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Immediate skeletal effects of rapid maxillary expansion at midpalatal suture opening with Differential, Hyrax and Haas expanders

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ABSTRACT

Objective: The aim of this study was to test the null hypothesis that there is no difference at the midpalatal suture opening after rapid maxillary expansion (RME) using Expander with Differential Opening (EDO), Hyrax-type and Haas-type expanders. **Methods:** Occlusal radiographs of 52 patients (19 males and 33 females; average age= 9.46±1.20 years) treated with RME were divided into three groups, according to the expander used: EDO (n=17), Hyrax-type (n=21) and Haas-type (n=14). The evaluated variables were: A) Distance between the maxillary central incisors at the incisal edge; B) Distance between the alveolar ridges at the midpalatal suture; C) Suture opening at 10-mm distance from the crest to posterior, at the midpalatal suture; D) Suture opening at 20-mm distance from the crest to posterior, at the midpalatal suture; and E) Suture opening at 30-mm distance from the crest to posterior, at the midpalatal suture. To assess the normality of variables, the Shapiro-Wilk test was performed. For intergroup comparison, ANOVA with a significance level of 5% was used. **Results:** At the region A, Hyrax-type (4.66 mm) and EDO (4.87 mm) groups presented larger openings than the Haas-type group (3.43 mm). In regions B and C, EDO showed a statistically significant greater opening than the Haas-type group. In region D, a smaller opening of the midpalatal suture was observed in the Haas-type group, compared to the Hyrax-type and EDO groups. **Conclusions:** EDO and Hyrax-type produced greater immediate skeletal effects, compared with Haas-type, but these differences were about 1 mm and might not be clinically significant.

Keywords: Palatal expansion technique. Orthodontics. Interceptive. Malocclusion. Sutures.

RESUMO

Objetivo: O objetivo do presente estudo foi testar a hipótese nula de que não existe diferença na abertura da sutura palatina mediana após a expansão rápida da maxila (ERM) usando os expansores Diferencial, tipo Hyrax e tipo Haas. **Métodos:** Radiografias oclusais de 52 pacientes (19 do sexo masculino e 33 do sexo feminino; idade média: 9,46 ± 1,20 anos) tratados com ERM foram divididas em três grupos, de acordo com o tipo de expansor usado: Diferencial (n = 17), tipo Hyrax (n = 21) e tipo Haas (n = 14). As variáveis avaliadas foram: A) distância entre os incisivos centrais superiores na borda incisal; B) distância entre os rebordos alveolares na sutura palatina mediana; C) abertura da sutura a 10 mm de distância da crista para posterior, na sutura palatina mediana; D) abertura da sutura a 20 mm da crista para posterior, na sutura palatina mediana; e E) abertura da sutura a 30 mm da crista para posterior, na sutura palatina mediana. Para verificar a normalidade das variáveis, utilizou-se o teste de Shapiro-Wilk. Para comparação intergrupos, usou-se a ANOVA com nível de significância de 5%. **Resultados:** Na região A, os grupos tipo Hyrax (4,66 mm) e Diferencial (4,87 mm) apresentaram uma abertura maior do que o grupo tipo Haas (3,43 mm). Nas regiões B e C, o Diferencial mostrou abertura significativamente maior do que o grupo tipo Haas. Na região D, uma abertura menor da sutura palatina mediana foi observada no grupo tipo Haas, comparado aos grupos tipo Hyrax e Diferencial. **Conclusões:** Os expansores Diferencial e tipo Hyrax produziram maiores efeitos esqueléticos imediatos, comparados ao tipo Haas, mas essas diferenças foram de aproximadamente 1 mm e podem não ser clinicamente significativas.

Palavras-chave: Técnica de expansão palatina. Ortodontia interceptora. Má oclusão. Suturas.

INTRODUCTION

Rapid maxillary expansion (RME) is the protocol of choice for early treatment of transverse malocclusions,[1,2,3] and it can be achieved with fixed expanders, which produce heavy forces, to achieve midpalatal suture opening with minimal tooth movement.[1-5] The midpalatal suture opens parallel to the antero-posterior direction, or shows an triangular shape, with its apex facing the nasal cavity.[3,6] Correction of transverse dysplasias in the mixed dentition phase is indicated due to the elastic characteristics of bone tissue during the child's growth, which has lower resistance to expansion and decreased pain symptoms during this process.[7]

Hyrax-type and Haas-type maxillary expanders are the classic orthodontic appliances used for this technique, and their therapeutic efficiency is well-documented in the literature.[1-4,7,8] Expander with differential opening (EDO) is a new option to perform RME. It was firstly proposed to treat cleft patients with expansion individualization of the anterior and posterior regions of maxilla.[9,10] More recently, EDO was tested for RME in non-cleft patients, and it seems to be an alternative to treat early posterior crossbite and maxillary constrictions.[11,12] No previous studies compared the immediate effects of RME with EDO, Hyrax-type and Haas-type maxillary expanders.

