ORIGINAL ARTICLE

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Dentoskeletal effects of 3 maxillary expanders in patients with clefts: A cone-beam computed tomography study

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Introduction: The purpose of this study was to evaluate the skeletal and dental changes in the maxillae of patients with clefts treated with 3 expanders: hyrax, fan-type, and inverted mini-hyrax supported on the first premolars. **Methods:** Thirty patients with unilateral cleft lip and palate with transverse maxillary deficiency were divided into 3 groups, according to the type of expander that they used. Cone-beam computed tomography images were taken before and 3 months after expansion, and the paired *t* test was used to evaluate the changes in each group. **Results:** The subjects in the inverted mini-hyrax group showed significant forward displacement of the maxilla ($P < 0.05$). On the transversal plane, the hyrax group showed greater expansion in the posterior region than in the anterior region ($P < 0.05$). However, the fan-type and the inverted mini-hyrax groups showed significantly greater maxillary expansion anteriorly than posteriorly ($P < 0.05$). There was a greater tendency for buccal inclination of the supporting teeth when the fan-type was used. The cleft and the noncleft sides expanded symmetrically with all appliances, and there was no difference in dental tipping between these sides ($P > 0.05$). **Conclusions:** The hyrax expander showed better results for cleft patients requiring anterior and posterior maxillary expansion. The inverted mini-hyrax most effectively restricted posterior expansion, optimizing anterior expansion without causing as much buccal tipping of the supporting teeth as did the fan-type. (Am J Orthod Dentofacial Orthop 2014;146:73-81)

Cleft lip and palate (CLP) is the most prevalent among all craniofacial anomalies, affecting one in every 700 births[1] and disturbing the quality of life of more than 7 million people around the world.[2] Patients with CLP have lip and alveolus repair surgeries during the first years of life and, later, repairs to the hard and soft palates. As a consequence, the growth and development of the maxillary segments are compromised by scar tissues, thus inducing maxillary constriction, particularly in the anterior region.[3,4] Rapid maxillary expansion (RME) is commonly used to correct this transverse deficiency. Often, the goal of RME for many cleft patients has been to increase the anterior maxillary expansion and restrain the posterior expansion, since there is a greater anterior than posterior maxillary constriction in most of these patients.[5,6]

Alternative RME appliances have been used to enhance the expansion in the anterior region of the maxillary arch.[5-9] However, no studies have confirmed this benefit in cleft patients, and only clinical observations have been described in some case reports.[5,6] Therefore, imaging studies are required to confirm or refute the effectiveness of these alternative expanders in enhancing anterior maxillary expansion in CLP patients and to confirm their actual dentoskeletal effects.

Therefore, the aim of this study was to evaluate the dentoskeletal effects of 3 maxillary expanders: the conventional hyrax and 2 modified types, especially designed to promote anterior expansion of the maxillary

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Table I. Distribution of age, sex, and cleft side

	Age (y)		*Sex*		*Cleft side*	
Group	*Mean*	*SD*	*Male*	*Female*	*Right*	*Left*
Hyrax	11.3	2.4	7	3	4	6
Fan-type	10.5	1.8	6	4	2	8
Inverted mini-hyrax	12.3	2.3	3	7	4	6

arch. The null hypothesis to be tested was that there are no differences in the type and amount of expansion with these 3 appliances.

MATERIAL AND METHODS

Approval for this study was obtained from the institutional review board of the Pontifical Catholic University of Minas Gerais, Brazil. Signed informed consents were obtained from all patients and their parents. The study sample comprised 30 children (16 boys, 14 girls) with unilateral CLP (UCLP) who sought orthodontic treatment at the center for treatment of craniofacial anomalies at this university. The selection criteria included UCLP, need for maxillary expansion, and no previous orthodontic intervention. The exclusion criteria were any additional craniofacial syndrome, no maxillary permanent first molars, deciduous molars or canines with accentuated mobility, and active periodontal disease. Each patient's stage of cervical vertebral maturation was assessed; all patients were before or at the growth spurt (CS1-CS4).[10]

