018
Record 1110-2624 | the ISSN Portal
portal.issn.org

RAPID ARCH EXPANSION IN CLEFT LIP AND PALATE CHILDREN: COMPARISON BETWEEN FAN-SHAPED EXPANDER AND HYRAX-TYPE EXPANDER BY USING CONE BEAM COMPUTED TOMOGRAPHY

Ahmed M. Sebaey*, Samy Y. El-Bayomy**, Abo Khalefa Y H Y *** *and* Abdel-Rahman I N ****

ABSTRACT

Purpose: The aim of the current study was to evaluate the skeletal and dentoalveolar effects of rapid palatal expansion (RPE) in children with cleft lip and palate (CLP) treated with 2 expanders. **Methods:** Twenty Egyptian children with complete unilateral or bilateral CLP exhibiting maxillary transverse deficiency were divided randomly into 2 groups according to the appliance used for expansion: **(A)** fan expander group and (**B)** hyrax expander group. Cone-beam computed tomography (CBCT) images were taken before and immediately after expansion procedure. **Results:** There was non-significant vertical movement of the maxilla for the 2 groups. On the transverse plane, there was more anterior expansion and posterior restriction for the fan group. However, the hyrax group showed significant posterior as well as anterior expansion. Both groups showed significant tipping between both sides posteriorly and anteriorly. Mandibular expansion was non-significant. **Conclusion:** Fan expander showed better results for children with cleft palate requiring anterior expansion only. Hyrax expander is better used for cases seeking for posterior and anterior expansion.

INTRODUCTION

Cleft lip and palate (CLP) is the most epidemic birth defect that affect the craniofacial series, disturbing the quality of life of more than 7 million people around the world [1,2] .Children with CLP have lip and alveolus repair surgeries during the first years of life and later, repairs to the soft and hard palates, affecting the development and growth of the maxillary arch which is compromised by scar tissues coupled with absence of the midpalatal suture inducing maxillary constriction in the anterior and posterior regions [3,4] .Consequently, rapid palatal expansion (RPE) is a common therapy used to correct this transverse deficiency, usually carried out at age 7-9 years before bone grafting which is used for replacing missing bone in the cleft alveolus (tooth bearing bone) [5] . RPE effects in non-cleft children are well documented in the literature [6-10]. However, the effects of RPE in CLP children seem to be different from those not registered for this deformity, probably due to variable anatomical structures [11,12]. Therefore, this anatomic variability in the maxillary arch has led to the development of maxillary expanders with alternative designs [13].

Among the appliances used for RPE in the CLP children, the fan-shaped and the hyrax-type expanders with only two points for anchorage. The main difference between them is the screw position and design.

Several investigations have analyzed the effects of RPE through 2D radiographs which do not allow accurate identification of dentoskeletal structures due to superimposition of many bones in the different planes of space. To overcome these drawbacks, Cone-Beam CT (CBCT) has ushered in a new era

* Dentist at Egypt Ministry of Health, Al-Azhar University, Assiut Branch.
** Professor and Head, Department of Pedodontics and Dental Public Health Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.
*** Lecturer, Department of Pedodontics and Dental Public Health Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.
**** Lecturer, Department of Orthodontics, Faculty of Dentistry, Ain shams university.

in dental diagnostics. This technology was designed for imaging hard tissues of the maxillofacial region with less distortion at a fairly lower cost and lower radiation emissions compared with conventional CT. The high resolution of CBCT images is due to the isotropic voxel which produces submillimeter resolution ranging from 0.4 mm to as low as 0.125 mm [14].

PATIENTS, MATERIALS AND METHODS

This prospective study carried out on 20 Egyptian children. All of them had complete unilateral or bilateral CLP, had undergone primary lip and palate repair surgeries at an earlier age, exhibiting maxillary transverse deficiency with an indication for rapid maxillary expansion ranging in age from 8 to 12 years (mean= 10 years).

The subjects were selected from the outpatient clinic of Orthodontic Department- Faculty of Dentistry- Ain Shams University, Cleft Care Clinic affiliated to the Oral and Maxillofacial Surgery Department- Faculty of Dentistry- Ain Shams University and the outpatient clinic of Oral and Maxillofacial Surgery Department- Sayed Galal Hospital.