Occlusal radiography is a simple examination that may conffirm the opening of the midpalatal suture, and its main advantage over cone-beam computed tomography is that it presents lower radiation and reduced biological and financial cost for the patient.[13] Some studies have validated maxillary disjunction by visualizing the suture opening in digitized occlusal radiographs.[2,14] Moreover, recently, a previous study assessed the midpalatal suture opening after RME using occlusal radiography.[12] Thus, the aim of this study was to evaluate the morphological pattern of midpalatal suture opening immediately after rapid maxillary expansion using EDO, Hyrax-type and Haas-type by means of digitized occlusal radiographs. The null hypothesis tested was that there would be no difference in suture opening after the RME protocol using these three appliances.

METHODS

This study was approved by a Research Ethics Committee. (CAAE 15836919.1.000.0108/ opinion number: 3.508.996), and all the subjects signed an informed consent.

The sample size was calculated according to a previous study,[15] based on an alpha of 5% and a power of 80%. This would allow detection of a mean difference of 0.89 mm between baseline and post-treatment distance between maxillary central incisors, with a standard deviation of 0.8 mm. This calculation showed the need of 8 patients for each group. The sample consisted of

52 patients treated with the rapid maxillary expansion technique with Haas-type, Hyrax-type and EDO expanders (Figs 1, 2 and 3). The groups were formed according to the expander used. The Haas-type group was composed by 14 patients (mean age: 9.25 ± 1.10 years); the Hyrax-type group, by 21 patients (mean age: 9.54 ± 1.69 years); and the EDO group, by 17 patients (mean age: 9.59 ± 0.82 years), of both genders, with the following inclusion criteria: age between 7 and 11 years, with presence of posterior crossbite, mixed dentition, with all permanent first molars fully erupted, Class I malocclusion and absence of anterior open bite. Exclusion criteria were: cleft patients, agenesis or supernumerary teeth, loss of permanent teeth, syndromes, extensive caries, anterior orthodontic treatment. For Hyrax-type and Haas-type groups, simple randomization was performed using a software program (Excel 2007, Microsoft Windows, Microsoft, Chicago, IL, USA) in a 1:1 ratio by a professional not involved in the study. Another professional not involved in the study placed randomization codes in consecutively numbered, sealed,

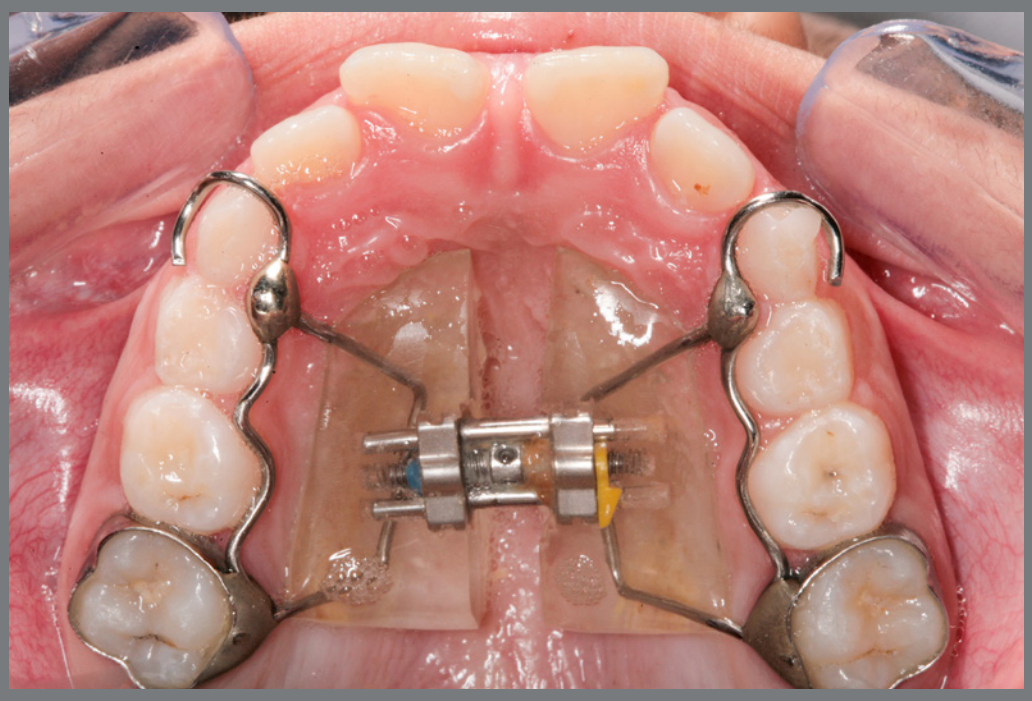

Figure 1: Patient in Haas-type group, after rapid maxillary expansion.