The subjects were distributed into 3 groups (10 patients each), according to the extension of the maxillary deficiency. The subjects with anterior and posterior maxillary deficiency received the hyrax expander. The ones with only anterior maxillary deficiency were treated with either the fan-type or the inverted mini-hyrax expander. Because of the characteristics of the inverted mini-hyrax expander, only patients with fully erupted first premolars were included in this group. The sex and age distributions for all groups are shown in Table I. The hyrax is a tooth-borne appliance with a jackscrew (Leone Orthodontics and Implantology, Firenze, Italy) located mesial to the maxillary permanent first molars (Fig 1, *A*). The fan-type expander is a tooth-and-tissue borne appliance with a jackscrew and a posterior hinge (Morelli Ortodontia, Sorocaba, Brazil) located in the region of the permanent first molars (Fig 1, *B*). The inverted mini-hyrax is a tooth-borne appliance constructed with a mini-hyrax screw (Dynaflex, Saint Ann, Mo) positioned in the anterior region, with its arms bent posteriorly and soldered to the first premolar bands bilaterally. It was used with a transpalatal arch (TPA) inserted at the permanent first molars (Fig 1, *C*). The same laboratory technician fabricated all expanders.

A pretreatment (T0) cone-beam computed tomography (CBCT) scan, rather than conventional radiographs, was obtained as part of the patients' initial orthodontic records. Each expander was cemented with a fluoride-releasing cement (Ultra Band-Lok; Reliance Orthodontic Products, Itasca, Ill), and the activation regimen was established at 2 turns per day until the tip of the lingual cusps of the maxillary teeth touched the tips of the buccal cusps of the mandibular teeth. After the 3-month retention period, the expander was removed, a postexpansion (T1) CBCT scan was acquired, and a TPA with anteriorly extending arms was immediately inserted to serve as a retainer until the next phase of orthodontic treatment. Obtaining the CBCT at T1 was justified because of its importance for adequate secondary bone graft surgical planning.

The same radiology technician captured all tomographic scans using an i-CAT machine (Imaging Sciences International, Hatfield, Pa). The scans were performed at 120 kV, 8 mA, scan time of 40 seconds, and 0.3-mm voxel dimension. All CBCT images were oriented and standardized using Dolphin software (version 11.5; Dolphin Imaging & Management Solutions, Chatsworth, Calif). The images of each patient's head were oriented in all 3 planes of space for frontal, right lateral, and top (facing down) views. In the frontal view of reconstruction orientation, the axial plane should coincide with the right and left frontozygomatic sutures. In the right lateral view, the axial plane must coincide with the Frankfort horizontal plane. In the top view, the midsagittal plane should coincide with the line connecting crista galli and basion.

The RME effects were examined to compare the measurements made at T0 and T1 in all 3 planes of space. The changes in the anteroposterior plane were assessed using the SNA angle measured in the lateral cephalograms obtained from the CBCT scans. The variations in the vertical plane were analyzed using CBCT sagittal slices, measuring the lesser distance between the Frankfort horizontal line and the anterior nasal spine (Fig 2). The effects on the transverse dimension were evaluated with axial and coronal cuts. The transverse posterior maxillary measurements were registered on the permanent first molars, and the transverse anterior measurements were recorded at the level of the most anterior appliance-supporting teeth. When the roots were used as a reference, the palatal roots were selected for both molars and premolars. The following parameters were used to quantify the transverse changes.

Fig 1. Rapid maxillary expanders tested: **A,** hyrax; **B,** fan-type; **C,** inverted mini-hyrax.

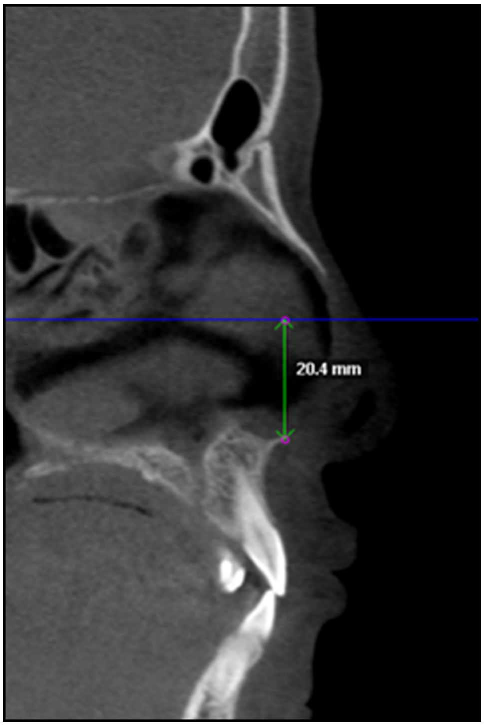

Fig 2. Vertical measurement: sagittal slice showing the Frankfort horizontal line to anterior nasal spine.

