UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

CAMILA DA SILVEIRA MASSARO

Maxillary expander with differential opening versus fan-type expander: a randomized clinical trial

Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado

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Orientadora: Prof.ª Dr.ª Daniela Gamba Garib Carreira

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ERRATA

FOLHA DE APROVAÇÃO

DEDICATÓRIA

Dedico este trabalho, com muito amor e gratidão,
aos meus pais, ***Carlos*** *e* ***Rose****,*
e às minhas irmãs, ***Carina*** *e* ***Carolina****.*
Meu maior apoio e incentivo sempre!

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Gratidão é a memória do coração...

Muito obrigada!


paciência
PACIÊNCIA:
o intervalo entre
a semente
e a flor.
ANA JÁCOMO

ABSTRACT

Maxillary expander with differential opening versus fan-type expander: a randomized clinical trial

Introduction: The aim of this two-arm parallel randomized clinical trial was to compare the dentoskeletal effects of the expander with differential opening (EDO) and the fan-type expander (FE) in the mixed dentition by means of cone-beam computed tomography (CBCT) and digital dental models. **Methods:** A sample of 48 patients were randomly allocated into 2 study groups. Group EDO comprised 24 patients (13 female, 11 male; mean age of 7.62 years) treated with the expansion with differential opening. Group FE was composed by 24 patients (14 female, 10 male; mean age of 7.83 years) treated with the fan-type expansion. CBCT scans and digital dental models were acquired before treatment and after rapid maxillary expansion. Maxillary three-dimensional (3D) dentoskeletal changes were assessed in 3D models derived from CBCT scans superimposed on the cranial base using the software ITK-SNAP and 3D Slicer. Changes in the maxillary interincisal diastema and maxillary and mandibular arch width, arch perimeter, arch length, arch size and arch shape were assessed in digital dental models using the software OrthoAnalyzer, Stratovan Checkpoint and MorphoJ. Intra-rater reliability was tested with Intraclass Correlation Coefficient. Intergroup comparisons were performed using t or Mann-Whitney U tests with Holm-Bonferroni correction ($P<0.05$). **Results:** The EDO group showed greater maxillary skeletal lateral displacements, while the vertical and anteroposterior changes were similar in both groups. The increase in the intercanine distance and the canine buccal inclination were greater in the FE group, while the intermolar changes and the molar buccal inclination were greater in the EDO group. Both groups demonstrated similar increases in the maxillary interincisal diastema width and similar changes were observed in the maxillary and mandibular arch length and arch perimeter. Changes in the mandibular arch width were mild and similar in both groups, except for the inter-first permanent molars distance that showed a slight greater increase in the EDO group. Maxillary arch shape changed significantly for both differential and fan-type expanders. The posttreatment arch shape was larger in the anterior region for patients treated with the FE and larger in the posterior region for patients treated with EDO. **Conclusions:** In the mixed dentition, the EDO produced a greater transversal skeletal

expansion compared to the FE, with similar vertical and anteroposterior effects. Dental changes were greater in the molar region for patients treated with EDO and in the canine region for patients treated with FE. Maxillary arch shape changes were distinct between EDO and FE. A slightly greater mandibular spontaneous expansion was observed for EDO only at the first molar region.

Keywords: Orthodontics. Palatal expansion technique. Orthodontic appliance design. Imaging, Three-Dimensional.

RESUMO

Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado

Introdução: O objetivo do presente estudo clínico randomizado foi comparar os efeitos dentoesqueléticos do expansor com abertura diferencial (ED) e do expansor com abertura em leque (EL) na dentadura mista, utilizando tomografia computadorizada cone-beam (TCCB) e modelos digitais. **Métodos:** Quarenta e oito pacientes foram aleatoriamente alocados em um de dois grupos de estudo. O grupo ED foi composto por 24 pacientes (13 do sexo feminino, 11 do sexo masculino; idade média de 7,62 anos) que foram submetidos à expansão rápida da maxila com o expansor com abertura diferencial. O grupo EL foi composto por 24 pacientes (14 do sexo feminino, 10 do sexo masculino; idade média de 7,83 anos) tratados com expansão rápida da maxila utilizando o expansor com abertura em leque. Exames de TCCB e modelos digitais foram obtidos para cada paciente antes do tratamento e após a expansão maxilar. Alterações esqueléticas tridimensionais (3D) na maxila foram avaliadas em modelos 3D obtidos a partir dos exames de TCCB superpostos na base do crânio. Alterações no diastema interincisal, larguras dos arcos dentários superior e inferior, comprimento dos arcos, perímetro dos arcos, tamanho dos arcos e forma dos arcos foram avaliadas em modelos digitais. O erro do método foi calculado utilizando o Coeficiente de Correlação Intraclasse. As comparações entre os grupos foram realizadas por meio dos testes *t* e Mann-Whitney com correção de Holm-Bonferroni ($P<0.05$). **Resultados:** O grupo ED apresentou maior expansão esquelética, enquanto os deslocamentos maxilares no sentido vertical e anteroposterior foram similares nos dois grupos. O aumento da distância intercaninos e da inclinação vestibular dos caninos foi maior do grupo EL, enquanto as alterações nas distâncias intermolares e na inclinação vestibular dos molares foram maiores no grupo ED. Os grupos ED e EL promoveram alterações similares no diastema interincisal e no comprimento e perímetro dos arcos dentários superior e inferior. As alterações no arco inferior foram discretas e similares entre os grupos, exceto para a distância entre os primeiros molares permanentes, que apresentou um ligeiro maior aumento no grupo ED. A forma do arco superior sofreu alterações após a expansão maxilar diferencial e em leque. Após a expansão, os dois grupos apresentaram formatos de arco distintos,

com o arco superior mais largo na região dos caninos no grupo EL, e mais largo na região dos molares no grupo ED. **Conclusão:** Na dentadura mista, o ED produziu um maior efeito esquelético no sentido transversal comparado com o EL, com efeitos similares no sentido vertical e anteroposterior. Maiores alterações dentárias foram observadas na região dos molares no grupo ED e na região dos caninos no grupo EL. As alterações na forma do arco superior foram distintas após a expansão diferencial e em leque. Um ligeiro maior aumento transversal no arco inferior foi observado no grupo ED apenas na região dos primeiros molares permanentes.

Palavras-chave: Ortodontia. Desenho de aparelho ortodôntico. Técnica de expansão palatina. Imagem tridimensional.

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LIST OF ABBREVIATIONS AND ACRONYMS

EDO	Expander with differential opening
FE	Fan-type expander
T1	Timing 1
T2	Timing 2
CAPES	Coordination for the improvement of higher education personnel
FAPESP	São Paulo research foundation
RME	Rapid maxillary expansion
RCT	Randomized clinical trial
CONSORT	Consolidated standards of reporting trials
ICC	Intraclass correlation coefficient
CBCT	Cone-beam computed tomography
SD	Standard deviation
3D	Three-dimensional

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1 INTRODUCTION

1 INTRODUCTION

The posterior crossbite is well defined in the literature and may occur since the primary dentition.[1,2] In the mixed dentition, an 18.2% incidence of posterior crossbite was previously reported.[3] In this scenario, the interceptive treatment is highly recommended since the posterior crossbites do not self-correct.[1,4,5]

The orthopedic procedure commonly used to treat maxillary constrictions and posterior crossbites in the mixed dentition is the rapid maxillary expansion (RME). This procedure became widely used in orthodontics since the mid-1960s.[6-8] Nowadays, a wide variety of appliances designs can be used for producing the midpalatal suture split and correct the transverse discrepancy of the maxillary arch. Conventional opening expanders, including Haas or Hyrax type, promote the increase of the maxillary intermolar and intercanine distances by means of a parallel opening of the expander screw, positioned at the center of the palate.[6,9] When the maxillary constriction is more evident in the anterior region of the arch with minimal effects in the molar region, the fan-type expander (FE) can be indicated.[10-12] Considering that maxillary constriction is present in both the anterior and posterior regions, the expander with differential opening (EDO) was recently proposed to individualize the expansion in both anterior and posterior regions of the dental arch.[13,14]

Previous studies compared the outcomes of the conventional and fan-type expanders demonstrating that the intercanine distance increase was similar in both groups, while a greater increase in the intermolar distance was found for the former.[10,11] A previous comparison between Hyrax and the EDO showed a similar inter-molar expansion in both groups with a greater intercanine expansion for the EDO.[14] In the same study, using occlusal radiographs, it was reported a greater split of the anterior region of the midpalatal suture in patients treated with EDO compared with the patients treated with the Hyrax expander.[14] No previous study compared the dentoskeletal outcomes of the EDO and FE.

Considering the above-mentioned information and in order to help clinicians decide between the EDO and FE, some questions should be answered. Are the orthopedic effects different between treatment with EDO and FE? Do both expanders produce similar effects in the dental arch dimensions and dental arch shape? Does the

EDO and FE induce similar spontaneous changes in the mandibular dental arch? The aim of the present study was to compare the dentoskeletal effects of the expander with differential opening and the fan-type expander in the mixed dentition by means of cone-beam computed tomography scans and digital dental models.

2 ARTICLES

2 ARTICLES

The articles presented in this Thesis were written according to the CONSORT 2010 check list and the American Journal of Orthodontics and Dentofacial Orthopedics instruction and guidelines for article submission.

ARTICLE 1 - Maxillary dentoskeletal outcomes of the expander with the differential opening and the fan-type expander: a randomized clinical trial

ARTICLE 2 - Dental arch comparison between expander with differential opening and fan-type expander: a randomized clinical trial

2.1 ARTICLE 1

Maxillary dentoskeletal outcomes of the expander with the differential opening and the fan-type expander: a randomized clinical trial

ABSTRACT

Introduction: The aim of this two-arm parallel randomized clinical trial was to compare the expander with differential opening (EDO) and the fan-type expander (FE) in the mixed dentition by means of cone-beam computed tomography (CBCT) 3D models superimposed on the cranial base. **Methods:** Forty-eight patients from 7 to 11 years old with maxillary dental arch constriction were randomly allocated into 2 study groups. Group EDO was composed of 24 patients (13 female, 11 male) with a mean age of 7.62 years treated with the expansion with differential opening. Group FE comprised 24 patients (14 female, 10 male) with a mean age of 7.83 years treated with the fan-type expander. A simple randomization was performed. CBCT scans were acquired before treatment and after rapid maxillary expansion. Linear and angular three-dimensional dentoskeletal changes were assessed after cranial base superimposition using the software ITK-SNAP and 3D Slicer. Intra-rater reliability was tested with Intraclass Correlation Coefficient. T or Mann-Whitney U tests with Holm-Bonferroni correction were used for intergroup comparisons ($P<0.05$). **Results:** Maxillary skeletal lateral displacements were greater in the EDO group, while the vertical and anteroposterior changes were similar in both groups. No intergroup differences were observed for the palatal plane rotation (pitch), while the maxillary lateral rotation (roll) was slightly greater in the EDO group. The increase in the intercanine distance and the canine buccal inclination were greater in the FE group, while the intermolar changes and the molar buccal inclination were greater in the EDO group. **Conclusions:** EDO produced a greater transversal skeletal expansion compared to FE, with similar vertical and anteroposterior effects. Dental changes were greater in the molar region for patients treated with EDO and in the canine region for patients treated with FE. **Registration:** This trial was registered at the ClinicalTrials.gov (NCT03705871). **Protocol:** The protocol was not published.

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KEYWORDS: Orthodontics. Palatal expansion technique. Orthodontic appliance design. Imaging, Three-Dimensional. Cone-beam computed tomography.

INTRODUCTION

Rapid maxillary expansion (RME) is the orthopedic procedure of choice to treat maxillary constriction and posterior crossbite. Dental, skeletal and periodontal effects of this procedure have been widely discussed in the orthodontic literature.[1-12] The correction of maxillary constrictions can be accomplished with different appliance designs. A variety of fixed expanders with screws produce heavy forces, resulting in the midpalatal suture split.[1,13,14] Conventional expanders (CE), including Haas and Hyrax-type, promote a similar increase of the maxillary intermolar and intercanine distances by means of a parallel opening of the expander screw.[1,10,12,15] When the maxillary constriction is more evident in the anterior region of the arch, the fan-type expander (FE) or the expander with differential opening (EDO) can be indicated.[13,14] The FE has a posterior hinge that concentrates the expansion effect in the intercanine region, with mild effects the intermolar distance.[8,10,13] The EDO has two palatal screws and the differential activation protocol promotes a different amount of expansion for the anterior and posterior regions of the maxillary arch.[12,14] The careful choice of the maxillary expander is important to correct the maxillary morphology avoiding negative side effects associated with undesired under or overexpansion.