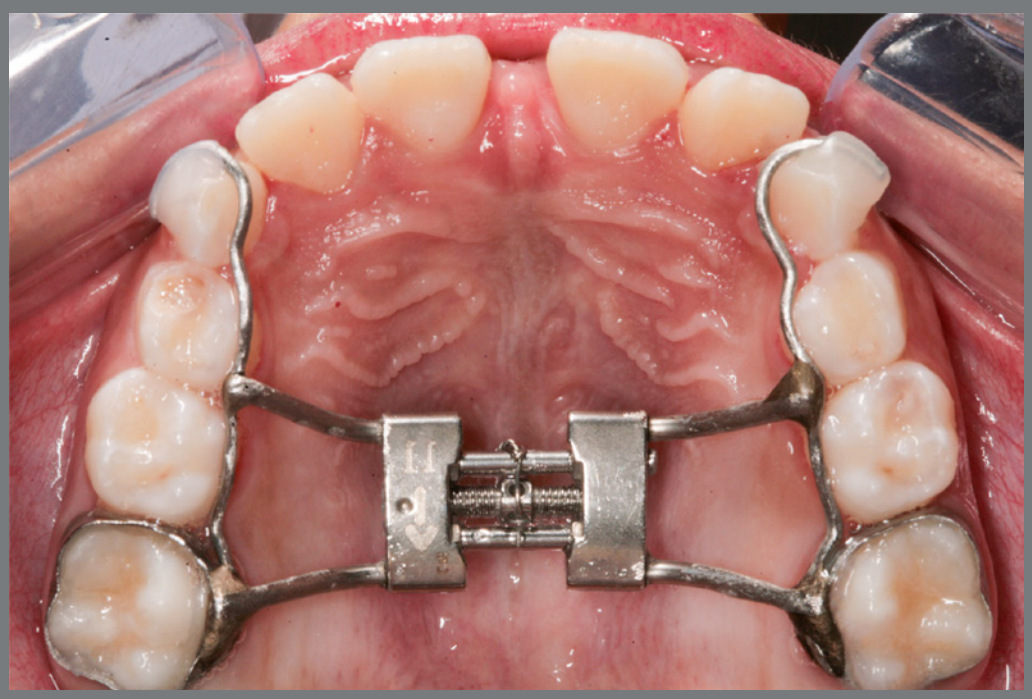

Figure 2: Patient in Hyrax-type group, after rapid maxillary expansion.

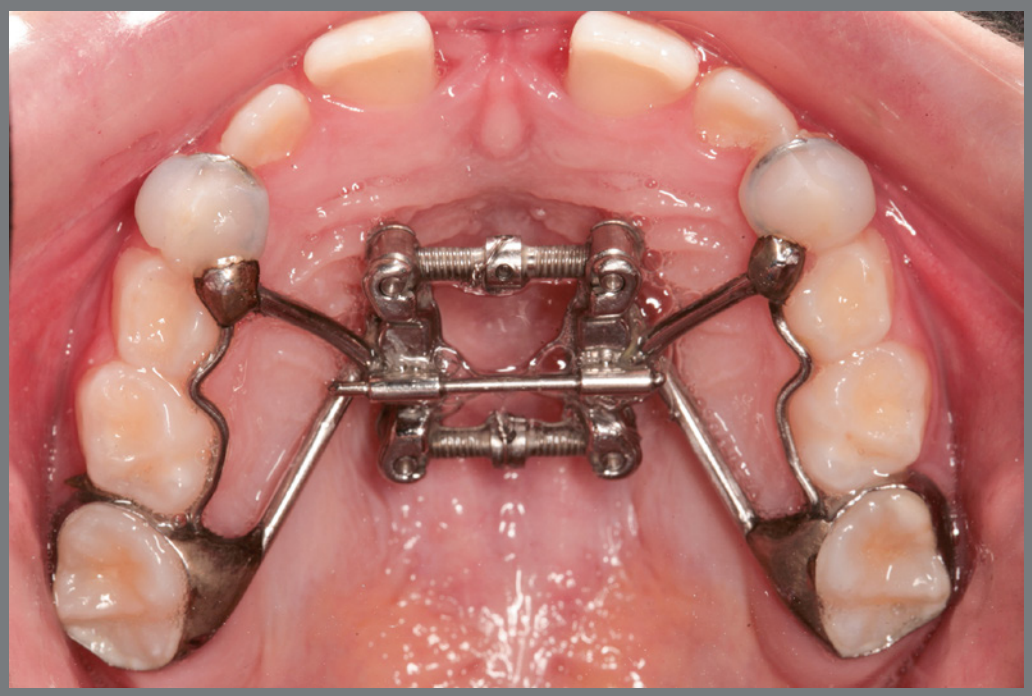

Figure 3: Patient in EDO group, after rapid maxillary expansion.

and opaque envelopes, ensuring concealed allocation into the groups. Participants were enrolled in the study and allocated. Sequentially, EDO group patients were selected and treated with the same inclusion criteria. All patients were treated prospectively at the same Institution. Three clinicians treated all the patients under the same supervision of an orthodontist with 10 years of experience.

The expanders' activation protocol consisted of 4/4 turn after their installation, followed by 2/4 turn in the morning, and 2/4 turn at night, for a period of 7 to 10 days in all groups. Screws were locked with average of 7-mm opening in Hyrax-type and Haas-type; and for EDO expander, the protocol was an average of 7 mm at posterior and 9 mm at anterior screw, measured with a digital caliper. This amount of activation was sufficient to perform overcorrection of posterior crossbite of all patients. Orthodontic bands were adapted only on permanent molars, to provide anchorage in the same posterior teeth for all groups; and expander hooks were bonded in maxillary deciduous canines. All appliances were made using a 1-mm wire thickness.