1. Dental crown width (DCW): the transverse width at the coronal slices between the most prominent lingual area of the right and left posterior (Pt-DCW) and anterior (At-DCW) teeth (Fig 3, *A*). The actual landmarks could be slightly different at different times because of the inclination of the teeth during treatment.
2. Maxillary basal width (MBW): the maxillary right first molar was identified at the axial slice. A landmark was placed in the center of the palatal root canal at the level of root separation. In the same slice, another landmark was placed in the root canal of the most anterior appliance-supporting tooth. The same procedure was performed on the left side. A line between the 2 landmarks in the posterior teeth determined the posterior MBW (Pt-MBW). A second line connecting the landmarks in the anterior teeth determined the anterior MBW (At-MBW) (Fig 3, *B*).
3. Dental apices width (DAW): the transverse width at the coronal section between posterior teeth apices (Pt-DAW) and between anterior teeth apices (At-DAW) (Fig 3, *A*).
4. Nasal cavity width (NCW): To measure the posterior NCW (Pt-NCW), the palatal root apex of the right permanent first molar was located at the coronal section. In the same slice, a landmark was placed on the right lateral wall at the widest portion of the nasal cavity. Using a line parallel to the floor passing through the first landmark, a second landmark was placed on the left lateral wall of the nasal cavity. The Pt-NCW was defined as the distance between these 2 points. The procedure was performed for the nasal width at the anterior region (At-NCW), using the right anterior tooth root apex as a reference (Fig 3, *A*).
5. Dental tipping (Tip): at the coronal section, 2 lines were used to calculate the tipping angle. The first line was perpendicular to the axial plane passing through the root apex. The second line was drawn passing through the palatal cusp tip and the palatal root apex. Dental tipping was obtained at the right and left sides of the posterior (Pt-Tip) and anterior (At-Tip) teeth (Fig 3, *C*). Even using the root apex for this measure, the root resorption of the deciduous teeth was not considered because of the short time between T0 and T1. Furthermore, RME does not influence the rate of resorption of deciduous teeth used as anchorage.[11]

To evaluate which maxillary segment was expanded more, the same landmarks described for the MBW measurement were used. A midsagittal line connecting crista galli and basion was defined as the reference line. In the axial slice, the lesser distance from this