Previous comparisons of the immediate outcomes produced by Haas and Hyrax expanders showed similar orthopedic effects.[9,16] When comparing Hyrax and FE using radiographies and maxillary dental models, a similar expansion in the intercanine distance was noted, while the conventional opening group showed a greater expansion in the nasal cavity, maxillary width and intermolar distance.[8,10] A recent randomized clinical trial comparing the Hyrax expander and the EDO using dental models and occlusal radiographs showed that EDO promoted a greater split of the anterior region of the midpalatal suture and greater increase of the intercanine distance.[12]

With the advent of cone-beam computed tomography (CBCT) in dentistry, studies were performed to assess the RME effects using this tool, contributing to understanding of dentoalveolar and skeletal effects.[9,17-21] However, no previous study has compared FE and EDO by means of computed tomography. In order to help clinicians make a decision between these two types of expanders, some questions should be clarified. Are anteroposterior, transversal and vertical orthopedic effects different between treatment with EDO and FE? Are zygomatic bone changes similar between the two type of expanders? Do both expanders produce similar orthodontic outcomes in the canine and molar regions?

Specific objectives or hypotheses

The aim of this study was to compare the expander with differential opening (EDO) and the fan-type expander (FE) in the mixed dentition, by means of CBCT 3D models superimposed on the cranial base. The null hypothesis is that both therapies show similar outcomes.

METHODS

Trial design and any changes after trial commencement

This was a single-center randomized clinical trial (RCT) with two-parallel arms and a 1:1 allocation ratio. This RCT followed the Consolidated Standards of Reporting Trials statement and guidelines and did not required changes after trial commencement.[22]

Participants, eligibility criteria, and settings

This study was approved by the Research Institutional Board of Bauru Dental School, University of São Paulo, Brazil (Process number: 71648917.6.0000.5417) before trial commencement. In addition, the protocol of this study was registered at Clinicaltrials.gov with the identifier NCT03705871.

Patients were recruited at the Orthodontic Clinic of Bauru Dental School, University of São Paulo, Brazil, from November 2017 to June 2018. The selection criteria were patients of both sexes from 7 to 11 years of age with maxillary constriction and posterior crossbites. The exclusion criteria were a Class III malocclusion, craniofacial syndromes, clinical absence of maxillary deciduous canines and history of previous orthodontic treatment. Informed consent was obtained from the patients and their parents or legal guardians before recruitment.

Interventions

The patients were randomly allocated into two study groups. The EDO group was treated with the expander with differential opening (n=24; Figures 1A to 1D), and the FE group was treated with the fan-type expander (n=24; Figures 1E to 1H). All patients from both groups were treated by the same orthodontist (CM). In both groups, orthodontic bands were adapted on the maxillary second deciduous molars, clasps were bonded on the maxillary deciduous canines and a wire extension was soldered on the palatal aspect of the first permanent molars (Figure 1).

The anterior and posterior screws of the EDO (Peclab Ltda., Belo Horizonte, MG, Brazil) were concurrently activated for six days, with an activation protocol of 1/2 turn in the morning and 1/2 turn in the evening. Afterwards, only the anterior screw was activated for 4 additional days following the same activation protocol. The amount of expansion was 8 mm and 4.8 mm in the anterior and posterior screw, respectively.

The screw of the FE (Morelli Ortodontia, Sorocaba, SP, Brazil) was activated 1/2 turn in the morning and 1/2 turn in the evening for 10 days, resulting in a screw expansion of 8 mm. In both groups, after a 10-day active phase, the expander was kept in the mouth as a retainer for 6 months. At the end of the retention phase, the expander was removed, and a removable retention plate was installed.

The 3D Accuitomo CBCT scanner (J. Morita Corp, Kyoto, Japan) was used to acquire CBCT scans at 2 time points for each patient. The image acquisition protocol was adjusted to reduce ionizing radiation effects, with 90Kvp, 7mA, FOV 12 cm, lower exposure time allowed of 17.5 seconds, and larger voxel size of 0.3mm, following the ALADAIP principles.[23] The first CBCT scan was obtained before treatment and the second scan after the active phase with a maximum 6-month interval between T1 and T2. Images were saved in DICOM format.

Outcomes (primary and secondary) and any changes after trial commencement

The primary outcomes were maxillary lateral, anteroposterior and vertical displacements, maxillary rotation, and changes in the molars and canines buccolingual inclination.

The 3D analysis was performed using the two open-source software ITK-SNAP, version 2.4.0 (www.itksnap.org),[24] and 3D Slicer, version 4.10.2 (www.slicer.org).[25] The following previously validated steps[26-28] for image analysis were performed:

1. Construction of the 3D volumetric label maps (segmentations) and 3D surface models (vtk files) of the T1 scans: ITK-SNAP and 3D Slicer software (Intensity Segmenter and Model Maker tools);
2. Head orientation of the T1 model: 3D Slicer (Transforms tool). The 3D model from each patient at T1 was oriented to a standardized fixed coordinate system using as a reference the Frankfurt plane (bilateral Orbitale and Porion) perpendicular to the midsagittal plane (Glabella, Crista Galli and Basion).[26] The matrix generated from this process was saved and applied to the T1 scans and segmentations;
3. Approximation: 3D Slicer (Transforms tool). The T2 scan was moved to to reach the best fit superimposition of the cranial base in relation to the oriented T1 scan;[27]
4. Construction of 3D volumetric label maps of the approximated T2 scans: ITK-SNAP and 3D Slicer (Intensity Segmenter and Model Maker tools);
5. Voxel-based registrations of the cranial base: 3D Slicer (Growing Registration on the CMF Registration tool). The software automatically superimposes the approximated T2 scan over the oriented T1 scan, using cranial base as reference;[27]
6. Pre-labelling: ITK-SNAP. The T1 oriented and T2 registered segmentations were cleaned, and the mandible was removed to facilitate the placing of the landmarks by changing the color of the label without modifying the anatomy.[28] The following landmarks were placed: right and left orbitale (Or_R and Or_L), right and left zygomatic (Zyg_R and Zyg_L), right and left nasal cavity (NC_R and NC_L), right and left palatine foramen (PF_R and PF_L), right and left apex of the mesial root of the maxillary first permanent molars (M'_R and M'_L), right and left root apex of the maxillary deciduous canines (C'_R and C'_L,),

right and left mesiobuccal cusp tip of the maxillary first permanent molars (M_R and M_L), right and left cusp tip of the maxillary deciduous canines (C_R and C_L), anterior nasal spine (ANS) and posterior nasal spine (PNS), as showed in Figure 2;

7. Generation of the T1 and T2 3D surface models with landmarks: 3D Slicer (Model Maker tool). 3D models were generated for the segmented skull and the pre-labelled landmarks for both T1 and T2 files of each patient;
8. Quantitative assessments: 3D Slicer (Quantification of 3D Components, Q3DC, tool). Anterior, inferior and lateral displacements as well as expansion, buccal inclination and clockwise rotation were considered positive values.

The maxillary lateral displacement comprised the changes in the distance between Or_R and Or_L, NC_R and NC_L, Zyg_R and Zyg_L, PF_R and PF_L, M_R and M_L and C_R and C_L. For the assessment of the maxillary AP and SI displacements, midpoints were generated for the following bilateral landmarks: orbitale (Or_M), nasal cavity (NC_M), zygomatic (Zyg_M), palatine foramen (PF_M), cusp tip of the maxillary first permanent molars (M_M) and cusp tip of the maxillary deciduous canines (C_M). Angular measurements were used to assess the maxillary rotation and the changes in the molar and canine buccolingual inclination. The vertical maxillary rotation was assessed through the pitch changes in the palatal plane (ANS-PNS). The lateral maxillary rotation was calculated considering the roll changes of the angle formed by the right and left orbitale-zygomatic lines (Or_R-Zyg_R / Or_L-Zyg_L). Changes in the molar and canine buccolingual inclination were measured comparing the T1-T2 roll angle of the tooth long axis relative to the Or-Zyg line on right and left sides.

Sample size calculation

The sample size was calculated based on a preliminary statistic including the first 10 patients of the sample (5 from each group). For a standard deviation of 0.58 for the intercanine distance changes and to detect a minimal difference of 0.5mm between the two study groups, a sample of 23 patients in each group was required to provide a statistical power of 80% and an alpha error of 5%.

Interim analyses and stopping guidelines

Not applicable.

Randomization (random number generation, allocation concealment, implementation)

Randomization was performed by an external collaborator using the Web site Randomization.com (http://www.randomization.com).[29] The software generated a randomization list, ensuring equal distribution in both groups. The 48 patients were randomized before trial commencement.

Allocation concealment was achieved with sequentially numbered, opaque, sealed envelopes, containing the treatment allocation cards. In addition, opacity was implemented by inserting the card with the assignment into foil. The envelopes containing the name of the expander were prepared before trial commencement and were sequentially opened for each participant during the recruitment. The initials of the name of the participant were written on the envelope before opening it.

The randomization process, allocation concealment and implementation were performed independently by different researchers.

Blinding

Blinding during treatment was not possible for the orthodontist and patient since both knew the type of maxillary expander that was installed. However, the study design was blinded during analysis since data was unidentified before assessment.

Statistical analyses (primary and secondary outcomes, subgroup analyses)

One orthodontist (CM) performed all the measurements and 30% of the sample was assessed twice after a 30-day interval. The intra-rater error was assessed using intraclass correlation coefficients (ICC).[30]

Normal distribution of the variables was verified with Shapiro-Wilk tests. Intergroup comparisons regarding age and sex were performed with t and Chi square tests, respectively. T tests or Mann-Whitney U tests with Holm-Bonferroni correction were used for intergroup comparisons. All statistical analyses were performed using IBM SPSS Statistics for Mac, version 24.0 (Armonk, NY: IBM Corp.). The level of significance considered was 5%.

RESULTS

Participant flow

A total of 300 participants were recruited and 252 patients were excluded (240 have not met the inclusion criteria and 12 declined to participate). Forty-eight patients were selected and randomized in a 1:1 ratio into two study groups. All 48 participants completed the study, 24 patients in the EDO group and 24 patients in the FE group. Figure 3 shows the participants' flow chart.

Baseline data

Demographic characteristics of each group at baseline are presented in Table I. Both groups were similar regarding sex, age and interorbitale, interzygomatic, intermolar and intecanine distances at baseline (Table I).

Numbers analyzed for each outcome, estimation and precision

No patients were lost during the study. Rapid maxillary expansion was performed in 24 patients in the EDO group with expander with the differential opening and in 24 patients in the FE group with the fan-type expander. The patients of the EDO and FE groups were properly analyzed in their original assigned groups. All patients in both groups showed a midpalatal suture split.

Intra-rater reliability varied from very good to excellent, with an intraclass correlation coefficient ranging from 0.76 to 0.99.[31]

Intergroup comparison is shown in Table II. The EDO promoted a greater expansion when compared with FE, except for the intercanine distance (Table II). The maxillary vertical and anteroposterior displacements were similar in both groups (Table II). Palatal plane rotation (ANS-PNS) was similar for both groups while the lateral maxillary rotation (Or_R-Zyg_R – Or_L-Zyg_L) was slightly greater in EDO group (Table II).

Molar and canine buccal inclination changes were greater in the EDO and FE groups, respectively. Figure 4 and 5 shows the cranial base superimposition for a patient from group EDO and FE, respectively.

Harms

No important harm was caused to the participants of this study. Molar crossbite was still present in 6 out of 24 patients in the FE group. These patients were assigned for a second intervention with slow maxillary expansion after the evaluation period.

DISCUSSION

Main findings in the context of the existing evidence, interpretation

The evaluation of maxillary constriction prior to treatment is required to determine whether the patient presents different severities of transverse deficiency at the level of the canine compared to the molar regions. The outcomes of expansion depending on the appliance design should be taken into account to guide treatment planning. Both EDO and FE caused a differential expansion between the anterior and the posterior maxillary arch widths.[8,10,12,14] Previous studies showed that both the EDO and FE demonstrated greater intercanine expansion when compared with conventional expanders.[8,10,12,14] The present study intended to elucidate the three-dimensional dentoskeletal differences between EDO and FE.