The Inclusion criteria included: complete CLP, transverse anterior and or posterior maxillary deficiency, requiring palatal expansion prior to alveolar bone grafting surgery, and at the stage of mixed dentition. Exclusion criteria were: children with syndromic cleft lip and palate, bad oral hygiene, children above 14 years of age and who undergone previous orthodontic or orthopedic expansion [15].

Informed consent was obtained from the parents of all children who agreed to participate in this study after receiving a full explanation of the aim and design of this study. This study was approved by the ethical committee of Faculty of Dental Medicine, Al-Azhar University.

The subjects were distributed in a blocked randomized manner according to appliance used for expansion into 2 groups (10 children each). Group (A): 4 girls and 6 boys were received fan expander[*] (stainless steel expansion screw 9 mm.). Group (B): 6 girls and 4 boys were received hyrax expander[**] (stainless steel expansion screw 11 mm.). Both appliances were tooth borne, banded not bonded and used 2 contact points for anchorage. Anchor teeth in both appliances were the upper two first permanent molars instead of four because malalignment or missed teeth may make parallel insertion of the appliance on four anchor teeth difficult or impossible [16]. The extension arms were extended anteriorly up to the most anterior tooth in transverse crossbite (in most of cases, they were extended to the deciduous canine). The difference between the 2 appliances was the position and design of the screw. The fan screw was positioned in a more anterior position due to its greater volume while the hyrax screw was positioned just anteriorly to the first permanent molars. Both appliances were fabricated in the same laboratory by the same technician.

Each subject was scanned at two different time points: T1, before the delivery of the expander and T2, immediately after removal of the expander. For image acquisition, subjects were standing with their chin on chin support, wearing the lower vacuum retainer on their lower teeth to keep separation of the maxillary teeth from the mandibular teeth and the Frankfort horizontal plane was parallel to the ground. Each subject was asked to hold his or her breath after the end of expiration, without swallowing. This position is stable and has high reproducibility for measurement. The CBCT scans were performed at 90 kV, 14 mA, scan time of 20 seconds, with a single 360 rotations and 400 μm voxel size. The same technician captured all tomographic

---

Leone s.p.a. Ortodonzia e implantologia, Italy.
Leone s.p.a. Ortodonzia e implantologia, Italy.

scans using Planmecha ProMax* scanner at a private radiology center**. The data for each subject was reconstructed by the Planmecha Romexis*** imaging software and stored in (DICOM) format.

For evaluation of the effects of RPE, measurements were analyzed at T1 and T2 in the transverse and vertical planes of space. The vertical plane was assessed from lateral cephalogram obtained from CBCT. Transverse changes were assessed in the anterior and posterior regions of the maxilla. Posterior maxillary measurements were taken at the level of permanent 1st molar while the anterior measurements were taken at the level of the most anterior teeth supporting the appliance. CBCT images that were stored in DICOM format files were processed into volumetric images by using In Vivo 5 version 5.2 software****. A craniofacial customized analysis was created for this study. The following parameters were used for linear and angular measurements:

Transverse measurements:

A. Skeletal measurements *(17)*

1- Inter-jugale distance (**IJ**).

2- Nasal cavity width (**NCW**).

B. Dental measurement

1- Inter-crown distance (ICD) measured at 6 posteriorly and at the most tooth supporting appliance anteriorly, C or D or 4 (12).

2- Mandibular inter- crown distance (Mn IC) measured at 6 and 4 (18).

3- Inter-furcation distance (IFD) measured at 6 posteriorly and inter-comentoenamel junction (ICEJ) measured at C or D or 4 anteriorly.

4- Dental tipping angle (DTA) measured at 6 and C or D or 4 (19).

C. Alveolar measurements

1- Buccal maxillary width (BMW) measured at 6 and C or D or 4 (20).

Vertical measurements:

The changes in the vertical plane were assessed by using lateral cephalogram generated from CBCT, measuring the vertical distance between anterior nasal spine (ANS) and Frankfort horizontal line (FHL) (12).

Statistical Analysis:

All Data were collected, tabulated and subjected to statistical analysis. Statistical analysis was performed by IBM# SPSS## (version 17), also Microsoft office Excel was used for data handling and graphical presentation. The significance level was considered at $P < 0.05$ by paired t test.

Kolmogorov-Smirnova and **Shapiro-Wilk tests** of normality were used to test normality hypothesis of all quantitative variables for further choice of appropriate parametric and non-parametric tests.

Quantitative variables were described by the mean, standard Deviation (SD), the Range (Maximum – Minimum).