Occlusal radiographs were taken before and after the maxillary expansion (Yoshida Dental MFG Co. Ltda. Tokyo, Japan at 70-kV; 7mA, with 2.2-mm filtration and a focus-sensor distance of 30 cm). For greater accuracy, an occlusal positioner (FPX, PRISMA Instrumentos Odontológicos, Pirituba, São Paulo, Brazil) was

used, with exposure time standardized at 1s. Occlusal radiographs were scanned on the HP Scanjet scanner, using its respective software (HP Photosmart Premier) for image capture. All images were captured maintaining the fixed resolution of 300 DPI and 100% scale. The images were archived in TIFF format.

Dolphin Imaging® 11.7 software was used to obtain the tracings, using the "implanner" option, which automatically shows the traced measurements in millimeters. For a 100% magnification, the length measurement of each expander in the anterior-posterior direction was used for calibration. All measurements (Fig 4) were performed by the same operator:

A) distance between the maxillary central incisors at the incisal edge;
B) distance between alveolar ridges in the midpalatal suture;
C) opening at a distance of 10 mm from the crest to posterior at the midpalatal suture;
D) opening at a distance of 20 mm from the crest to posterior at the midpalatal suture;
E) opening at a distance of 30 mm from the crest to posterior at the midpalatal suture.

Features offered by the software to facilitate the visualization of structures at the time of marking points for the tracing were used, such as: brightness and contrast changes, image enlargement or reduction, edge enhancement and image inversion.

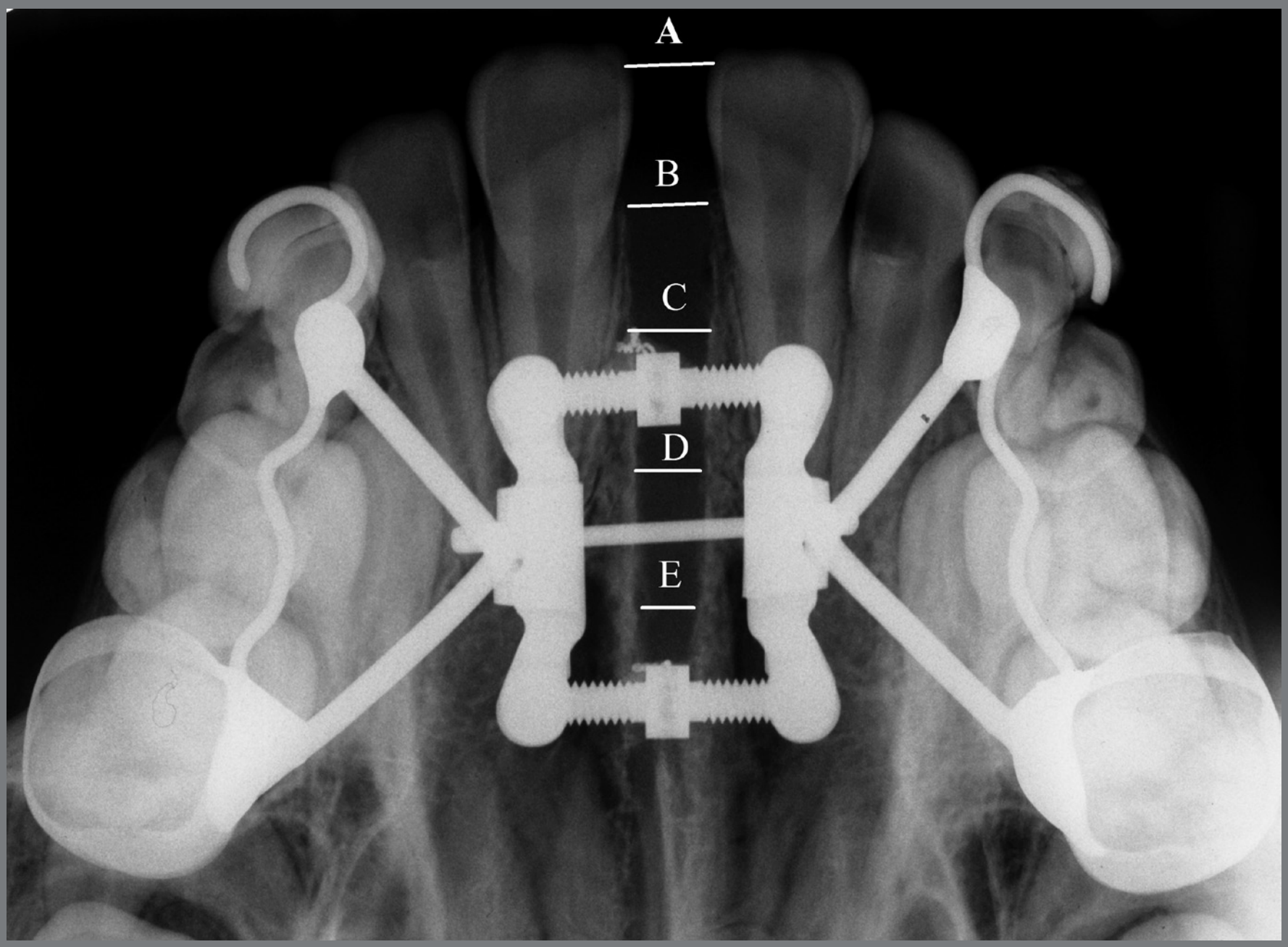

Figure 4: Scanned occlusal radiograph, and measurements performed. The following anatomical points were evaluated and used for analysis of the digitized radiographs: **A**) distance between the maxillary central incisors at the incisal edge; **B**) distance between the alveolar ridges at the midpalatal suture; **C**) suture opening at 10-mm distance from the crest to posterior, at the midpalatal suture; **D**) suture opening at the distance of 20mm from the crest to posterior, at the midpalatal suture and **E**) suture opening at 30-mm distance from the crest to posterior, at the midpalatal suture.