In the present study, to overcome the limitations of a two-dimensional assessment, CBCT scans were used. CBCT imaging allows to assess skeletal changes in craniofacial imaging analysis, demonstrating high accuracy and reliability.[32,33] CBCT scans have lower cost, lower radiation dose and less metallic artifacts compared to helical CT.[34,35] The use of CBCT scans in this study allowed the assessment of the maxillary 3D displacements relative to the cranial base. A previous systematic review evaluating RME outcomes in growing patients showed that both CT and CBCT are useful tools to assess the three-dimensional expansion effects.[20] Among the advantages, the quantification of the lateral changes in the zygomatic bone region, not possible in a bidimensional image, was successfully demonstrated in the present 3D assessment. CBCT replaced the initial and postexpansion orthodontic records. Many previous studies used CBCT to evaluate RME outcomes in growing patients.[9,17-19,21] Additionally, the good to excellent intra-rater reliability showed that the method was reliable.

The results of the intergroup comparison for initial age, sex ratio and maxillary widths at baseline (Table I) confirmed the sample homogeneity and ensured an effective randomization and allocation of the patients, minimizing the risk of bias in intergroup comparisons.[36] The activation amount was also standardized to ensure a viable intergroup comparison.

The present study outcomes confirm that both EDO and FE are capable of producing orthopedic effects (Table II and Figures 4 and 5). The EDO promoted a statistically significant greater increase in all transverse skeletal distances including the interzygomatic (Zyg-Zyg) and interorbital (Or-Or) distances (Table II). The greatest intergroup skeletal difference was observed for the interpalatine foramen distance (PF-PF) that increased on average 1.19mm more in the EDO group (Table II). The skeletal expansion at the level of palatine foramen was approximately 26% of the anterior screw activation in the EDO group and 11% of the screw activation in the FE group. In addition, the treatment with EDO led to a slightly greater and statistically significant lateral rotation of the maxillary halves (Or_R-Zyg_R - Or_L-Zyg_L) than treatment with FE (Table II). These intergroup differences are probably due to the posterior screw activation of EDO. Previous studies with anteroposterior cephalometric radiographs showed a greater maxillary and nasal cavity expansion for Hyrax expander compared to fan-type expander.[8,10] No previous study using CBCT scans has assessed outcomes of the fan-type expander in noncleft patients. A previous study using CBCT in a sample of individuals with cleft lip and palate also demonstrated that fan-type expanders produced a slight less maxillary transverse increase compared to Hyrax expanders.[11] A previous RCT comparing EDO and Hyrax expanders using occlusal radiographs showed a greater midpalatal suture split in the anterior region for the EDO.[12] On the other hand, a previous CBCT study in patients with cleft lip and palate demonstrated similar nasal cavity and maxillary width changes of EDO and Hyrax expanders.[37] A nasal cavity expansion of an average of 3.09 and 2.28mm was observed in EDO and FE groups, respectively, supporting the theory that maxillary expansion can expand the nasal cavity improving the nasal breathing.[1-3,6] The nasal cavity expansion was slightly greater in EDO group, and further studies should evaluate the functional impact of these changes in pediatric obstructive sleep apnea.

The intermolar expansion was twice greater in the EDO group (Table II). These intergroup differences are explained by the expansion of the posterior screw in EDO. Interestingly, in the FE group, although the amount of expansion in the intermolar distance was smaller (mean 2.51mm), 16 out of 24 patients displayed the correction of the molar crossbite after expansion. Previous studies comparing the Hyrax expander and the FE using digital dental models showed a greater increase in the intermolar distance in the conventional expansion group.[8,10] Conversely to intermolar distance, the intercanine distance had a slightly greater increased in the FE group compared to the EDO group (Table II). The difference between groups was small (mean 0.78mm) and a possible explanation is the greater canine buccal inclination observed in the FE group when compared to the EDO group (Table II).

No intergroup difference was observed for the maxillary sagittal and vertical effects relative to the cranial base (Table II). The anteroposterior and superoinferior maxillary displacements were mild in both groups. The anterior displacement of the anterior nasal spine, nasal cavity and palatine foramen showed that the nasomaxillary complex moved slightly forward in both groups (Table II; Figures 4 and 5). The inferior displacement of maxillary skeletal landmarks showed a slight downward movement of the maxilla with a negligible clockwise rotation of the palatal plane (less than 1^{o} using both EDO and FE). Facial growth might have had a limited influence on the sagittal and vertical displacements observed in this study considering the short T1-T2 interval. Additionally, previous studies assessing the RME outcomes reported a slight downward and forward maxillary displacements right after RME.[1-6,8,20,21] With the midpalatal suture split, the wider maxilla is moved forward and downward.[1-3,17,18] Our results showed that independently of the geometry of screw expansion, the maxilla was similarly displaced in the vertical and sagittal directions.

To assess pure dental buccolingual inclination regardless maxillary movements, an angle between the long axis of the molars and canines (M´-M and C´-C) and a maxillary line (Or-Zyg) was used in both sides. The average between right and left side changes was used for the intergroup comparison. Both permanent first molars and deciduous canines showed a buccal inclination after the expansion in both the EDO and FE groups (Table II). Previous studies reported buccal inclination in the anchorage teeth after expansion procedure with both EDO and FE.[11,12] A greater molar buccal inclination was observed in the EDO group and can be explained by the greater posterior activation in this expander. However, the slightly greater canine buccal inclination in the FE group is harder to explain since the anterior activation was the same in both study groups. A possible explanation is that the posterior hinge in the FE concentrates the activation force in the canine region during the complete active phase of the expansion. In a different manner, the activation of both anterior and posterior screws in the EDO group during the first 6 days of activation better distributes the expansion force between molars and canines, concentrating the stress on the canines only in the final period of activation. Future investigations using finite element analysis may compare the stress distribution between EDO and FE to clarify this assumption.

A previous study assessing the dental arch morphology in patients with maxillary constriction revealed that one third of the patients display a greater constriction in the anterior region of the arch.[38] Both fan-shape and differential expanders are alternative options when a greater intercanine expansion is required. In cases with significant need for intermolar expansion, EDO should be preferred. Further evaluation of the influence of expander design on the changes of nasal air permeability and pediatric sleep apnea index might also contribute to expander type choice in the mixed dentition.

Limitations

One limitation of the study is the absence of a conventional expander group to compare the outcomes. Further studies should compare EDO and FE with the conventional expander and evaluate the functional impact of the orthopedic differences observed after RME.

Generalizability

The results of the present study can be generalized to non-cleft patients in the mixed dentition. Additionally, the generalizability of the results should be limited to similar expanders using the same activation amount and protocol.

CONCLUSION

- In the mixed dentition, the expander with differential opening showed a greater maxillary lateral displacement compared with the fan-type expander, at the level of the palate, nasal cavity, zygomatic bone and orbit.
- Maxillary vertical and anteroposterior displacements as well as palatal plane rotation were similar for both expander types.
- The intercanine distance increase and the canine buccal inclination were greater for the fan-type expander.
- The intermolar distance increase and the molar buccal inclination were greater for the differential expander.

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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;31:73-90.
2. Haas AJ. The Treatment of Maxillary Deficiency by Opening the Midpalatal Suture. Angle Orthod 1965;35:200-217.
3. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod 1970;57:219-255.
4. da Silva Filho OG, Boas MC, Capelozza Filho L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1991;100:171-179.
5. Akkaya S, Lorenzon S, Ucem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. Eur J Orthod 1999;21:175-180.

6. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004;126:569-575.

7. Lagravere MO, Major PW, Flores-Mir C. Long-term skeletal changes with rapid maxillary expansion: a systematic review. Angle Orthod 2005;75:1046-1052.

8. 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;74:184-194.

9. Weissheimer A, de Menezes LM, Mezomo M, Dias DM, de Lima EMS, Rizzatto SMD. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2011;140:366-376.

10. Corekci B, Goyenc YB. Dentofacial changes from fan-type rapid maxillary expansion vs traditional rapid maxillary expansion in early mixed dentition. Angle Orthod 2013;83:842-850.

11. Figueiredo DS, Bartolomeo FU, Romualdo CR, Palomo JM, Horta MC, Andrade I, Jr. et al. Dentoskeletal effects of 3 maxillary expanders in patients with clefts: A cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2014;146:73-81.

12. de Medeiros Alves AC, Janson G, Mcnamara Jr JA, Lauris JRP, Garib DG. Maxillary expander with differential opening vs Hyrax expander: A randomized clinical trial. Am J Orthod Dentofacial Orthop 2020;157:7-18.

13. Cozza P, De Toffol L, Mucedero M, Ballanti F. Use of a modified butterfly expander to increase anterior arch length. J Clin Orthod 2003;37:490-495.

14. Garib D, Garcia L, Pereira V, Lauris R, Yen S. A rapid maxillary expander with differential opening. J Clin Orthod 2014;48:430-435.

15. Camporesi M, Franchi L, Doldo T, Defraia E. Evaluation of mechanical properties of three different screws for rapid maxillary expansion. Biomed Eng Online 2013;12:128.

16. 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;75:548-557.

17. Leonardi R, Sicurezza E, Cutrera A, Barbato E. Early post-treatment changes of circumaxillary sutures in young patients treated with rapid maxillary expansion. Angle Orthod 2011;81:36-41.
18. Leonardi R, Cutrera A, Barbato E. Rapid maxillary expansion affects the spheno-occipital synchondrosis in youngsters. A study with low-dose computed tomography. Angle Orthod 2010;80:106-110.
19. Pangrazio-Kulbersh V, Wine P, Haughey M, Pajtas B, Kaczynski R. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. Angle Orthod 2012;82:448-457.
20. Bazargani F, Feldmann I, Bondemark L. Three-dimensional analysis of effects of rapid maxillary expansion on facial sutures and bones. Angle Orthod 2013;83:1074-1082.
21. 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 Dentofacial Orthop 2013;144:398-403.
22. Schulz KF, Altman DG, Moher D, Group C. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMC Med 2010;8:18.
23. Oenning AC, Jacobs R, Pauwels R, Stratis A, Hedesiu M, Salmon B et al. Cone-beam CT in paediatric dentistry: DIMITRA project position statement. Pediatr Radiol 2018;48:308-316.
24. Yushkevich PA, Gerig G. ITK-SNAP: An Intractive Medical Image Segmentation Tool to Meet the Need for Expert-Guided Segmentation of Complex Medical Images. IEEE Pulse 2017;8:54-57.
25. Slicer D. Available at: https://download.slicer.org/ Last accessed at 3 June 2019.
26. Ruellas AC, Tonello C, Gomes LR, Yatabe MS, Macron L, Lopinto J et al. Common 3-dimensional coordinate system for assessment of directional changes. Am J Orthod Dentofacial Orthop 2016;149:645-656.
27. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop 2006;129:611-618.
28. Ruellas AC, Huanca Ghislanzoni LT, Gomes MR, Danesi C, Lione R, Nguyen T et al. Comparison and reproducibility of 2 regions of reference for maxillary

regional registration with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2016;149:533-542.

29. Pandis N. Randomization. Part 1: sequence generation. Am J Orthod Dentofacial Orthop 2011;140:747-748.
30. Fleiss JL. Analysis of data from multiclinic trials. Control Clin Trials 1986;7:267-275.
31. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med 2016;15:155-163.
32. Ludlow JB, Laster WS, See M, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy in cone beam computed tomography images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:534-542.
33. Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. J Periodontol 2006;77:1261-1266.
34. Loubele M, Van Assche N, Carpentier K, Maes F, Jacobs R, van Steenberghe D et al. Comparative localized linear accuracy of small-field cone-beam CT and multislice CT for alveolar bone measurements. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:512-518.
35. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75-80.
36. Berger VW, Exner DV. Detecting selection bias in randomized clinical trials. Control Clin Trials 1999;20:319-327.
37. Garib D, Lauris RDCMC, Calil LR, Alves ACDM, Janson G, De 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;150:564-574.
38. Belluzzo RHL, Faltin Junior K, Lascala CE, Vianna LBR. Maxillary constriction: are there differences between anterior and posterior regions? Dental Press J Orthod 2012;17:1-6.

Legend of figures

Fig 1. Expander with differential opening (A-D) and fan-type expander (E-H).

Fig 2. 3D models illustrating the pre-labelled landmarks: right and left orbitales (Or_R and Or_L), placed at the lowest point in the inferior margin of the right and left orbitals; right and left zygomatic (Zyg_R and Zyg_L), placed at the most inferior portion of the right and left zygomatic bones; right and left nasal cavity (NC_R and NC_L), placed at the most inferior and external point of the concavity of the right and left nasal cavity; right and left palatine foramen (PF_R and PF_L), placed at the middle and most inferior point of the right and left palatine foramen; right and left apex of the mesial root of the maxillary first permanent molars (M'_R and M'_L); right and left root apex of the maxillary deciduous canines (C'_R and C'_L); right and left cusp tip of the mesiobuccal cusp of the maxillary first permanent molars (M_R and M_L); right and left cusp tip of the maxillary deciduous canines (C_R and C_L); posterior nasal spine (PNS) and anterior nasal spine (ANS).