Paired sample t test was used for testing pre – post measurements within the same group, while independent sample t test was used for comparing the mean changes between the two groups.

Dahelberg Error and the Concordance Correlation Coefficient tests were used for the assessment of the reliability of measurements.

* PLANMECHA, ProMax, 3D Classic, Helsinki, Finland.
** Photon Scan, Abbas El-Akkad, Nasr City, Cairo, Egypt.
*** Planmecha Romexis viewer (version 4.4.2.R).
**** Anatomage, Sanjose, CA, USA.
# IBM Corporation, NY, USA.
SPSS, Inc, IBM Company.

RESULTS

A significant skeletal correction of the maxillary constriction was observed for both groups. There was no statistically significant difference regarding the skeletal measurement (maxillary basal bone and nasal cavity width) in either one of the 2 groups ($p > 0.05$) as shown in table (1). However, in the hyrax group, the amount of expansion increase for the basal bone (inter-jugale distance) was higher than that in the fan group.

Regarding the dental linear measurements, the results of inter-crown distance (ICD) showed statistically significant greater expansion in the anterior region for the fan group rather than the group of hyraxes ($p < 0.05$). On the other hand, there was a restriction in the posterior region for the fan group unlike the hyrax group that showed significant expansion posteriorly ($p < 0.01$) as shown in table (2).

There was no significant difference in mandibular inter- crown expansion between the 2 expanders. There were no statistically significant differences in the posterior or anterior regions of the lower teeth ($p > 0.05$) as shown in table (3).

Inter-furcation distance (IFD) posteriorly was found to be significant statistically as there is more expansion for the hyrax group unlike the group of the fan expander which presents more restriction as inter-crown ($p < 0.01$) while for the inter-comentoenamel junction (ICEJ), the expansion was found to be non-significant for the 2 groups ($P > 0.05$) as expansion occurs anteriorly as well (table 4).

Regarding the dental tipping, buccal inclination of the supporting teeth was found to be statistically significant for both groups especially in the anterior region as shown in table (5).

For the buccal maxillary width (BMW), it was significant for the posterior teeth to be expanded at the alveolar level for the hyrax group unlike the

Table (1): The results for the comparison between change in IJ and NCW measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
INTERJUGALE Distance	Group I (FAN)	1.54	0.62	-1.89	1.34	-1.41	0.18536	P > 0.05 Non-Significant
	Group II (HYRAX)	3.43	3.50					
NASAL cavity width	Group I (FAN)	1.12	1.38	-0.20	0.59	-0.33	0.74519	P > 0.05 Non-Significant
	Group II (HYRAX)	1.32	0.72					

TABLE (2): The results for the comparison between change in ICD posteriorly and anteriorly measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
POSTERIOR ICD	Group I (FAN)	0.33	1.78	-5.78	1.14	-5.08	0.00027	P < 0.001 Significant
	Group II (HYRAX)	6.11	2.43					
ANTERIOR ICD	Group I (FAN)	7.97	2.72	3.79	1.27	2.99	0.01128	P < 0.05 Significant
	Group II (HYRAX)	4.18	1.96					

TABLE (3): The results for the comparison between change in Mnd ICD posteriorly and anteriorly measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
MANDIBULAR POSTERIOR ICD	Group I (FAN)	0.09	0.56	-0.33	0.28	-1.18	0.26106	$P > 0.05$ Non-Significant
	Group II (HYRAX)	0.42	0.48					
MANDIBULAR ANTERIOR ICD	Group I (FAN)	-0.15	0.72	-0.10	0.37	-0.28	0.78450	$P > 0.05$ Non-Significant
	Group II (HYRAX)	-0.05	0.65					

TABLE (4): The results for the comparison between change in posterior IF and anterior CEJ measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
POSRERIOR IF	Group I (FAN)	0.13	0.88	-3.71	1.10	-3.38	0.00549	$P < 0.01$ Significant
	Group II (HYRAX)	3.84	2.77					
ANTERIOR CEJ	Group I (FAN)	4.99	1.79	1.31	0.96	1.36	0.19945	$P > 0.05$ Non-Significant
	Group II (HYRAX)	3.68	1.81					

TABLE (5): The results for the comparison between change in dental tipping angles measurements of both groups.

			Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
Dental Tipping Angle	RT POST	Group I (FAN)	-0.82	6.66	-10.18	2.90	-3.51	0.00430	$P < 0.01$ Significant
		Group II (HYRAX)	9.36	3.82					
	LT POST	Group I (FAN)	2.50	12.92	-3.02	4.75	-1.39	0.00671	$P < 0.01$ Significant
		Group II (HYRAX)	5.52	8.03					
	RT ANT	Group I (FAN)	19.99	10.47	13.33	4.35	3.07	0.00976	$P < 0.01$ Significant
		Group II (HYRAX)	6.66	4.76					
	LT ANT	Group I (FAN)	15.76	5.36	10.67	3.64	2.93	0.01257	$P < 0.05$ Significant
		Group II (HYRAX)	5.09	8.00					

TABLE (6): The results for the comparison between change in posterior and anterior BMW measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
Posterior Buccal Maxillary Width	Group I (FAN)	0.86	1.76	-3.32	0.88	-3.76	0.00271	P < 0.01 Significant
	Group II (HYRAX)	4.18	1.53					
Anterior Buccal Maxillary Width	Group I (FAN)	3.87	1.48	1.00	0.72	1.38	0.19128	P > 0.05 Non-Significant
	Group II (HYRAX)	2.86	1.21					

TABLE (7): The results for the comparison between change in vertical measurements of both groups.

		Mean	Std. Deviation	Mean Difference	Std. Error Difference	t	Probability	
Vertical Measurement	Group I (FAN)	-1.78	2.33	-2.16	1.10	-1.97	0.07275	P > 0.05 Non-Significant
	Group II (HYRAX)	0.38	1.73					

fan group, where the increase was non-significant ($p < 0.01$) while for the anterior teeth, there was no statistically difference between the 2 groups, it was non-significant ($p > 0.05$) as shown in table (6).

For the change in the vertical plane of the maxilla, it was found that no significant downward movement of the maxilla when the 2 expanders were used ($p > 0.05$) as shown in table (7).

DISCUSSION

Skeletal and dentoalveolar effects of RPE in growing children without oral clefts are well documented in the orthodontic literature [21]. On the other hand, there is a lack of clinical studies that evaluate orthodontic and orthopedic effects of expansion procedures in children with complete CLP especially by means of CBCT. The random use of CBCT for research purposes in the last years arose reservation regarding exposing patients to great doses of ionizing radiation with unnecessary risks. Moreover, the use of CBCT images in orthodontics is considered acceptable when there is a clinical benefit and rational doses are used. Furthermore, both American and European guidelines for CBCT use include the rehabilitation of CLP as one of the indications [21].

In this study, the skeletal effects of RPE by the fan and hyrax expanders groups were assessed. A significant skeletal correction of the maxillary constriction was observed for both groups. However, the amounts of skeletal expansion measured at the nasal cavity laterally (nasal cavity width) were not greater for the fan group when compared with the hyrax group (table 1).

The lower results obtained from the fan in comparison to the hyrax could be explained as the restrictive effect of the fan expander occurs only in the dentoalveolar area, it gradually decreases at the skeletal level.

On the other hand, a previous study carried out by Almeida et al [21] and they observed that, there is a decreasing expanding effect on the nasal cavity width with the main increase was 1.08 mm when they used hyrax and Haas expanders.

This finding contradicts that of Figueiredo et al.[12,22] They found that there was an increase at the posterior and anterior regions in nasal cavity width and there were no differences when both hyrax or inverted mini-hyrax were compared. Although, in a previous study, they stated that; fan, hyrax and inverted mini-hyrax expanders produced significant expansion in the nasal cavity, except in the anterior region when the inverted mini-hyrax was used. Their measurement depends on locating the palatal root apex of the right permanent 1st molar as a reference at the coronal slice from CBCT. At the same slice 2 landmarks were placed on the right and left lateral wall at the widest portion of the nasal cavity. Also, they had used the right central root apex as a reference for measurement of the anterior nasal cavity width. While in this study, the nasal cavity width was measured laterally as 3D volume using InVivo 5 version 5.2 software.

Another finding by Trindade-Suedam et al [23] had demonstrated the impact of RPE on the nasal cavity of children and showed that orthopedic expansion increases internal nasal dimensions in children with BCLP as well as UCLP when they used Haas and hyrax expanders.

The amount of transverse dental increase was measured by means of inter-crown distance. The inter-crown difference showed a statistically significant increase in both groups. For the fan group, there was more anterior expansion, while restricting intermolar transverse changes. However, for the hyrax group, there was almost even expansion both anteriorly and posteriorly.