To assess the normality of the measured variables, the Shapiro-Wilk test was performed. For intergroup comparison, ANOVA was used, followed by Tukey test, with a significance level of 5%. Chi square test was used to compare sex and ANOVA, to compare age between groups.

RESULTS

To verify the method error, 30 days after the first evaluation, the measurements of 30% of the sample were repeated. Errors were evaluated by Intraclass Correlation Coefficient (ICC) and Bland-Altman test. The range of intraclass correlation coefficients showed excellent intraexaminer agreement, ranging from 0.87 to 0.97 (Table 1). The sample was compatible regarding sex and age; there was no statistically significant difference between the groups before treatment (Tables 2 and 3).

Comparing the changes (T2–T1) between the groups, there was a greater opening at the distance between the maxillary central incisors in the Hyrax-type (4.66 mm) and EDO (4.87 mm) groups, when compared to the Haas-type group (3.43 mm). At the distance between the alveolar ridges, in the midpalatal suture, and at the distance of 10 mm from the crest to posterior, the EDO

Table 1: Intraclass correlation coefficients (ICC) of the measurements.

Measurement (mm)	ICC	Bland Altman		
		Bias	Upper	Lower
A. Distance between the maxillary central incisors at the incisal edge	0.97	0.18	1.04	-0.68
B. Distance between alveolar ridges in the midpalatal suture	0.96	0.03	0.6	-0.4
C. Opening at a distance of 10 mm from the crest to posterior at the midpalatal suture	0.88	0	0.69	-0.69
D. Opening at a distance of 20 mm from the crest to posterior at the midpalatal suture	0.94	-0.5	0.37	-0.67
E. Opening at a distance of 30 mm from the crest to posterior at the midpalatal suture	0.87	0.22	0.56	-1

Table 2: Description of the sample, regarding sex and age (Chi square and ANOVA).

Variables	Haas-type	Hyrax-type	EDO	p
	n = 14	n = 21	n = 17	
AGE mean (SD)	9.25 (1.10)	9.54 (1.69)	9.59 (0.82)	p = 0.745
SEX				p = 0.432;
Male	7	6	6	DF = 2;
Female	7	15	11	X^2 = 1.68
TOTAL	14	21	17	52

Table 3: Initial intergroup comparison of the variables evaluated (ANOVA, followed by Tukey).

Variables	Haas-type	Hyrax-type	EDO	p
	n = 14	n = 21	n = 17	
	Mean (SD)	Mean (SD)	Mean (SD)	
A. Distance between maxillary central incisors at incisal edge	1.72 (0.90)	2.39 (0.95)	1.89 (0.77)	0.073
B. Distance between alveolar ridges at midpalatal suture	0 (0)	0 (0)	0 (0)	1.0
C. Opening at 10-mm distance from the crest to posterior, at the midpalatal suture	0 (0)	0 (0)	0 (0)	1.0
D. Opening at 20-mm distance from the crest to posterior, at the midpalatal suture	0 (0)	0 (0)	0 (0)	1.0
E. Opening at 30-mm distance from the crest to posterior, at the midpalatal suture	0 (0)	0 (0)	0 (0)	1.0

* Statistically significant at $p < 0.05$.

group presented a statistically significant larger opening than the Haas-type group. At the opening region within a distance of 20 mm from the crest to posterior, still at the midpalatal suture, the EDO (2.51 mm) and Hyrax-type (2.23 mm) groups provided a larger opening than the Haas-type group (1.68 mm). However, at a distance of 30 mm from the crest to posterior in the midpalatal suture, the most posteriorly measured point, there was no statistically significant difference in suture opening provided by rapid maxillary expansion between the three groups evaluated (Table 4).

Table 4: Intergroup changes (T2-T1) of the evaluated variables (ANOVA, followed by Tukey).

Variables	Haas-type n = 14 Mean (SD)	Hyrax-type n = 21 Mean (SD)	EDO n = 17 Mean (SD)	p
A. Distance between maxillary central incisors at incisal edge	3.43 (1.06)^{B}	4.66 (1.08)^{A}	4.87 (2.04)^{A}	0.020*
B. Distance between alveolar ridges at midpalatal suture	3.14 (0.59)^{B}	3.69 (0.69)^{A,B}	4.22 (1.12)^{A}	0.003*
C. Opening at 10-mm distance from the crest to posterior, at the midpalatal suture	2.22 (0.48)^{B}	2.58 (0.55)^{A,B}	3.03 (0.86)^{A}	0.005*
D. Opening at 20-mm distance from the crest to posterior, at the midpalatal suture	1.68 (0.54)^{B}	2.23 (0.41)^{A}	2.51 (0.83)^{A}	0.002*
E. Opening at 30-mm distance from the crest to posterior, at the midpalatal suture	0.83 (0.64)	1.25 (0.68)	0.81 (1.00)	0.174

* Statistically significant at $p < 0.05$.