Fig 3. Patient flow chart according to Consolidated Standards of Reporting Trial.

Fig 4. Cranial base superimposition of the pre- (white) and post- (red) expansion 3-dimensional surface models in an anterior, lateral and inferior view of a patient treated with the expander with differential opening.

Fig 5. Cranial base superimposition of the pre- (white) and post- (green) expansion 3-dimensional surface models in an anterior, lateral and inferior view of a patient treated with the fan-type expander.

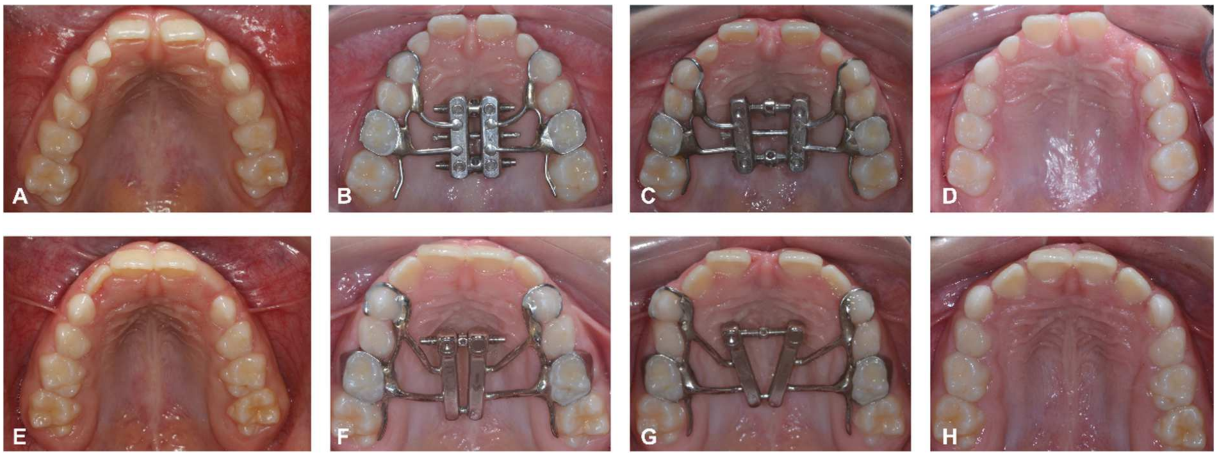

Fig. 1

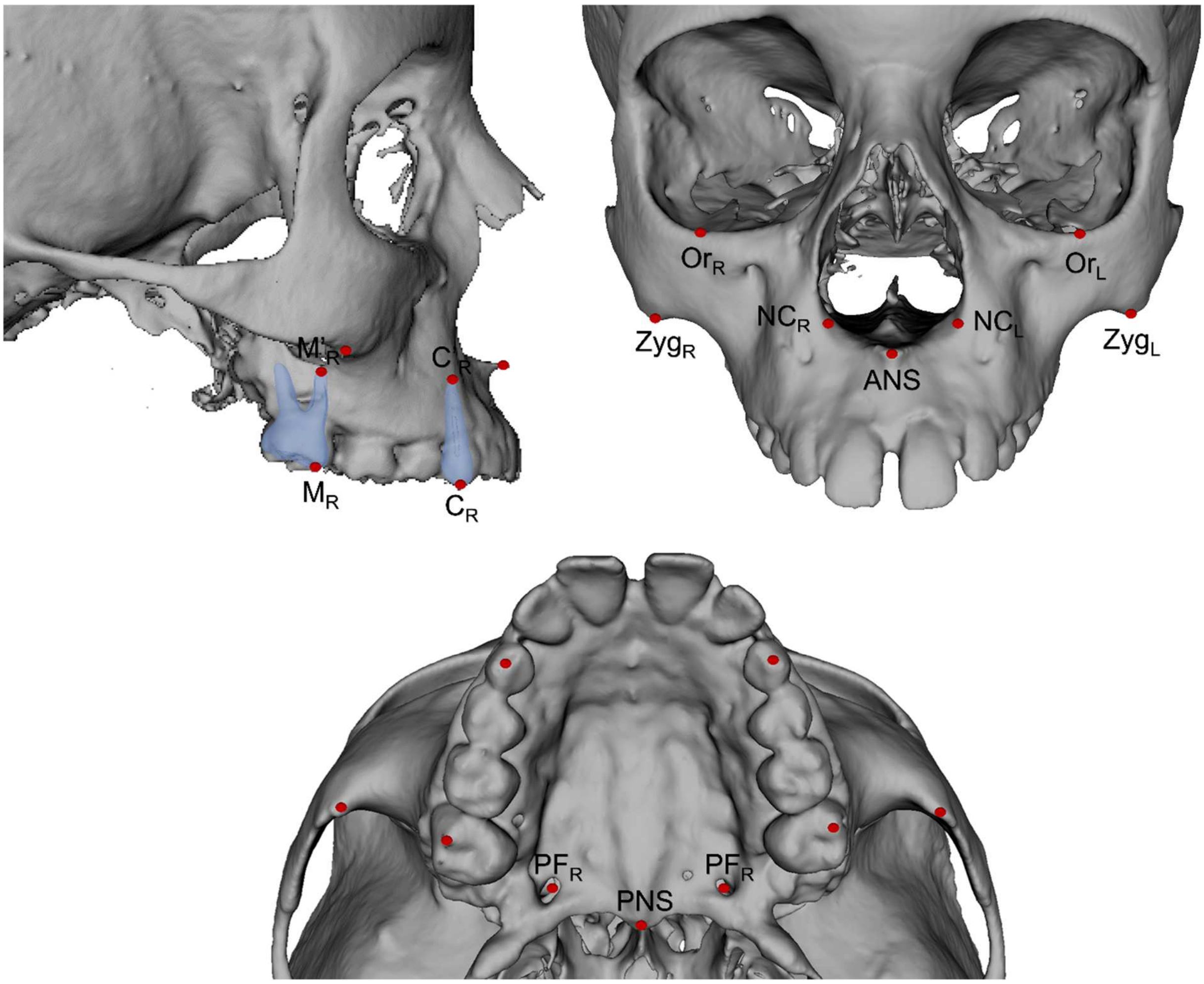

Fig 2.

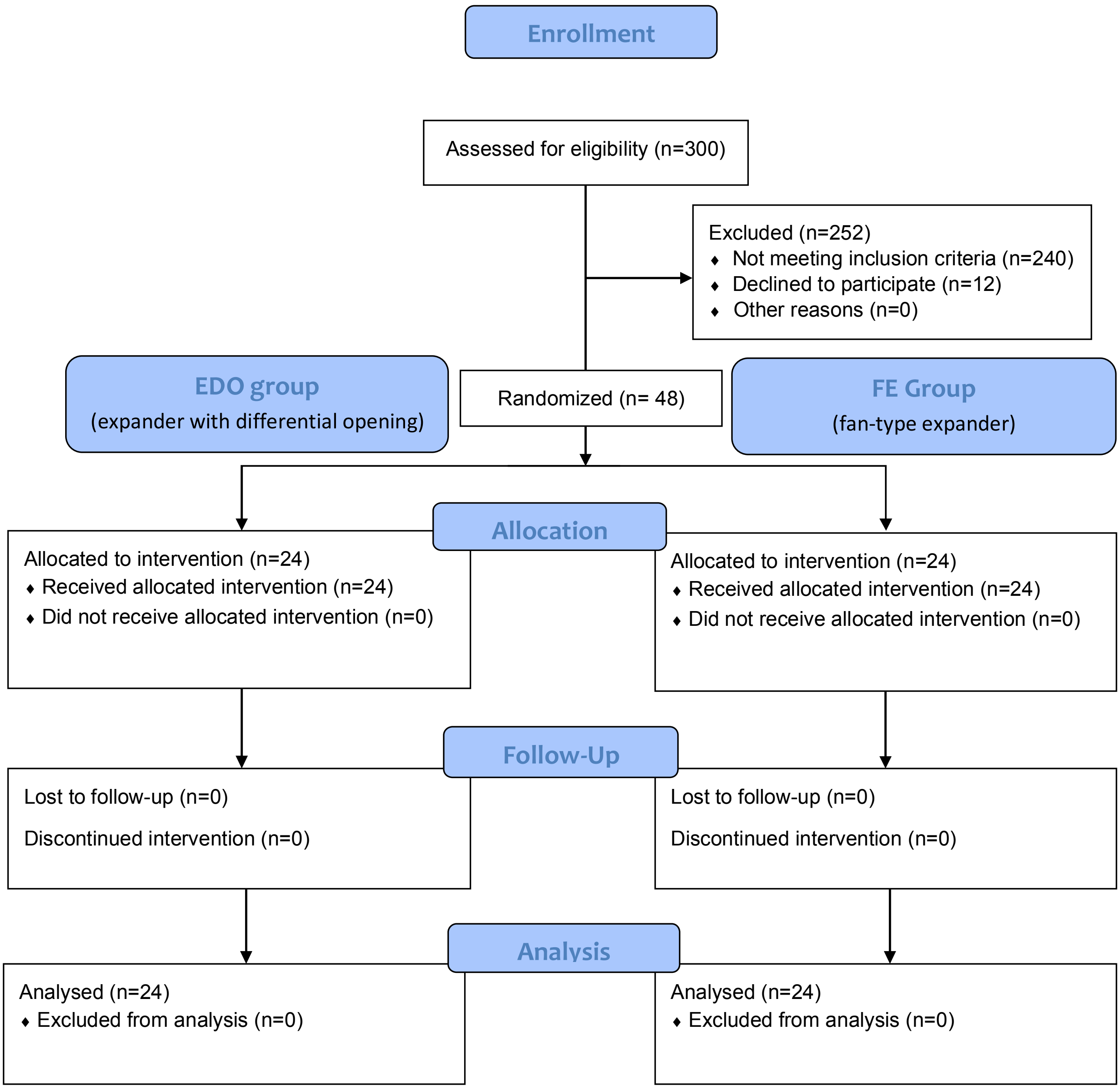
Enrollment
Assessed for eligibility (n=300)
Excluded (n=252)
Not meeting inclusion criteria (n=240)
Declined to participate (n=12)
Other reasons (n=0)
EDO group
(expander with differential opening)
Randomized (n= 48)
FE Group
(fan-type expander)
Allocation
Allocated to intervention (n=24)
Received allocated intervention (n=24)
Did not receive allocated intervention (n=0)
Allocated to intervention (n=24)
Received allocated intervention (n=24)
Did not receive allocated intervention (n=0)
Follow-Up
Lost to follow-up (n=0)
Discontinued intervention (n=0)
Lost to follow-up (n=0)
Discontinued intervention (n=0)
Analysis
Analysed (n=24)
Excluded from analysis (n=0)
Analysed (n=24)
Excluded from analysis (n=0)

Fig 3.

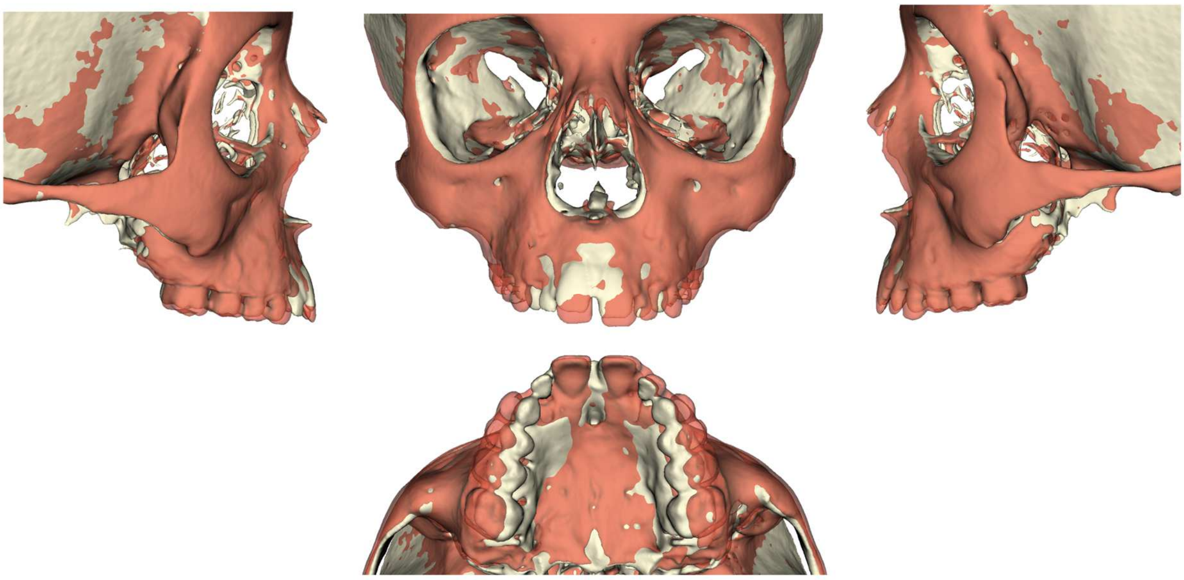

Fig 4.