This could be explained by the incorporation of a posterior hinge in the fan expander playing a role in restricting the posterior expansion, unlike the hyrax expander, where the jackscrew was directly connected to the bands of the anchorage teeth by a rigid stainless-steel framework.

Janson et al [24] also measured the inter-crown distance but they used the hyrax expander in comparison with the quad-helix appliance. Their results regarding the hyrax expander were the same of this study except that the anterior expansion was greater than the posterior.

In the study done by Figueiredo et al [12] the results of the hyrax group showed greater posterior expansion than the anterior while for the fan and inverted mini-hyrax groups, the results showed effective restriction in the posterior maxillary expansion.

The distance between inter-furcation posteriorly and inter cementoenamel junction anteriorly was measured as they were considered points of resistance giving an indication on the dental response to the expansion procedure, whether the teeth moved bodily or by tipping so that the amount of expansion increase was much lower than at ICD.

In subjects of the fan group, no bodily tooth movement occurs posteriorly while anteriorly, it was found to be significant, denoting anterior bodily tooth movement. However, for the hyrax group, the bodily movement of the teeth occurred both anteriorly and posteriorly as seen in (table 4).

In this study, in order to achieve accurate results, this measurement was considered due to almost incomplete root formation of the newly erupted permanent 1st molar in many of children treated in this study and nearly resorbed roots of the future exfoliated deciduous anterior teeth denoting there is no fixed reference at all.

While in other studies done for RPE in children with cleft, they measured the transverse width apically between posterior and anterior teeth apices which may be inaccurate due to previously mentioned reasons [11,12,22].

The mandibular inter-cuspal distance was measured to detect the effect of the palatal expansion procedures on the mandibular teeth. It was found that no mandibular trans-arch expansion both posteriorly and anteriorly or might be constriction and hence it was non-significant as seen in (table 3). There was a previous expectation that there would be an increase in the mandibular inter-cuspal distance due to dental compensation following maxillary arch expansion. However, this expectation was not confirmed and might be attributed to the lack of sufficient intercuspation between upper and lower teeth.

The dental tipping was measured to find out the amount of buccal or labial tipping posteriorly and anteriorly that occurred as a result of the expansion procedure. This would further confirm the results found by comparing ICD and IFD or CEJ that occurred with expansion.

In this study, both expanders caused some buccal or labial dental tipping, however, there were major differences in the amount of tipping generated by each expander.

The two expanders established greater anterior tipping than posterior. This could be explained by the increased rigidity of the fan and hyrax expanders obtained with first permanent molar bands and therefore, as the screw was activated, the bands provided resistance to inclination leading to less tipping posteriorly and more tipping anteriorly as the anterior supporting teeth were just connected by extended palatal arm as seen in (table 5).

Almeida et al [21] had concluded that RPE promoted significant buccal inclination at the maxillary permanent first molar with a mean increase of 6.87° and explained their results by the lateral rotation of the maxillary segments associated with more lateral displacement of the anchor tooth crown comparable to the movement of the apex.

This finding contradicts that of Almeida et al. [21] They had observed that there was a significant decreases of buccal bone plate thickness after RPE, however, the reducing changes were less than 1 mm and not clinically relevant.

No significant vertical movement of the maxilla was observed either by the fan expander or the hyrax expander groups. This pattern was similar to that reported by a Figueiredo et al. [12,22] These results also agree with the results of a previous study in children with CLP who had palatal expansion [12].

CONCLUSION

The following could be concluded from this study:

- Both fan and hyrax expanders were effective in transverse skeletal expansion of the maxillary base as well as the nasal cavity laterally.
- The hyrax expander exhibited significant buccal tooth movement (translation) and dental tipping between crowns of anterior and posterior teeth.
- The fan expander exhibited significant restriction posteriorly and dental tipping between crowns of only anterior teeth.
- There was no significant dental transverse increase in the lower arch.
- There was no significant vertical movement of the maxilla with RPE.

REFERENCES

1- Mossey P, Shaw W, Munger R, Murray J, Murthy J, Little J. Global oral health inequalities: challenges in the prevention and management of orofacial clefts and potential solutions. Adv Dent Res 2011; 23: 247-58.

2- IPDTOC Working Group. Prevalence at birth of cleft lip with or without cleft palate: data from the International Perinatal Database of Typical Oral clefts. Cleft Palate Craniofac J 2011; 48: 66-81.