DISCUSSION

The maxillary occlusal radiography is a complementary exam that validates the opening of the midpalatal suture.[1,4,14] This suture can be opened by means of expanders, to treat transverse discrepancies.[1-4,7] There is a tendency to use 3D images,[16] even being recognized that there is no safe dose of radiation exposure, which is cumulative, and its risk is justified only when there is benefit to the health of the patient. The decision for any radiographic imaging procedure should be performed following the ALARA principle, and CBCT can be justified only if the anticipated information has the potential to change a patient's treatment modality or outcome.[17] The need for conventional radiographs was carefully considered and adopted in this study.

When the midpalatal suture opening was evaluated in the regions between maxillary central incisors at the incisal edge, the distance between the alveolar ridges at the midpalatal suture, and the opening at distances of 10 mm, 20 mm and 30 mm from the crest to posterior in the midpalatal suture, the three appliances showed higher opening values in the anterior region, and the most posterior point presented the smallest opening. The opening shape was triangular, with a wider base at the anterior portion of maxilla.[18,19,20] The greater expansion in the anterior region may be explained by the resistance of the medial and lateral pterygoid plates of the sphenoid to

movement of the tip of the maxilla during RME.[18] Another possible explanation is that the direction of the expansion force produced by the expanders would be located prior to the center of resistance of each maxillary half. [21]

The Hyrax-type and EDO expanders produced greater skeletal expansion than did the Haas-type expander, at the region between the maxillary central incisors at the incisal edge, region between the alveolar ridges at the midpalatal suture, and suture region at 10-mm and 20-mm distances from the crest to posterior, at the midpalatal suture (Table 4, Fig 5). In the Haas-type group, the opening was smaller in 4 of 5 points evaluated. In a previous study,[5] the results of rapid maxillary expansion using the Hyrax-type and Haas-type were described, and the authors concluded that the increase in the intermolar distance was similar for both appliances. However, in the anterior region, the incisors interapical distance was greater in patients treated with the Hyrax-type group than in those treated with the Haas-type. Similar result was found in the present study for Hyrax-type and EDO expanders, compared to Hass-type group. The main difference between these expanders is the acrylic pad close to the palate in the Haas-type appliance, which Hyrax-type and EDO appliances do not have. The Hyrax-type has only one screw and EDO has two screws, an anterior and a posterior one. EDO was proposed aiming to promote greater expansion on the anterior region than on the posterior region.[9]