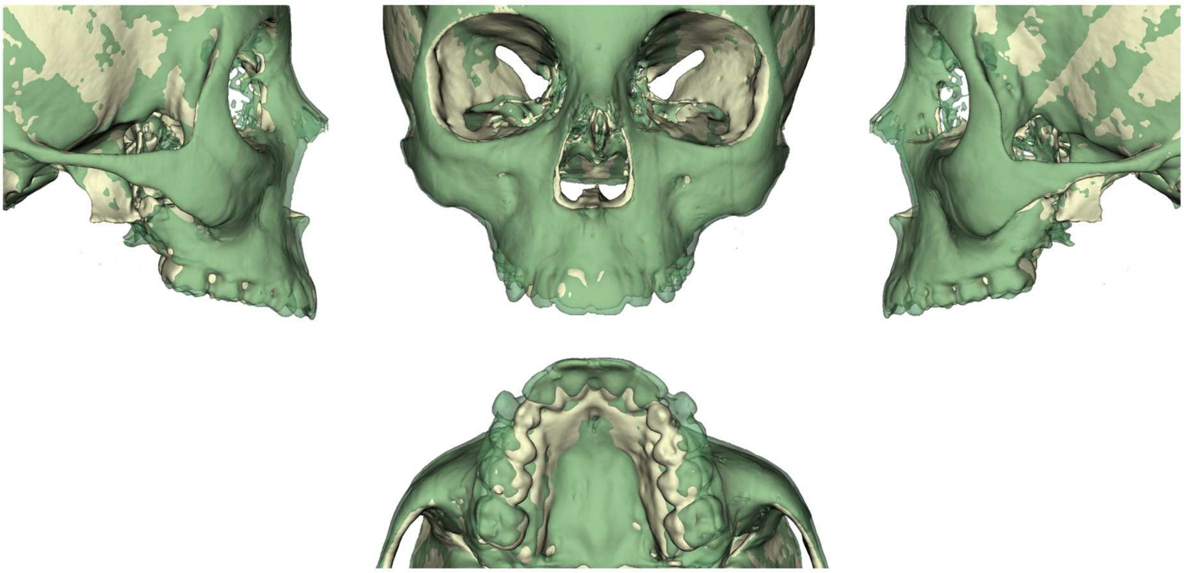

Fig 5.

Table I. Intergroup comparisons for sex ratio, age and maxillary widths at baseline (t test and Chi-square test).

Variable		**EDO n=24 Mean (SD)**	**FE n=24 Mean (SD)**	***P***
Initial Age *(y)*		7.62 (0.92)	7.83 (0.96)	0.448†
Sex	**Female**	13 (54.2%)	14 (58.3%)	0.771§
	Male	11 (45.8%)	10 (41.7%)	
Or_R-Or_L		63.54 (4.91)	64.03 (3.67)	0.701†
Zyg_R-Zyg_L		78.88 (4.20)	77.01 (3.22)	0.091†
M_R-M_L		49.61 (2.70)	48.26 (2.55)	0.084†
C_R-C_L		30.24 (2.91)	29.78 (2.36)	0.549†

†t test; §Chi-square test; P<0.05; Or, orbitale; Zyg, zygomatic; M, first permanent molars; C, deciduous canines; R, right; L, left.

Table II. Intergroup comparisons for treatment changes (t or Mann-Whitney U tests).

Variable		EDO n=24 Mean (SD)	FE n=24 Mean (SD)	Difference (SD)	P
Lateral Displacements (mm)	Or_R-Or_L	1.50 (0.47)	1.00 (0.50)	0.49 (0.14)	0.001†*
	NC_R-NC_L	3.09 (0.62)	2.28 (1.03)	0.80 (0.24)	0.002†*
	Zyg_R-Zyg_L	3.63 (0.46)	1.65 (0.52)	0.97 (0.14)	<0.001†*
	PF_R-PF_L	2.12 (0.50)	0.92 (0.30)	1.19 (0.12)	<0.001†*
	M_R-M_L	5.03 (1.09)	2.51 (0.75)	2.51 (0.27)	<0.001†*
	C_R-C_L	8.16 (1.03)	8.95 (1.36)	-0.78 (0.34)	0.011‡*
Sagittal Displacements (mm)	Or_m	0.27 (0.19)	0.23 (0.17)	0.03 (0.05)	0.386‡
	NC_m	0.80 (0.27)	0.82 (0.46)	-0.02 (0.10)	0.829†
	Zyg_m	-0.12 (0.22)	-0.14 (0.28)	0.01 (0.07)	0.810†
	PF_m	0.51 (0.26)	0.45 (0.39)	0.06 (0.09)	0.140‡
	M_m	0.18 (0.64)	0.11 (0.45)	0.07 (0.16)	0.643†
	C_m	1.34 (0.70)	1.58 (0.70)	-0.23 (0.20)	0.250†
	ANS	0.75 (0.38)	0.74 (0.51)	0.00 (0.13)	0.982†
Vertical Displacements (mm)	Or_m	0.10 (0.18)	0.08 (0.13)	0.01 (0.04)	0.570‡
	NC_m	0.58 (0.41)	0.47 (0.39)	0.10 (0.11)	0.397‡
	Zyg_m	0.04 (0.17)	0.10 (0.23)	-0.05 (0.05)	0.316†
	PF_m	1.03 (0.40)	0.88 (0.46)	0.15 (0.12)	0.215†
	M_m	0.35 (0.34)	0.56 (0.35)	-0.21 (0.10)	0.043†
	C_m	0.47 (0.41)	0.27 (0.55)	0.19 (0.14)	0.165†
	ANS	1.09 (0.28)	0.93 (0.34)	0.16 (0.09)	0.068†
Angular changes (º)	ANS-PNS	0.46 (0.35)	0.64 (0.42)	-0.17 (0.11)	0.120†
	Or_R-Zyg_R / Or_L-Zyg_L	3.43 (1.80)	2.21 (1.21)	1.22 (0.44)	0.009†*
	Or-Zyg / M´-M	2.19 (1.28)	1.27 (0.71)	0.92 (0.30)	0.004†*
	Or-Zyg / C´-C	5.01 (2.25)	8.09 (3.70)	-3.08 (0.88)	0.001†*

†t test; ‡Mann-Whitney U test; P<0.05; *Statistically significant after Holm-Bonferroni correction. SD, standard deviation; Or, orbitale; NC, nasal cavity; PF, palatine foramen; Zyg, zygomatic; M, first permanent molars cusp tip; C, deciduous canines cusp tip; M´, first permanent molars root apex; C´, deciduous canines root apex; $_m$, midpoint; $_R$, right; $_L$, left.

2.2 ARTICLE 2

DENTAL ARCH COMPARISON BETWEEN EXPANDER WITH DIFFERENTIAL OPENING AND FAN-TYPE EXPANDER: A RANDOMIZED CLINICAL TRIAL

ABSTRACT

Introduction: The aim of this randomized clinical trial was to compare the maxillary and mandibular dentoalveolar changes of the expander with differential opening (EDO) and the fan-type expander (FE) in the mixed dentition. **Methods:** Patients aged from 7 to 11 years old with maxillary constriction were randomly allocated into 2 study groups. The EDO group was composed by 24 patients (13 female, 11 male; mean age of 7.62 years) treated with the expander with differential opening. The FE group was composed by 24 patients (14 female, 10 male; mean age of 7.83 years) treated with the fan-type expansion. A simple randomization process was performed. Digital dental models were acquired for each patient before treatment (T1) and 6 months after rapid maxillary expansion (T2). The primary outcomes were the changes in the maxillary interincisal diastema, maxillary and mandibular changes in arch width, arch perimeter, arch length and arch size. Arch shape and the amount of differential expansion were considered secondary outcomes. Intra-rater reliability was tested using Intraclass Correlation Coefficient. Comparisons between EDO and FE were performed using t tests with Holm-Bonferroni correction ($P<0.05$). **Results:** Both groups demonstrated similar changes in the maxillary interincisal diastema width. The EDO showed greater increases in the maxillary inter-second deciduous and inter-first permanent molars distances. The increase in the intercanine distance was slightly greater in the FE group. Changes in the mandibular arch were mild and similar in both groups for most of the variables, except for the inter-first permanent molars distance that showed a slight greater increase in the EDO group. Maxillary and mandibular arch length and arch perimeter changes were similar in both groups. The FE group showed a greater differential expansion between anterior and posterior arch widths. Maxillary arch shape changed significantly for both differential and fan-type expanders. The posttreatment arch shape was different between groups with a larger anterior width for FE and a larger posterior width for EDO. **Conclusions:** Maxillary arch width and shape changes were distinct between EDO and FE. A greater transversal increase of the anterior and

posterior regions was observed for FE and EDO, respectively. A slightly greater mandibular spontaneous expansion was observed for EDO only at the molar region.
Registration: This trial was registered at ClinicalTrials.gov (ID, NCT03705871). **Protocol:** The protocol was not published **Funding:** This research was supported by the São Paulo Research Foundation – FAPESP (grant #2017/12911-9 and #2017/24115-2) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

KEYWORDS: Orthodontics. Palatal expansion technique. Orthodontic appliance design. Imaging, Three-Dimensional. Dental models.

INTRODUCTION

Maxillary constriction and posterior crossbites are common conditions in pediatric orthodontic patients. The interceptive treatment starting in the mixed dentition is highly recommended since posterior crossbites do not self-correct.[1] The rapid maxillary expansion (RME) is a viable option to treat maxillary constriction and posterior crossbites.[2-5] A wide variety of appliance designs can be used for producing the midpalatal suture split with successful correction of maxillary constriction.[2,6-8]

Conventional expanders promote a transverse increase in the maxillary arch by means of a parallel opening of the expander screw positioned on the center of the palate.[2,9] Similar increases in the intercanine and intermolar distances were found after RME with Haas-type and Hyrax expanders.[10,11] The fan-type expander (FE) can be indicated when an increase in the anterior arch width with minimal effects in the molar region is desired.[10,12,13] More recently, the expander with differential opening (EDO) was proposed to treat the maxillary constriction individualizing the expansion in the anterior and posterior regions of the dental arch.[4,6,11]

Previous studies compared the Hyrax and fan-type expanders outcomes demonstrating that the intercanine distance increase was similar in both groups, while a greater increase in the intermolar distance was found for the Hyrax expander.[10,12] A previous comparison between Hyrax and the expander with differential opening showed a similar inter-molar expansion in both groups and a greater intercanine expansion for EDO.[11]

Patients with cleft lip and palate and noncleft individuals can demonstrate a greater constriction in the anterior region of the dental arch.[4,14-16] In this scenario, a greater expansion in the anterior region of maxillary dental arch should be indicated in order to avoid an over and undesired expansion in the molar region. However, no previous no previous studies compared the FE with the EDO guiding the clinician in the expander selection.

A spontaneous dentoalveolar expansion might be expected in the mandibular arch after a rapid maxillary expansion procedure.[2,17,18] A recent systematic review concluded that negligible short and long-term spontaneous dentoalveolar changes occur in the mandibular dental arch after RME in the mixed and early permanent dentitions.[19] No previous study assessed the spontaneous mandibular dental arch changes with the EDO and FE.

Considering the above-mentioned concerns, some questions remain: is there difference between EDO and FE for the maxillary arch dimensions changes? Is the arch shape influenced by the different appliances design? Does the EDO and FE induce similar spontaneous changes in the mandibular arch dimensions and shape? No clinical study compared the expander with differential opening and the fan-type expander.

Specific objectives or hypotheses

The aim of this study was to compare the maxillary and mandibular dental arch changes of the expander with differential opening and the fan-type expander in the mixed dentition using digital dental models. The null hypothesis is that both expanders have similar dentoalveolar effects in the maxillary and mandibular arches.