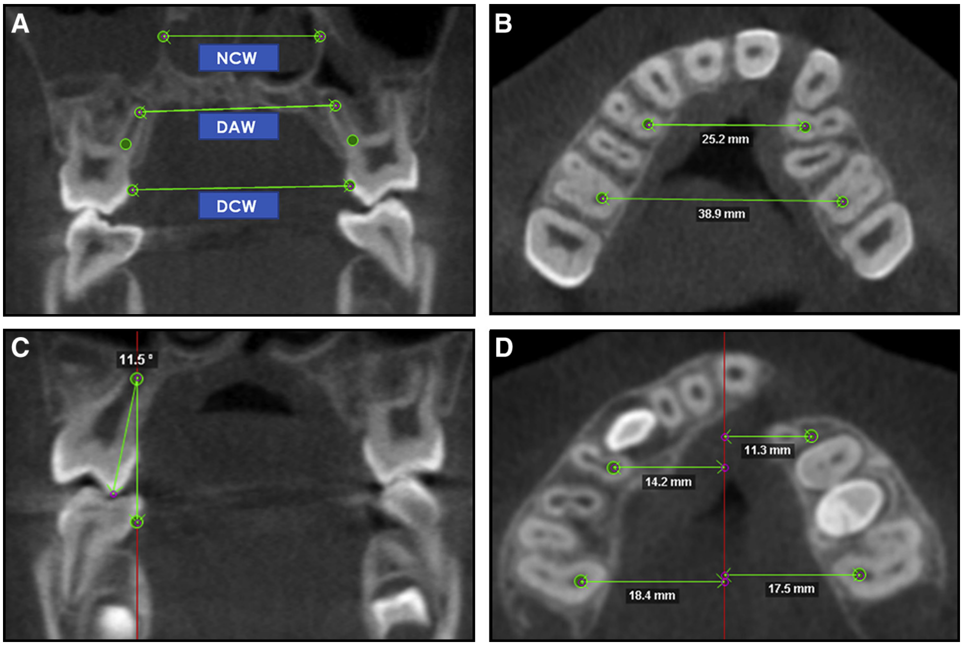

Fig 3. Transversal measurements. **A,** Coronal slice showing DCW, DAW, and NCW. The same procedure was performed for the anterior appliance-supported teeth. **B,** Axial slice showing At-MBW and Pt-MBW. **C,** Coronal slice showing posterior tipping. The same procedure was performed for the cleft and noncleft sides in the posterior and anterior regions. **D,** Measurements of lateral displacements between the cleft and noncleft sides (*right*, cleft side; *left*, noncleft side).

midsagittal line to the 4 MBW landmarks was measured (Fig 3, *D*).

Statistical analysis

The same operator (D.S.F.F.), who was blinded to the group status, made all measurements. To test intraexaminer reproducibility, the same examiner reassessed the raw images and remeasured 18 random images at least 1 week later, and the results were compared with the original measurements. The intraexaminer reliability values were determined using the intraclass correlation coefficient, which varied between 0.98 and 0.99, indicating high reproducibility of the measurements.

Descriptive statistics, including means and standard deviations, were calculated for all measurements. The paired *t* test was used to evaluate whether the changes from T0 to T1 were significantly different in each group. The paired *t* test was also used to evaluate differences in transverse changes between the anterior and posterior regions for each expander and differences in alveolar expansion and dental tipping between the cleft and noncleft sides. The data obtained from all measurements were processed with GraphPad software (version 5.01; GraphPad Software, La Jolla, Calif). The level of significance for all statistical tests was predetermined at 5%.

RESULTS

There was no statistically significant movement of the maxilla in either the vertical or the anteroposterior plane ($P > 0.05$) when the hyrax and fan-type appliances were used. However, in the inverted mini-hyrax group, a significant forward maxillary displacement ($P < 0.05$) was registered, as shown in Tables II through IV.

All expanders increased the anterior region of the maxilla transversely, but the fan-type and the inverted mini-hyrax restricted the posterior expansion.

The results of the 3 groups showed statistically significant expansion in the anterior maxilla ($P < 0.05$), as seen with the DCW, MBW, and DAW measurements in Tables II through IV.

The comparison between the anterior and posterior regions showed that the hyrax caused significantly greater posterior than anterior expansion ($P < 0.05$). However, both the fan-type and the inverted mini-hyrax groups showed significantly greater amounts of expansion in the anterior region of the maxillary arch ($P < 0.05$), as shown in Table V.

Despite the restriction of posterior expansion, compared with anterior expansion, there was still significant posterior expansion from T0 to T1 in the fan-type group (except DAW; Table III). However, there were

Table II. Comparison of the maxillary dimensions at T0 and T1 in the hyrax group

Measurement	*T0* Mean	*T0* SD	*T1* Mean	*T1* SD	*Mean of difference (T1−T0)*	P *value*	*95% CI*
Anteroposterior							
SNA (°)	81.77	6.68	81.75	4.96	−0.02	NS	−1.86 to 1.82
Vertical							
FH-ANS (mm)	17.13	2.19	17.86	1.96	0.73	NS	−0.69 to 2.15
Transverse							
Anterior maxilla							
DCW (mm)	19.65	2.62	24.34	3.59	4.69	<0.05	3.76 to 5.62
MBW (mm)	25.95	2.35	29.80	3.05	3.85	<0.05	2.70 to 5.00
DAW (mm)	26.84	2.65	29.64	3.91	2.80	<0.05	1.45 to 4.14
NCW (mm)	25.15	3.17	26.74	2.87	1.59	<0.05	1.01 to 2.16
Dental tip CS (°)	−3.73	14.88	0.21	14.19	3.94	NS	−3.31 to 11.19
Dental tip NCS (°)	3.99	9.12	12.50	8.17	8.51	<0.05	3.29 to 13.73
Posterior maxilla							
DCW (mm)	30.47	2.20	35.20	2.53	4.73	<0.05	3.92 to 5.53
MBW (mm)	38.15	2.59	42.49	2.63	4.34	<0.05	3.49 to 5.18
DAW (mm)	29.74	3.33	33.49	2.61	3.75	<0.05	2.73 to 4.76
NCW (mm)	29.41	2.85	31.28	2.67	1.87	<0.05	0.80 to 2.94
Dental tip CS (°)	13.02	4.57	13.82	5.12	0.80	NS	−0.27 to 1.87
Dental tip NCS (°)	11.37	3.17	13.74	4.55	2.37	<0.05	0.27 to 4.46