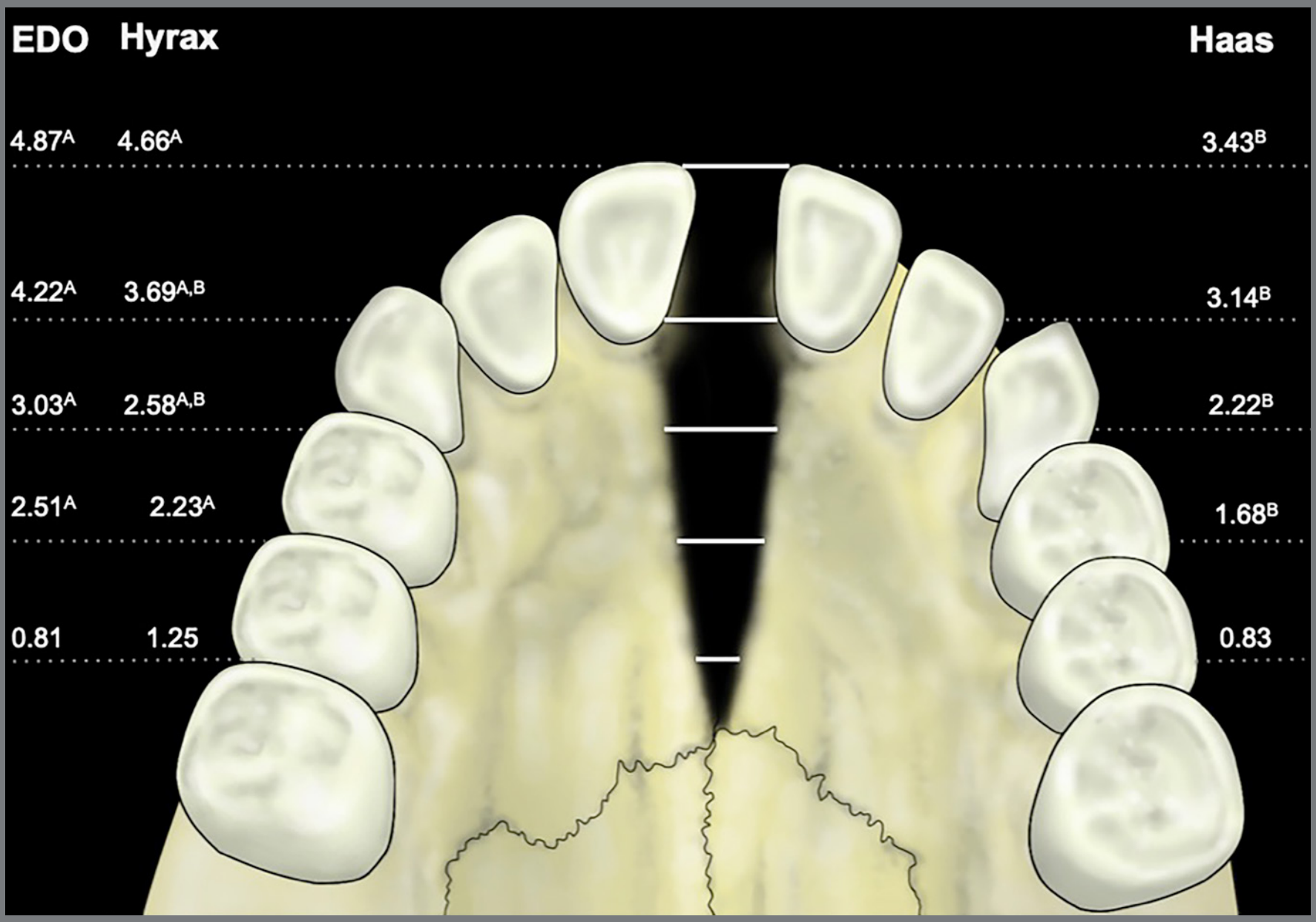

Figure 5: Intergroup changes (T2-T1) of the evaluated variables.

The purpose of the acrylic pad is to reinforce the anchorage, for greater orthopedic response during RME.[3] However, the results of the present study did not support this theory. Better results in skeletal response were obtained by Hyrax-type and EDO expanders. Appliance designs that use an acrylic interface with the teeth, as Haas-type used in our study, are far less stiff than those made exclusively of soldered stainless steel wire,[21] as Hyrax-type and EDO, which may explain the results found in the present study.

EDO was recently introduced to the market, and its main advantage would be to allow the expansion individualization in the anterior and posterior regions. The need for this differentiated expansion is justified when there is a risk of intermolar distance overexpansion to correct extreme constrictions in the intercanine distance region, very common in cleft patients.[10] It is believed that this individualization of anterior and posterior expansions can also be applied to non-fissured patients presenting marked maxillary atresia in the anterior region, in order to avoid overexpansion of the posterior region, considering that overexpansion of the intermolar distance is undesirable and can cause negative periodontal repercussions on the buccal aspects, such as bone dehicences and gingival recessions on a long term basis.[22,23] In some situations, cases of severe maxillary atresia in the anterior region require the use of a conventional expander with a subsequent fan expander,[11,24] in order to avoid expansions beyond or below the required for correction of transverse dysplasia. Therefore, EDO would be an alternative appliance for the orthodontist to use in such cases.[11] Similar changes in maxillary dental arch size were produced by EDO and Hyrax-type expander in patients with bilateral complete cleft lip and palate,[10] similar to the results found in the present study with non-cleft patient sample. There was no statistically significant difference between Hyrax-type and EDO groups for the midpalatal suture opening in any of the five measurements performed (Table 4). However, different

results were found in a previous study with non-cleft patient sample, in which EDO produced greater anterior opening of the midpalatal suture and greater increase in the intercanine distance than the Hyrax-type expander.[12]

In this current study, the protocol of activation adopted to perform RME in EDO group (7 mm at posterior screw and 9 mm at anterior screw) provided a statistically significant difference in the distance between the alveolar ridges at the midpalatal suture opening (EDO = 4.22 ± 1.12 mm and Hyrax-type = 3.69 ± 0.69 mm), compared to Haas-type expander (3.14 ± 0.59 mm) (Table 4). EDO showed higher expansion (5.49±2.06 mm), compared to Hyrax-type expander (3.18±1.03 mm) in a previous study that used activation for 6 days, with an activation protocol of half a turn in the morning and half a turn in the evening in EDO and Hyrax-type groups, and an extra 4-day time with the same protocol only at the EDO anterior screw.[12] This can be explained due to the different amount of activation protocols, with a greater opening of the anterior screw of EDO in this previous study (2 mm more than the present study).[12] Moreover, they adopted a smallest EDO posterior screw and Hyrax-type screw protocol activation than in the present study.[12] The results of RME achieved by expanders must be analyzed taking into account the amount of screw activation.[5]

The present results indicate that the expander type chosen for RME influences the opening of the midpalatal suture. Therefore, depending on the orthopedic response desired in the early treatment of posterior crossbite, consideration should be given for choosing which appliance would be appropriate in each case, to improve the appliance's response to the needs of each patient.

In this study, there were evaluated the immediate effects of RME at the midpalatal suture opening; therefore, long-term evaluation is necessary for a better understanding of the differences between Haas-type, Hyrax-type and EDO expanders, especially during the retention and post-retention phases of RME. Moreover, it was impossible to blind the operator that performed the measures, because occlusal radiographs were made immediately after the expansion, and all patients were with the appliance, necessary as retention. Other limitation was that the tridimensional orthopedic effect of the expanders was assessed using conventional radiograph, with two-dimensional (2D) images. However, the use of three-dimensional (3D) images, which uses a higher dose of radiation, would be inappropriate in such a short period of time. Principles of radiation protection — that is justification, optimization, and dose limitation— should always be followed when considering radiation exposure for orthodontics reasons, especially in children.[17]

CONCLUSIONS

From the results obtained in this study, the null hypothesis, which suggested that there were no differences at the midpalatal suture opening region after the RME protocol using the different maxillary expanders, was rejected. EDO produced greater immediate skeletal effects in 4 of 5 and Hyrax-type in 2 of 5 of the evaluated variables, compared with Haas-type, but these differences were about 1 mm and might not be clinically significant. The appliance used for RME influences the immediate effects at the midpalatal suture opening.