METHODS

Trial design and any changes after trial commencement

This two-parallel arm was a single-center randomized clinical trial (RCT) with a 1:1 allocation ratio. Consolidated Standards of Reporting Trials (CONSORT) statement and guidelines were followed no changes were required after trial commencement.[20]

Participants, eligibility criteria, and settings

Ethical approval was obtained by the Research Institutional Board of Bauru Dental School, University of São Paulo, Brazil (Process number: 71648917.6.0000.5417) before trial commencement. In addition, the protocol of this study was registered at Clinicaltrials.gov with the identifier NCT03705871.

From November 2017 to June 2018, patients were recruited at the Orthodontic Clinic of Bauru Dental School, University of São Paulo, Brazil. Eligibility criteria included Class I and Class II patients from 7 to 11 years of age with maxillary constriction and posterior crossbites. Individuals with a Class III malocclusion, craniofacial syndromes, clinical absence of maxillary deciduous canines and history of previous orthodontic treatment were excluded.

Interventions

Participants who met the eligibility criteria were invited to participate. Informed consent was obtained from all patients and their parents or legal guardians. After recruitment, patients were randomized allocated into two study groups. The treatment of all patients was conducted by the same orthodontist (CM).

Group EDO comprised 24 patients (13 female, 11 male) with a mean age of 7.62 years (SD=0.92) treated with the expander with differential opening (EDO). The EDO was composed by two 10-mm screws, one posteriorly and the other anteriorly positioned on the palate (Peclab Ltda., Belo Horizonte, MG, Brazil). During the first 6 days of activation, both expander screws were activated two-quarter turns in the morning and two-quarter turns in the evening. For an extra 4 days, only the anterior screw was activated following the same activation protocol. The total expansion was 4.8 mm in the posterior screw and 8 mm in the anterior screw (Figure 1).

Group FE comprised 24 patients (14 female, 10 male) with a mean age of 7.83 years (SD=0.96) who underwent RME using the fan-type expander (FE). The FE was composed by one 11-mm screw anteriorly positioned on the palate (Morelli Ortodontia, Sorocaba, SP, Brazil). For 10 consecutively days, the expander screw was activated two-quarter turn in the morning and two-quarter turn in the evening, resulting in an expansion of 8mm in the screw (Figure 2).

In both groups, orthodontic bands were adapted on the right and left maxillary second deciduous molars. Claps were bonded on the right and left maxillary deciduous canines and a bilateral palatal extension from the maxillary second deciduous molars to the first permanent molars was added (Figures 1 and 2). After a 10-day active phase, the expander was kept as a retainer for 6 months. At the end of the retention phase, the expander was removed, and a removable retention plate was delivered.

Digital dental models of the maxillary and mandibular dental arches were obtained for each patient before (T1) and 6 months after RME (T2) using TRIOS 3 intraoral scanner (3 Shape, Copenhagen, Denmark). Digital dental models were saved in .stl file format.

Outcomes (primary and secondary) and any changes after trial commencement

The primary outcomes were the changes in the maxillary interincisal diastema, maxillary and mandibular arch widths at the level of deciduous canines (c-c), inter-first deciduous molars (d-d), inter-second deciduous molars (e-e) and inter-first permanent molar (6-6), arch perimeter, arch length and arch size. The amount of differential expansion in the maxillary anterior region compared with the posterior region and dental arch shape changes were considered secondary outcomes.

The width of the maxillary interincisal diastema was clinically measured immediately before the expansion and at the end of the active phase using an odontometric caliper (Precision equipment co., Boston, US) as showed in Figure 3.

The measurements of the maxillary and mandibular arch widths (Figure 4A), arch length (Figure 4B) and arch perimeter (Figure 4C) were performed on the pre- and post-expansion digital dental models using the OrthoAnalyzer 3D software (3Shape A/S, Copenhagen, Denmark).

For the dental arch size and shape analyses, 14 landmarks were placed on the occlusal surface of the T1 an T2 digital dental models of each patient using the software Stratovan Checkpoint (Stratovan Corporation, Davis, Calif, US), as showed in Figure 4D.[21] The x and z coordinates for each landmark were extracted and imported into the software MorphoJ (Klingenberg Lab, Manchester, UK). For arch size analysis, the centroid size of each dental arch was calculated from the raw coordinates and used as a dental arch size measurement.[21,22] Using the same coordinates, a Generalized Procrustes Analysis[21,23] was performed in the software MorphoJ to assess the maxillary and mandibular arch shapes. A mean shape of the dental arch was obtained for each group at the two timepoints and a Procrustes mean shape superimposition was performed.

Sample size calculation

For a standard deviation of 2.18 for the intercanine distance [11] change and to detect a minimal difference of 2.0 mm between the two groups, a sample of 20 patients was required to provide a statistical power of 80% and an alfa of 5%. Considering possible losses, 24 patients were selected in each group.

Interim analyses and stopping guidelines

Not applicable.

Randomization (random number generation, allocation concealment, implementation)

A simple electronically generated randomization was performed before trial commencement using the Web site Randomization.com (http://www.randomization.com).[24] Opaque, sealed and sequentially numbered envelopes containing the treatment allocation cards were prepared before trial commencement. The envelopes were sequentially opened for each participant during the recruitment. The initials of the name of the participant were written on the envelope before opening it.

The generation of randomization list, allocation concealment, and implementation were performed independently by different researches.

Blinding

Double-blinding was not possible since patient and operator were aware of the type of expander delivered. However, blinding was accomplished during outcome assessment since all data were unidentified before analysis.

Statistical analyses (primary and secondary outcomes, subgroup analyses)

All assessments were performed by the same observer and 30% of the sample was evaluated twice after a 30-day interval. The intra-rater reliability was assessed using intraclass correlation coefficients (ICC).[25]

Kolmogorov Smirnov test was used to verify normal distribution. All variables showed a normal distribution. Initial age and sex ratio at baseline were assessed with t and chi square tests, respectively. T tests with Holm-Bonferroni correction were used for intergroup comparisons. The significance level considered was 5%. All statistical analyses were performed using Statistica software (Statistica for Windows version 11.0; StatSoft, Tulsa, Okla).

RESULTS

Participant flow

Figure 1 shows the CONSORT flow diagram of the study. A total of 48 patients were selected and were followed during the entire observation period (Figure 5).

Baseline data

Similar characteristics were presented by both groups regarding sex ratio and age at baseline (Table I). No significant intergroup differences were found for the initial dental arch dimensions showing adequate intergroup comparability (Tables II and Figure 6).

Numbers analyzed for each outcome, estimation and precision

Rapid maxillary expansion was performed in 24 patients with the expander with differential opening and in 24 patients with the fan-type expander. All patients were properly analyzed in their original assigned groups. All patients from both groups demonstrated a midpalatal suture split. No patients were lost during the follow-up period.

The error study showed an excellent intraexaminer reproducibility, with ICC varying from 0.947 to 1.00.[26]

Both groups demonstrated similar changes in the maxillary interincisal diastema width (Table III). The interincisal diastema width opened 3.6mm and 3.4mm in group EDO and FE, respectively. Group EDO showed greater increases in the maxillary inter-second deciduous and inter-first permanent molars distances (Table III). Conversely, group FE showed a greater increase in the intercanine distance (Table III).

The mandibular dental arch showed mild spontaneous changes after RME in both groups (Table III). No intergroup differences were observed excepted for the slight greater increase in the mandibular inter-first permanent molars distance observed in group EDO. Changes in the maxillary and mandibular arch length and perimeter after RME were similar in both groups (Table III). Group EDO showed a greater increase in arch size (centroid method) than group FE (Table III).

The maxillary arch shape demonstrated a significant change in both groups (Figure 6). Mandibular arch shape changed very slightly only in the EDO group (Figure 6). The post-expansion maxillary arch shape was different in group EDO and group FE (Figure 6D). A larger anterior width was observer for group FE while a larger posterior width was found for group EDO (Figure 6D). Post-expansion mandibular arch shape was similar in both groups (Figure 6H).

Both groups showed significant differential expansion in the anterior and posterior regions of the maxillary dental arch with a greater change in the intercanine distance (Table IV). The differential expansion was greater in group FE (Table IV).

Harms

After RME, posterior crossbite was still present in 6 out of 24 patients of the FE group. A new expansion with quad-helix appliance was planned for these patients after the study was completed.

DISCUSSION

Main findings in the context of the existing evidence, interpretation

No previous study compared the outcomes of EDO and FE. Comparisons between the RME treatment outcomes is difficult since the clinical studies vary regarding sample size, age of the patients and amount of expansion achieved.[3,27] A controlled prospective study with sufficient power and standardized methodology is important for answering clinical questions. An expansion of 8 mm was performed in the anterior screw of both EDO and FE to allow the intergroup comparisons. Additionally, the comparisons at baseline showed no intergroup differences confirming the homogeneity of the sample (Tables I and II). These results ensure the effectiveness of the randomization and allocation of the patients, decreasing the risk of bias in the intergroup comparisons of the treatment changes.[28]

In the present study, digital dental models were obtained using an intraoral scanner. Previous studies showed an adequate accuracy and reliability of inter and intra-arch measurements performed on digital dental models derived from intraoral scans.[29-31] Our results are in accordance with previous studies demonstrating an adequate intraexaminer reproducibility. The dental arch size and shape analyses were based on the centroid size and location,[21-23,32] providing a visual representation of intergroup comparisons.

A similar opening of the interincisal diastema was observed in both groups (Table III). An opening of 3.65 mm for EDO and 3.43 for FE (45% and 42% of the screw activation, respectively) were observed. These outcomes were expected since the same amount of expansion was performed in the anterior screw of EDO and in the FE (8mm). A previous study reported an opening of 4.11 mm in the interincisal diastema width with EDO and 2.43mm with Hyrax expanders.[11] A meta-analysis showed a mean increase in the midline diastema of 2.98 mm after a RME with conventional expanders.[27] The slight greater means values found for the EDO and FE compared to conventional expanders might be explained by the greater anterior activation.

The increase in the intercanine distance was slightly greater in the FE group (Table III). Since the anterior expansion amount was the same in both groups, it is possible to suggest that this small transverse difference (approximately 1mm) was probably caused by a greater canine buccal inclination after a fan expansion. A greater tendency for buccal inclination of the anterior supporting teeth with the FE was previously reported in cleft patients.[14] The assumption is that fan-type expander concentrates the activation force in the canine region. On the other hand, EDO might distribute the expansion stress by all anchored teeth, mainly in the first days of the active phase.

Conversely to intercanine increase, the intermolar expansion was greater in group EDO (Table III). The possible explanation is the presence of the posterior screw in the EDO. A previous RCT showed that EDO caused an intermolar expansion similar to Hyrax expander.[11] Using a fan-shape expander, the intermolar increase was not clinically important (2.3 mm). These results corroborate with a previous study showing an intermolar width of 2.65mm after RME with a fan-type expander.[10] Although the intergroup differences in the increase of maxillary arch widths, arch perimeter increased similarly in group EDO and FE (Table III). In this perspective, both appliances can be indicated to solve maxillary incisor crowding.[3,33,34] A slight decrease in the maxillary arch length was observed in both groups and might be explained by the slight palatal inclination of the maxillary central incisors after RME related to interincisal diastema closure.[5,35,36]

The mandibular dental arch changes were very mild in both EDO and FE groups (Table III). Additionally, the mandibular outcomes were similar in both groups, except for the greater increase in the inter-first permanent molar distance in EDO group (mean difference of 0.8mm, Table III). The greater transverse change in the posterior region of the mandibular arch in group EDO might be explained by the greater maxillary molar expansion caused by the expander with differential opening (Table III). Previous studies assessing the mandibular arch changes after a conventional RME also showed a spontaneous increase in the mandibular intermolar width.[2,17] The small widening in the mandibular dental arch after RME might be explained by changes in balance between the tongue and bucinador muscles. The cone-funil occlusal contact between the palatal cusp tip of maxillary molar and the occlusal aspect of the mandibular molars also might have contributed to the slight uprighting of the lower posterior teeth.[2,18] Both EDO and FE induced a very small widening of the mandibular dental arch, however without causing a perimeter arch increase (Table III). Mandibular arch length decreased equally in group EDO and FE probably as a result of dental development in the mixed dentition leading to Leeway Space loss.[37]

Interestingly, both EDO and FE were capable of change the maxillary arch shape (Figures 6B and 6C, respectively). In this study, the post-expansion maxillary arch shape differed between EDO and FE (Figure 6D). The mean final arch shape was wider in the molar region for group EDO and wider in the canine region for group FE (Figure 6D). Mandibular arch shape after RME was similar in both groups. The literature is scarce for arch shape analysis after RME. A previous study showed that the arch shape changed in 98% of the patients after the conventional expansion.[38] In cleft patients, using similar methodology, arch shape changes were observed after expansion with Quad-helix and EDO.[21] In addition, the arch size calculated thought the centroid method increased more in group EDO, both in the maxilla and mandible (Table III). These differences might be explained by a greater expansion in the posterior region of both dental arches in EDO group. No previous study evaluated the arch size after RME using the centroid method in a noncleft population. In patients with cleft lip and palate, the arch size increased similarly after slow and rapid maxillary expansion with Hyrax, Quad-helix and EDO.[21]

Differential expansion between molar and canine region was observed in both groups with more intensity for FE. The ratio between intercanine and intermolar expansions were approximately 1.5:1 in group EDO and 3.5:1 in FE group. Our results are in accordance with previous studies that found a ratio of 1.7:1 for EDO[11] and 3.5:1[12] for the FE. EDO and FE are two viable options to treat maxillary arch constriction with very similar impact on the canine region. The decision between both expander designs should consider the required amount of expansion in the intermolar distance and the presence of posterior crossbite including the molars.