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$); *CS*, cleft side; *NCS*, noncleft side.

virtually no posterior dental changes in the inverted mini-hyrax group ($P > 0.05$), as shown in Table IV (DCW and DAW).

The fan-type group showed statistically significant ($P < 0.05$) buccal inclinations of the supporting teeth on both sides, particularly in the anterior region (Table III), and the hyrax group showed this only on the noncleft side (Table II). Conversely, the inverted mini-hyrax group showed no significant ($P > 0.05$) supporting tooth inclinations in either region of the maxilla (Table IV).

There were no significant differences ($P > 0.05$) in the amount of expansion when the cleft and noncleft sides were compared in each group (Table VI). Furthermore, when we evaluated the 30 patients together, we observed no significant differences ($P > 0.05$) between the cleft and noncleft sides (Table VI). There were also no significant differences ($P > 0.05$) in dental tipping between the cleft and noncleft sides (Table VII).

DISCUSSION

Despite previous reports on alternative maxillary expanders especially designed for cleft patients,[5,6] the conventional hyrax appliance remains one of the most widely used expanders for these patients around the world. This might be due to the lack of clinical trials evaluating the effects of conventional and nonconventional expanders in patients with clefts. Improving the knowledge of the dentoskeletal effects of RME with different expanders in cleft patients might indicate ways to customize the expansion therapy to each patient's needs. Thus, the aim of this study was to use CBCT to evaluate the effects of 3 maxillary expanders in UCLP patients: hyrax, fan-type, and inverted mini-hyrax. In this study, we also addressed the following questions of clinical interest. Would the fan-type or the inverted mini-hyrax be more effective in achieving greater anterior maxillary expansion and restricting posterior expansion than the conventional hyrax appliance? Do the cleft and the noncleft sides expand symmetrically?

Based on previous studies with CBCT images in noncleft patients who underwent RME,[12-17] our investigation had some important features: (1) it was a prospective clinical trial, (2) the procedures were performed on growing patients with clefts, and (3) the stage of cervical vertebral skeletal maturation was assessed in all patients.

All subjects received RME treatment before or during the pubertal growth spurt (cervical maturation stage varied from CS1 to CS4). Patients treated before and during the pubertal growth peak exhibited more effective skeletal changes than did those treated after the growth spurt.[18] There was no untreated control group because of ethical concerns of not providing ideal care at the appropriate time to patients who already had a significantly compromised quality of life.

Our results indicated no significant forward movement of the maxilla in either the hyrax or the fan-type

Table III. Comparison of the maxillary dimensions at T0 and T1 in fan-type group

	T0		*T1*				
Measurement	*Mean*	*SD*	*Mean*	*SD*	*Mean of difference (T1−T0)*	P *value*	*95% CI*
Anteroposterior							
SNA (°)	80.00	5.12	79.53	4.85	−0.47	NS	−2.31 to 1.36
Vertical							
FH-ANS (mm)	3.03	4.28	3.17	4.40	0.14	NS	−0.01 to 0.29
Transverse							
Anterior maxilla							
DCW (mm)	21.09	2.36	27.20	4.49	6.11	<0.05	3.71 to 8.50
MBW (mm)	26.54	2.04	30.87	3.47	4.33	<0.05	2.38 to 6.28
DAW (mm)	26.61	3.45	27.84	3.55	1.23	<0.05	0.62 to 1.84
NCW (mm)	26.99	2.76	28.81	2.31	1.82	<0.05	0.37 to 3.27
Dental tip CS (°)	−5.93	11.17	12.47	10.75	18.40	<0.05	6.80 to 30.00
Dental tip NCS (°)	−1.75	10.75	12.15	10.02	13.90	<0.05	6.41 to 21.39
Posterior maxilla							
DCW (mm)	32.46	3.38	35.62	2.67	3.16	<0.05	2.17 to 4.15
MBW (mm)	39.95	2.99	42.72	2.09	2.77	<0.05	1.68 to 3.86
DAW (mm)	30.64	2.06	31.65	1.59	1.01	NS	−0.28 to 2.30
NCW (mm)	30.38	2.84	31.89	2.94	1.51	<0.05	0.67 to 2.34
Dental tip CS (°)	13.98	6.33	17.64	4.61	3.66	<0.05	0.47 to 6.84
Dental tip NCS (°)	13.29	3.34	17.00	4.23	3.71	<0.05	1.52 to 5.90