3- Silva O, Ramos A, Abdo R. The influence of unilateral cleft lip and palate on maxillary dental arch morphology. Angle Orthod 1992; 62: 283-90.

4- Capelozza I, DeAlmeida A, Ursi W. Rapid maxillary expansion in cleft lip and palate patients. J Clin Orthod 1994; 28: 34-9.

5- Aizenbud D, Hafer T, Rachmiel A, Figueroa A, Joachims H, Laufer D. A possible ontological complication due to maxillary expansion in a cleft lip and palate patient. Cleft Palate Craniofac J 2000; 37: 416-20.

6- Weissheimer A, Menezes L, Mezomo M, Dias D, Lima E, Rizzatto S. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. Am J Orthod Dentofac Orthop. 2011; 140(3):366-76.

7- Garrett B, Caruso J, Rungcharassaeng K, Farrage J, Kim J, Taylor G. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofac Orthop. 2008; 134(1): 8-9.

8- Lione R, Ballanti F, Franchi L, Baccetti T, Cozza P. Treatment and post treatment skeletal effects of rapid maxillary expansion studied with low-dose computed tomography in growing subjects. Am J Orthod Dentofac Orthop. 2008; 134(3): 389-92.

9- Silva O, Boas M, Capelozza L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofac Orthop. 1991; 100(2): 171-9.

10- Haas A. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod. 1961; 31(2): 73-90.

11- Pan X, Qian Y, Yu J, Wang D, Tang Y, Shen G. Biomechanical effects of rapid palatal expansion on the craniofacial skeleton with cleft palate: a three-dimensional finite element analysis. Cleft Palate Craniofac J. 2007; 44(2): 149-54.

12- Figueiredo D, Bartolomeo F, Romualdo C, Palomo J, Horta C, Andrade I, et al. Dentoskeletal effects of 3 maxillary expanders in patients with clefts: a cone-beam computed tomography study. Am J Orthod Dentofac Orthop. 2014; 146(1): 73-81.

13- Oliveira D, Bartolomeo F, Cardinal L, Figueiredo D, Palomo J, Andrade I. An alternative clinical approach to achieve greater anterior than posterior maxillary expansion in cleft lip and palate patients. J Craniofac Surg. 2014; 25(6): 523-6.

14- Mah J, Yi L, Huang R, Choo H. Advanced applications of cone beam computed tomography in orthodontics. Semin Orthod. 2011; 17: 57-71.

15- Weissheimer A, Menezes L, Mezomo M, Dias D, Lima A, Rizzatto S. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders. Am J Orthod Dentofac Orthop 2011; 140: 368.

16- Howe R. Palatal expansion using a bonded appliance. Am J Orthod 1982; 82: 464-8.

17- Hakan E, Palomo J. Three-dimensional evaluation of upper airway following rapid maxillary expansion. A CBCT study. Angle Orthod 2014; 84: 267.

18- Handelman C, Wang L, BeGole E, Haas A. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. Angle Orthod 2000; 70: 129-44.

19- Wertz R. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970; 58: 41-66.

20- Garrett B, Caruso J, Rungcharassaeng K, Farrage J, Kim J, Taylor G. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofac Orthop. 2008; 134: 1-11.

21- Almeida A, Ozawa T, Alves A, Janson G, Lauris J, Ioshida M, et al. Slow versus rapid maxillary expansion in bilateral cleft lip and palate: a CBCT randomized clinical trial. Clin. Oral Invest. 2016; 6-9.

22- Figueiredo D, Cardina L, Bartolomeo F, Palomo J, Horta M, Oliveira D, et al. Effects of rapid maxillary expansion in cleft patients resulting from the use of two different expanders. Dent Press J Orthod. 2016; 2-8.

23- Trindade-Suedam I, Castilho R, Sampaio-Teixeira A, Araujo B, Fukushiro A, Campos L, et al. Rapid maxillary expansion increases internal nasal dimensions of children with bilateral cleft lip and palate. Cleft Palate-Craniofac J. 2015; 52: 4.

24- Janson G, Alves A, Garib D, Calil L, Almeida A. Analysis of the dentoalveolar effects of slow and rapid maxillary expansion in complete bilateral cleft lip and palate patients: a randomized clinical trial. Clin Oral Invest. 2016; 20: 1837-47