Limitations

The limitation of this study was the lack of a tension distribution analyses. Further studies should assess EDO and FE force concentration using finite element analysis.

Generalizability

The generalizability of the results of the present study might be generalized to patients in the mixed dentition without cleft lip and palate. In addition, these results might not be generalized to different expander designs and activation protocols.

CONCLUSIONS

The null hypothesis was rejected. The expander with differential opening showed a greater expansion at the level of the maxillary second deciduous and first permanent molars. The fan-type expander produced a greater maxillary intercanine distance increase. A greater mandibular dental arch change was observed after RME with the differential opening expander compared to the fan-type expander. The expander with differential opening and the fan-type expander induced distinct post-expansion arch shapes.

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REFERENCES:

1. da Silva Filho OG, Boas MC, Capelozza Filho L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1991;100:171-179.
2. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod 1961;31:73-90.
3. Lagravere MO, Major PW, Flores-Mir C. Long-term dental arch changes after rapid maxillary expansion treatment: a systematic review. Angle Orthod 2005;75:155-161.

4. Garib D, Lauris RDCMC, Calil LR, Alves ACDM, Janson G, De 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;150:564-574.
5. Haas AJ. The Treatment of Maxillary Deficiency by Opening the Midpalatal Suture. Angle Orthod 1965;35:200-217.
6. Garib D, Garcia L, Pereira V, Lauris R, Yen S. A rapid maxillary expander with differential opening. J Clin Orthod 2014;48:430-435.
7. Cozza P, De Toffol L, Mucedero M, Ballanti F. Use of a modified butterfly expander to increase anterior arch length. J Clin Orthod 2003;37:490-495.
8. Algharbi M, Bazargani F, Dimberg L. Do different maxillary expansion appliances influence the outcomes of the treatment? Eur J Orthod 2018;40:97-106.
9. Weissheimer A, de Menezes LM, Mezomo M, Dias DM, de Lima EMS, Rizzatto SMD. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2011;140:366-376.
10. 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;74:184-194.
11. de Medeiros Alves AC, Janson G, Mcnamara Jr JA, Lauris JRP, Garib DG. Maxillary expander with differential opening vs Hyrax expander: A randomized clinical trial. Am J Orthod Dentofacial Orthop 2020;157:7-18.
12. Corekci B, Goyenc YB. Dentofacial changes from fan-type rapid maxillary expansion vs traditional rapid maxillary expansion in early mixed dentition. Angle Orthod 2013;83:842-850.
13. Cozza P, Giancotti A, Petrosino A. Butterfly expander for use in the mixed dentition. J Clin Orthod 1999;33:583.
14. Figueiredo DS, Bartolomeo FU, Romualdo CR, Palomo JM, Horta MC, Andrade I, Jr. et al. Dentoskeletal effects of 3 maxillary expanders in patients with clefts: A cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2014;146:73-81.
15. Belluzzo RHL, Faltin Junior K, Lascala CE, Vianna LBR. Maxillary constriction: are there differences between anterior and posterior regions? Dental Press J Orthod 2012;17:1-6.

16. da Silva Filho OG, de Castro Machado FM, de Andrade AC, de Souza Freitas JA, Bishara SE. Upper dental arch morphology of adult unoperated complete bilateral cleft lip and palate. Am J Orthod Dentofacial Orthop 1998;114:154-161.
17. Lima AC, Lima AL, Filho RM, Oyen OJ. Spontaneous mandibular arch response after rapid palatal expansion: a long-term study on Class I malocclusion. Am J Orthod Dentofacial Orthop 2004;126:576-582.
18. McNamara JA. Maxillary transverse deficiency. Am J Orthod Dentofacial Orthop 2000;117:567-570.
19. Alves ACM, Maranhao OBV, Janson G, Garib DG. Mandibular dental arch short and long-term spontaneous dentoalveolar changes after slow or rapid maxillary expansion: a systematic review. Dental Press J Orthod 2017;22:55-63.
20. Schulz KF, Altman DG, Moher D, Group C. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMC Med 2010;8:18.
21. Pugliese F, Palomo JM, Calil LR, de 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 2019.
22. Klingenberg CP. Size, shape, and form: concepts of allometry in geometric morphometrics. Dev Genes Evol 2016;226:113-137.
23. Gower JC. Generalized procrustes analysis. Psychometrika 1975;40:33-51.
24. Pandis N. Randomization. Part 1: sequence generation. Am J Orthod Dentofacial Orthop 2011;140:747-748.
25. Fleiss JL. Analysis of data from multiclinic trials. Control Clin Trials 1986;7:267-275.
26. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med 2016;15:155-163.
27. Lagravère MO, Heo G, Major PW, Flores-Mir C. Meta-analysis of immediate changes with rapid maxillary expansion treatment. J Am Dent Assoc 2006;137:44-53.
28. Berger VW, Exner DV. Detecting selection bias in randomized clinical trials. Control Clin Trials 1999;20:319-327.

29. Aragon ML, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review. Eur J Orthod 2016;38:429-434.
30. Hack GD, Patzelt S. Evaluation of the accuracy of six intraoral scanning devices: an in-vitro investigation. ADA Prof Prod Rev 2015;10:1-5.
31. Camardella LT, Breuning H, de Vasconcellos Vilella O. Accuracy and reproducibility of measurements on plaster models and digital models created using an intraoral scanner. J Orofac Orthop 2017;78:211-220.
32. Webster M, Sheets HD. A practical introduction to landmark-based geometric morphometrics. Quant Methods Paleobiol 2010;16:163-188.
33. Agostino P, Ugolini A, Signori A, Silvestrini-Biavati A, Harrison JE, Riley P. Orthodontic treatment for posterior crossbites. Cochrane Database of Systematic Reviews 2014.
34. McNamara Jr JA, Baccetti T, Franchi L, Herberger TA. Rapid maxillary expansion followed by fixed appliances: a long-term evaluation of changes in arch dimensions. Angle Orthod 2003;73:344-353.
35. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod 1987;91:3-14.
36. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41-66.
37. Moorrees CF, Gron AM, Lebret LM, Yen PK, Frohlich FJ. Growth studies of the dentition: a review. Am J Orthod 1969;55:600-616.
38. Mutinelli S, Cozzani M, Manfredi M, Bee M, Siciliani G. Dental arch changes following rapid maxillary expansion. Eur J Orthod 2008;30:469-476.

Legend of Figures

Fig 1. Maxillary expander with differential opening. A. Pre-expansion phase. B. Post-expansion phase.

Fig 2. Fan-type expander. A. Pre-expansion phase. B. Post-expansion phase.

Fig 3. Maxillary interincisal diastema before (A) and after the rapid maxillary expansion (B). The interincisal diastema width was measured between the mesial incisal edge of right and left maxillary incisors before and after the active phase of the expansion using an odontometric caliper (C). T1-T2 differences were considered interincisal diastema width changes.

Fig 4. Maxillary and mandibular arch dimensions assessment: A. arch widths (in black) were measured at the level of the cusp tips of the deciduous canines (c-c), first deciduous molars (d-d), second deciduous molars (e-e) and first permanent molars (6-6); B. arch perimeter (in red) was the sum of the 4 segments from mesial aspect of the right first permanent molar to the mesial aspect of the contralateral tooth; C. arch length (in yellow) was measured on the horizontal plane from the mesial aspect of the first permanent molars to the mesial edge of the right permanent incisor. D. Fourteen landmarks at the level of cusp tips and incisal edges of the maxillary and mandibular teeth were selected on the digital dental model surface to provide raw coordinates representing dental arch shape and size.

Fig 5. Consolidated Standards of Reporting Trial flow diagram showing the study design.

Fig 6. Superimpositions of maxillary dental arch shape. A. Pre-expansion maxillary dental arch in group FE (gray line) and EDO (black line); B. Maxillary dental arch before (gray line) and after expansion (black line) in the group EDO; C. Maxillary dental arch before (gray line) and after expansion (black line) in the group FE; D. Post-expansion maxillary dental arch in group FE (gray line) and EDO (black line). The *P* value is observed for each comparison (variance analysis).

Fig 7. Superimpositions of mandibular dental arch shape. A. Pre-expansion mandibular dental arch in group FE (gray line) and EDO (black line); B. Mandibular dental arch before (gray line) and after expansion (black line) in the group EDO; C. Mandibular dental arch before (gray line) and after expansion (black line) in the group FE; D. Post-expansion mandibular dental arch in group FE (gray line) and EDO (black line). The *P* value is observed for each comparison (variance analysis).

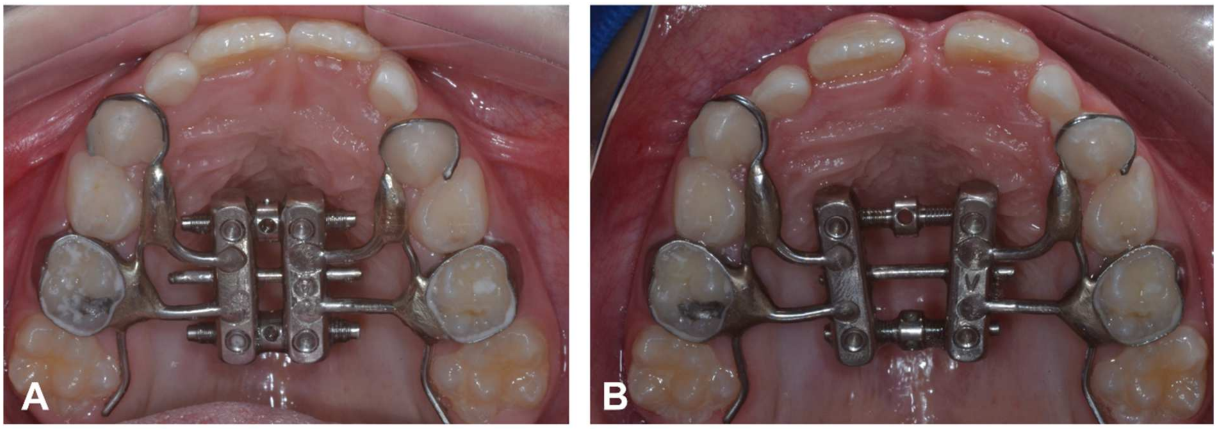


Fig 1.

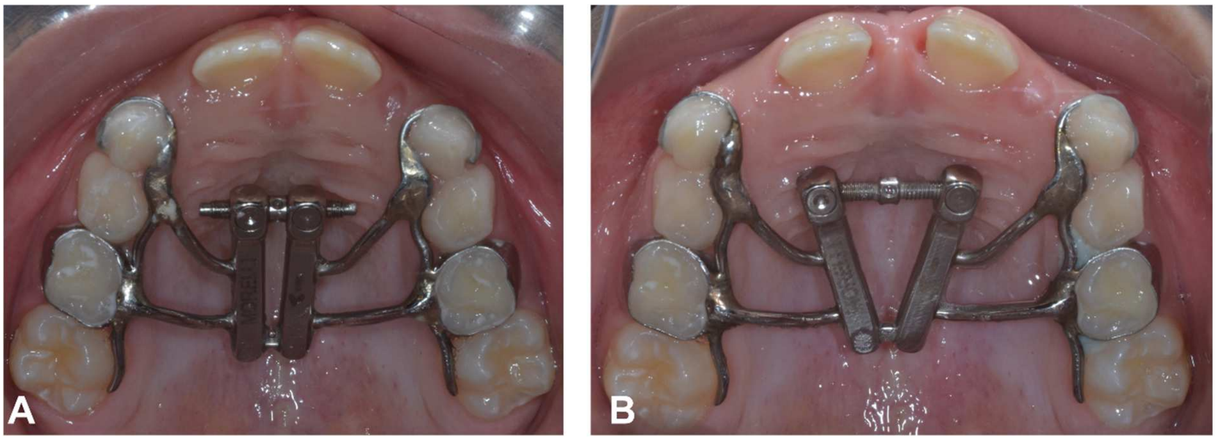


Fig 2.