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$); *CS*, cleft side; *NCS*, noncleft side.

group. These findings agree with the results of a previous study in patients with clefts who had maxillary transverse expansion.[19] However, these results are not in agreement with those previously reported for noncleft patients.[9,20-22] Conversely, there was a statistically significant increase in the SNA angle of patients treated with the inverted mini-hyrax, but this increase might not be clinically significant, especially with more severe anteroposterior discrepancies (Table IV). No significant vertical movement of the maxilla was observed, contrasting with previous reports of downward maxillary displacement for noncleft patients.[9,20,21,23,24] Therefore, these findings might suggest that the anatomic differences of the maxilla in patients with clefts or the variations in expander design induced a slightly different spatial response of the maxilla.

The maxillary arch of patients with clefts commonly has atresia limited to the anterior region.[3,4] Thus, these patients would benefit from the use of a maxillary expander that favors intercanine and interpremolar expansion, while restricting intermolar transverse changes. Both the fan-type and the inverted mini-hyrax were designed for this purpose. Our study is the first prospective clinical trial that used CBCT to confirm or refute whether these alternative expanders generated such effects. Overall, all groups had significant anterior dental expansions. However, the posterior transverse changes markedly varied among the groups.

The results of the hyrax group showed greater posterior than anterior maxillary expansion. Conversely, the findings from subjects who used the fan-type and the inverted mini-hyrax showed effective restrictions in the posterior expansion of the maxilla. These findings confirm the clinical impressions of previous reports, indicating that the incorporation of a posterior hinge in the expander has a positive effect in restricting posterior expansion and can be useful in patients who require only anterior expansion.[5-9] However, our results showed that a TPA cemented to the permanent first molars with the inverted mini-hyrax expander was the most effective approach to limit posterior transverse changes in the maxilla while expanding it anteriorly. These differences between the fan-type and the inverted mini-hyrax might be explained by the greater rigidity of the TPA when compared with the smaller structure of the posterior hinge that was added to the acrylic pads of the fan-type appliance.

All appliances produced significant expansion in the nasal cavity, except in the anterior region when the inverted mini-hyrax was used. This exception was inconsistent with our expectations, since we thought this restriction would take place in the posterior nasal cavity because of the rigidity of the TPA. However, these results might suggest that the restrictive effect of the fan-type hinge or the TPA occurs only in the dentoalveolar area, gradually decreasing at the skeletal level. This can be

Table IV. Comparison of the maxillary dimensions at T0 and T1 in the inverted mini-hyrax group

Measurement	T0 Mean	T0 SD	T1 Mean	T1 SD	Mean of difference (T1−T0)	P value	95% CI
Anteroposterior							
SNA (°)	79.38	5.27	80.54	4.71	1.16	<0.05	0.16 to 2.17
Vertical							
FH-ANS (mm)	6.54	9.17	6.24	8.42	−0.30	NS	−0.91 to 0.31
Transverse							
Anterior maxilla							
DCW (mm)	23.32	2.17	27.26	2.50	3.93	<0.05	2.78 to 5.08
MBW (mm)	28.69	3.07	31.98	3.96	3.28	<0.05	1.94 to 4.63
DAW (mm)	29.50	3.80	32.38	5.16	2.87	<0.05	1.01 to 4.74
NCW (mm)	31.34	3.47	31.94	3.39	0.60	NS	−0.81 to 2.01
Dental tip CS (°)	−10.00	12.92	−7.68	17.74	2.31	NS	−4.06 to 8.68
Dental tip NCS (°)	−1.98	13.08	−0.96	12.65	1.02	NS	−3.24 to 5.28
Posterior maxilla							
DCW (mm)	34.83	2.71	35.20	2.38	0.36	NS	−0.11 to 0.84
MBW (mm)	42.39	3.38	42.70	3.22	0.31	<0.05	0.07 to 0.54
DAW (mm)	32.34	6.02	32.44	3.78	0.10	NS	−3.11 to 3.31
NCW (mm)	32.50	4.82	33.49	4.44	0.98	<0.05	0.43 to 1.54
Dental tip CS (°)	15.46	7.85	14.37	6.85	−1.08	NS	−3.16 to 0.98
Dental tip NCS (°)	13.26	4.91	12.44	5.87	−0.81	NS	−2.98 to 1.35