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Patients displayed in this article previously approved the use of their facial and intraoral photographs.

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REFERENCES

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

2. Haas AJ. The treatment of maxillary deficiency by opening the midpalatal suture. Angle Orthod. 1965 Jul;35:200-17.

3. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod. 1970 Mar;57(3):219-55.

4. Haas AJ. Long-term posttreatment evaluation of rapid palatal expansion. Angle Orthod. 1980 Jul;50(3):189-217.

5. Rodrigues AP, Monini AC, Gandini LG Jr, Santos Pinto A. Rapid palatal expansion: a comparison of two appliances. Braz Oral Res. 2012 Jun;26(3):242-8.

6. Silva Filho OG, Lara TS, Almeida AM, Silav HC. Evaluation of the midpalatal suture during rapid palatal expansion in children: a CT study. J Clin Pediatr Dent. 2005;29(3):231-8.

7. Biederman W. A hygienic appliance for rapid expansion. JPO J Pract Orthod. 1968 Feb;2(2):67-70.

8. Biederman W. Rapid correction of Class 3 malocclusion by midpalatal expansion. Am J Orthod. 1973 Jan;63(1):47-55.

9. Garib D, Lauris RC, Calil LR, Alves AC, Janson G, Almeida AM, et al. Dentoskeletal outcomes of a rapid maxillary expander with differential opening in patients with bilateral cleft lip and palate: a prospective clinical trial. Am J Orthod Dentofacial Orthop. 2016 Oct;150(4):564-74.

10. Pugliese F, Palomo JM, Calil LR, Medeiros Alves A, Lauris JRP, Garib D. Dental arch size and shape after maxillary expansion in bilateral complete cleft palate: a comparison of three expander designs. Angle Orthod. 2020 Mar;90(2):233-8.

11. Massaro C, Janson G, Miranda F, Aliaga-Del Castillo A, Pugliese F, Lauris JRP, et al. Dental arch changes comparison between expander with differential opening and fan-type expander: a randomized controlled trial. Eur J Orthod. 2021 Jun;43(3):265-73.

12. Alves ACM, Janson G, Mcnamara JA Jr, Lauris JRP, Garib DG. Maxillary expander with differential opening vs Hyrax expander: a randomized clinical trial. Am J Orthod Dentofacial Orthop. 2020 Jan;157(1):7-18.

13. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006 Feb;72(1):75-80.

14. Silva Filho OG, Montes LA, Torelly LF. Rapid maxillary expansion in the deciduous and mixed dentition evaluated through posteroanterior cephalometric analysis. Am J Orthod Dentofacial Orthop. 1995 Mar;107(3):268-75.

15. David SMN, Castilho JCM, Ortolani CLF, David AF, Manhães LRCM Jr, Matsui RH. Evaluation and measurement of midpalatal suture through the digitalized occlusal radiography in patients submitted to rapid maxillary expansion. Rev Dent Press Ortodon Ortop Facial. 2009 Out;14(5):62-8.

16. Weissheimer A, Menezes LM, Mezomo M, Dias DM, Lima EM, Rizzatto SM. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. Am J Orthod Dentofacial Orthop. 2011 Sep;140(3):366-76.

17. Grauwe A, Ayaz I, Shujaat S, Dimitrov S, Gbadegbegnon L, Vannet BV, et al. CBCT in orthodontics: a systematic review on jusfication of CBCT in a paediatric population prior to orthodontic treatment. Eur J Orthod. 2019 Oct;41(4):381-9.

18. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod Dentofacial Orthop. 1987 Jan;91(1):3-14.

19. Garrett BJ, Caruso JM, Rungcharassaeng K, Farrage JR, Kim JS, Taylor GD. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2008 Jul;134(1):8-9.

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

21. Braun S, Bottrel JA, Lee KG, Lunazzi JJ, Legan HL. The biomechanics of rapid maxillary sutural expansion. Am J Orthod Dentofacial Orthop. 2000 Sep;118(3):257-61.

22. Garib DG, Henriques JF, Janson G, Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. Am J Orthod Dentofacial Orthop. 2006 Jun;129(6):749-58.

23. Brunetto M, Andriani JS, Ribeiro GL, Locks A, Correa M, Correa LR. Three-dimensional assessment of buccal alveolar bone after rapid and slow maxillary expansion: a clinical trial study. Am J Orthod Dentofacial Orthop. 2013 May;143(5):633-44.

24. Doruk C, Bicakci AA, Basciftci FA, Agar U, Babacan H. A comparison of the effects of rapid maxillary expansion and fan-type rapid maxillary expansion on dentofacial structures. Angle Orthod. 2004 Apr;74(2):184-94.