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$); *CS*, cleft side; *NCS*, noncleft side.

Table V. Transverse changes (mm) between the anterior and posterior regions for each expander

Expander	Measurement	Anterior maxilla Mean	Anterior maxilla SD	Posterior maxilla Mean	Posterior maxilla SD	Mean of difference (At−Pt)	P value	95% CI
Hyrax	DCW	4.69	1.26	4.73	1.09	−0.04	NS	−0.69 to 0.61
	MBW	3.85	1.56	4.34	1.14	−0.49	<0.05	−1.09 to 0.11
	DAW	2.80	1.83	3.75	1.37	−0.95	<0.05	−2.29 to 0.39
	NCW	1.59	0.77	1.87	1.45	−0.28	NS	−1.14 to 0.58
Fan-type	DCW	6.11	3.26	3.16	1.35	2.95	<0.05	1.18 to 4.71
	MBW	4.33	2.64	2.77	1.48	1.56	<0.05	0.18 to 2.93
	DAW	1.23	0.82	1.01	1.75	0.22	NS	−0.72 to 1.16
	NCW	1.82	1.96	1.51	1.13	0.31	NS	−1.42 to 2.04
Inverted mini-hyrax	DCW	3.93	1.44	0.36	0.60	3.56	<0.05	2.11 to 5.01
	MBW	3.28	1.69	0.31	0.29	2.97	<0.05	1.53 to 4.43
	DAW	2.87	2.35	0.10	4.05	2.77	<0.05	−0.52 to 6.07
	NCW	0.60	1.78	0.98	0.70	−0.38	NS	−1.75 to 0.97

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$).

clinically relevant because even when using an appliance designed to restrain posterior dentoalveolar expansion, it was still possible to increase nasal cavity width and obtain the associated benefits such as an airway increase, which is important in patients with CLP.[25]

All expanders caused some buccal dental tipping, which was expected since the forces were applied occlusally from the center of resistance of the supporting teeth. However, there were major differences in the amounts of tipping generated by each appliance. There were approximately a 5:1 ratio between crown and apex expansion on the anterior appliance-supported teeth in the fan-type group and a 1.5:1 ratio for the inverted mini-hyrax. This remarkable difference might be due to the increased rigidity of the inverted mini-hyrax obtained with premolar bands. As the screw was activated, the bands might have provided resistance to inclination, leading to greater bodily buccal movement.[12] Thus, probably if the hyrax and fan-type were 4-band appliances, the inclination of the anterior anchorage teeth would be lower than was found in this study. But even so, we believe that the design of the fan-type

Table VI. Cleft side and relative alveolar expansion (mm)

Expander	Maxillary region	CS expansion		NCS expansion		Mean of difference (CS−NCS)	P value	95% CI
		Mean	SD	Mean	SD			
Hyrax (n = 10)	Anterior	2.00	1.43	1.83	1.25	0.17	NS	−1.37 to 1.75
	Posterior	2.87	2.80	1.83	0.87	1.04	NS	−1.45 to 3.52
Fan-type (n = 10)	Anterior	2.23	1.74	2.04	1.15	0.19	NS	−0.73 to 1.11
	Posterior	1.28	1.21	1.41	0.46	−0.13	NS	−0.85 to 0.59
Inverted mini-hyrax (n = 10)	Anterior	1.88	1.47	1.47	1.63	0.41	NS	−1.55 to 2.38
	Posterior	0.18	1.09	0.16	1.17	0.02	NS	−1.69 to 1.73
All groups (n = 30)	Anterior	2.04	1.50	1.79	1.32	0.25	NS	−0.50 to 1.00
	Posterior	1.49	2.14	1.16	1.09	0.32	NS	−0.60 to 1.24

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$); *CS*, cleft side; *NCS*, noncleft side.

Table VII. Cleft side and relative dental tipping

Expander	Maxillary region	Dental tip CS (°)		Dental tip NCS (°)		Mean of difference (NCS−CS)	P value	95% CI
		Mean	SD	Mean	SD			
Hyrax (n = 10)	Anterior	3.94	10.14	8.51	7.29	4.57	NS	−2.89 to 12.04
	Posterior	0.80	1.50	2.37	2.92	1.57	NS	−0.38 to 3.52
Fan-type (n = 10)	Anterior	18.40	16.22	13.90	10.47	−4.50	NS	−14.51 to 5.50
	Posterior	3.66	4.44	3.71	3.06	0.05	NS	−1.84 to 1.94
Inverted mini-hyrax (n = 10)	Anterior	2.31	8.29	1.02	5.55	−1.28	NS	−8.75 to 6.17
	Posterior	−1.08	2.69	−0.81	2.82	0.27	NS	−2.21 to 2.76
All groups (n = 30)	Anterior	8.42	13.85	8.04	9.45	−0.37	NS	−4.87 to 4.12
	Posterior	1.20	3.61	1.85	3.41	0.64	NS	−0.44 to 1.73

P values were obtained by paired *t* test.
NS, Not significant ($P > 0.05$); *CS*, cleft side; *NCS*, noncleft side.

appliance might contribute to the excessive inclination, since the hyrax was also a 2-band appliance rather than a 4-band appliance and had considerably less inclination than did the fan-type. Furthermore, the reduced size of the screw used in the inverted mini-hyrax allowed a more apical placement of the expander in the palate; thus, the force applied with this appliance was closer to the center of resistance of the anterior supporting teeth than when the fan-type was used.[26]

Some studies have evaluated whether the asymmetrical anatomy of the maxilla in patients with UCLP led to asymmetrical expansion of the cleft and noncleft sides after RME.[27-29] A 3-dimensional finite element study suggested that uneven movement of the maxillary segments occurred in RME simulations.[27] An evaluation of frontal cephalometric radiographs showed increased expansion on the cleft side and more dental tipping on the noncleft side.[28] Moreover, a 2-dimensional implant study suggested that the response of the maxillary segments was unpredictable.[29] However, those studies had small[28,29] and heterogeneous[29] samples, as well as 2-dimensional cephalometric radiographs. CBCT facilitated the clear visualization and quantification of the lateral changes of the maxillary basal bone in relation to the cranial base. Our results showed that in all groups, there was greater expansion on the cleft side, but the differences were not statistically significant. When the 30 patients were evaluated together, no significant differences between the cleft and noncleft sides were observed, not even in the amount of dental tipping.

Our results might impact the clinical decision of which maxillary expander should be used in cleft patients. When both anterior and posterior expansion is required, the hyrax might be the appliance of choice. However, the use of the hyrax appliance in patients with atresia only in the intercanine region might limit the amount of anterior expansion, since the posterior limit of the expansion would probably be achieved before the desired anterior expansion is obtained. Both the fan-type and the inverted mini-hyrax appliances might be better options if only anterior expansion is required. However, if buccal dental tipping is not needed, the inverted mini-hyrax would achieve better results than the fan-type.

The use of CBCT to evaluate different appliances in patients with clefts might have great value, enhancing the possibilities and knowledge concerning their treatment. We assessed the short-term effects of RME. Therefore, a long-term evaluation is necessary to obtain a better understanding of the stability and potential periodontal consequences of each treatment.

CONCLUSIONS

1. The hyrax appliance caused both anterior and posterior maxillary expansion and might be better indicated for patients with clefts and an overall maxillary transverse deficiency.
2. The inverted mini-hyrax and the fan-type appliances enhanced expansion in the maxillary anterior region and restricted posterior expansion. Furthermore, the inverted mini-hyrax caused significantly less buccal tipping of the anterior supporting teeth.
3. The cleft and noncleft sides were symmetrically expanded and showed no significant differences in dental tipping.

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