Fig 3.

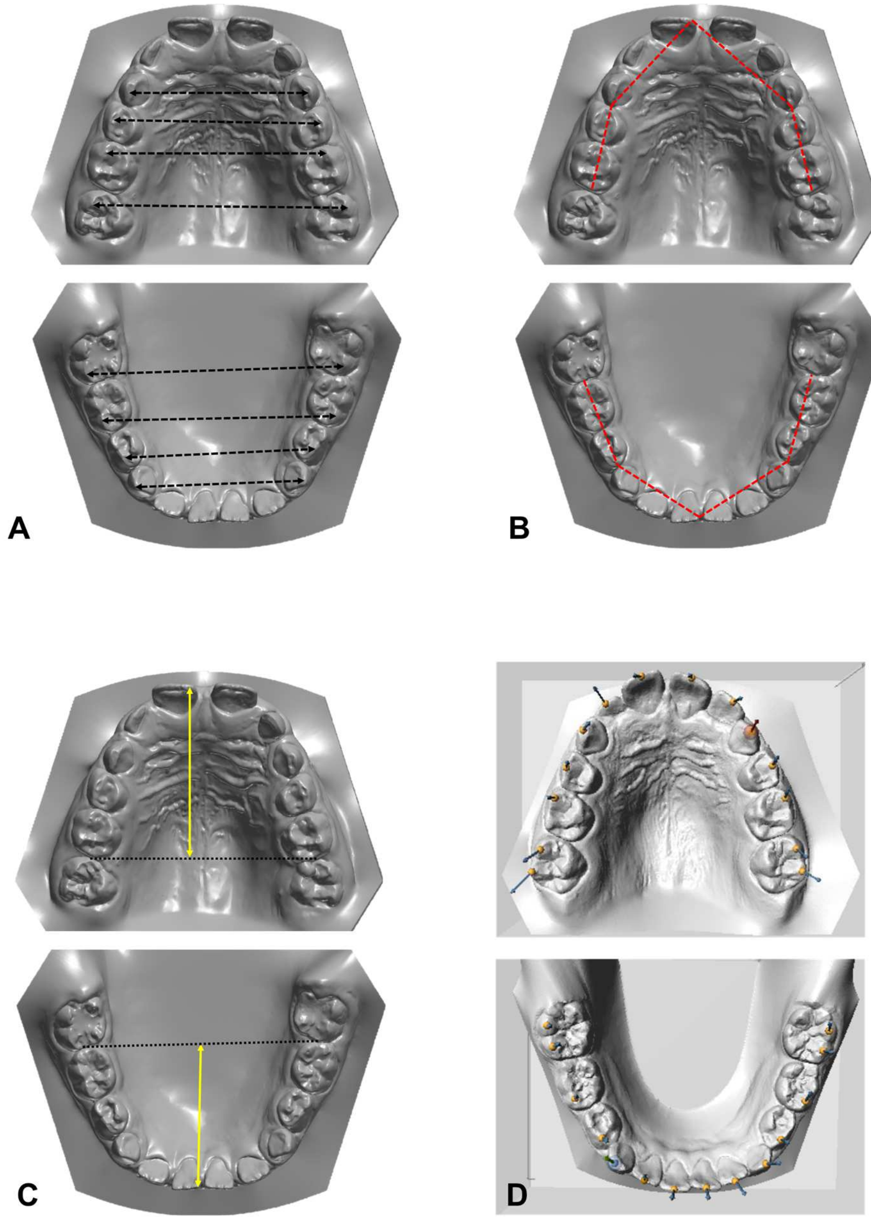


Fig 4.

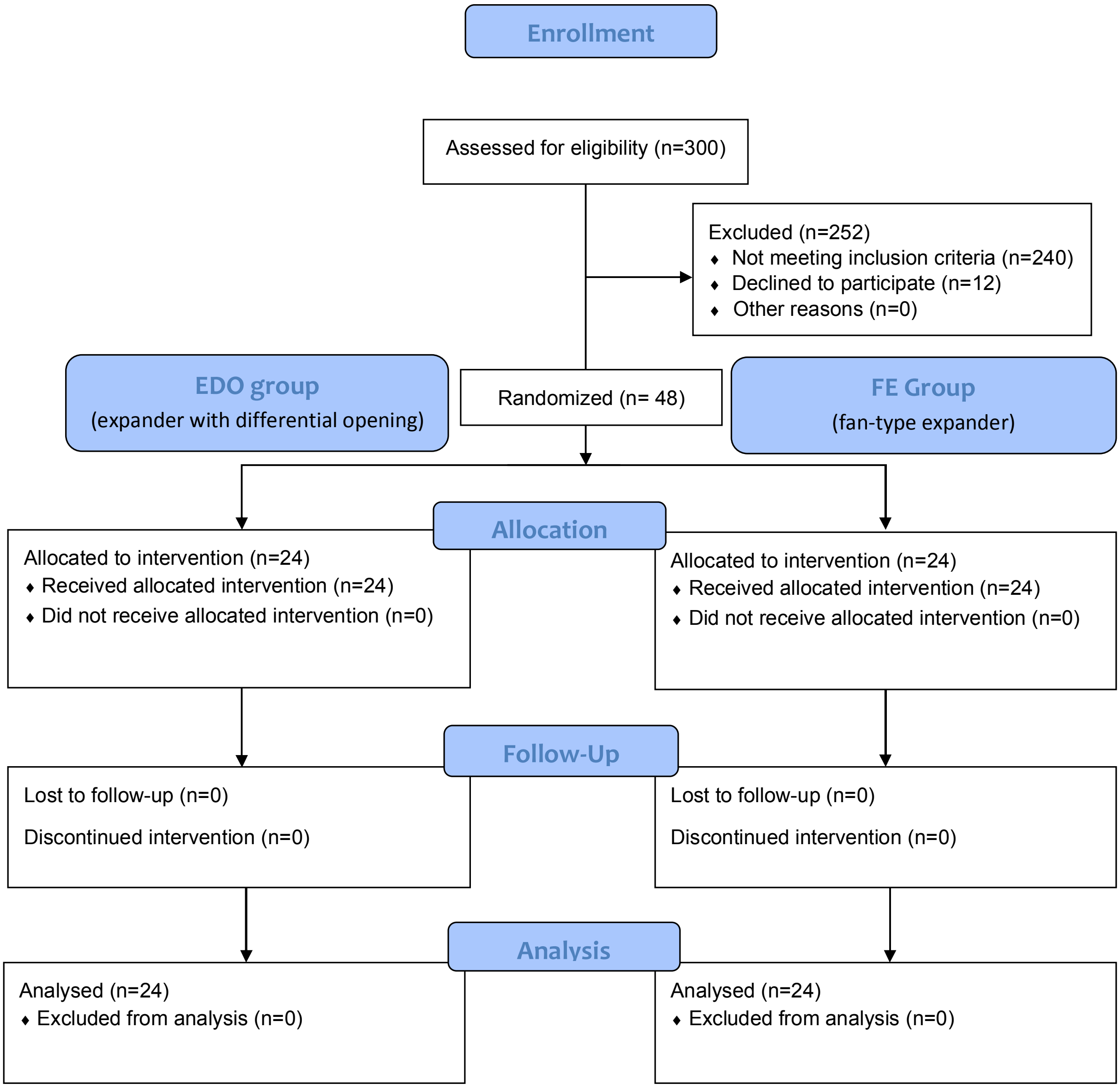

Enrollment
Assessed for eligibility (n=300)
Excluded (n=252)
♦ Not meeting inclusion criteria (n=240)
♦ Declined to participate (n=12)
♦ Other reasons (n=0)
EDO group
(expander with differential opening)
Randomized (n= 48)
FE Group
(fan-type expander)
Allocation
Allocated to intervention (n=24)
♦ Received allocated intervention (n=24)
♦ Did not receive allocated intervention (n=0)
Allocated to intervention (n=24)
♦ Received allocated intervention (n=24)
♦ Did not receive allocated intervention (n=0)
Follow-Up
Lost to follow-up (n=0)
Discontinued intervention (n=0)
Lost to follow-up (n=0)
Discontinued intervention (n=0)
Analysis
Analysed (n=24)
♦ Excluded from analysis (n=0)
Analysed (n=24)
♦ Excluded from analysis (n=0)

Fig 5.

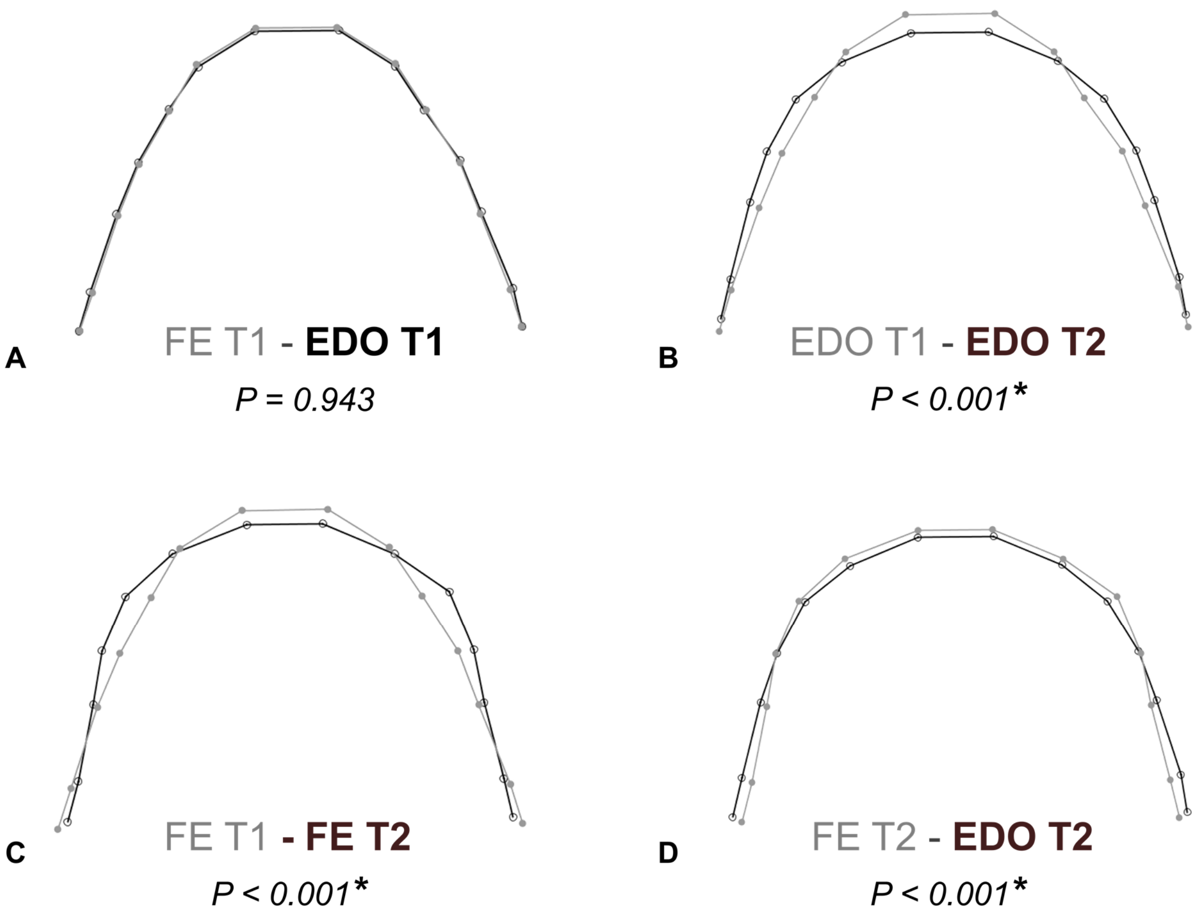
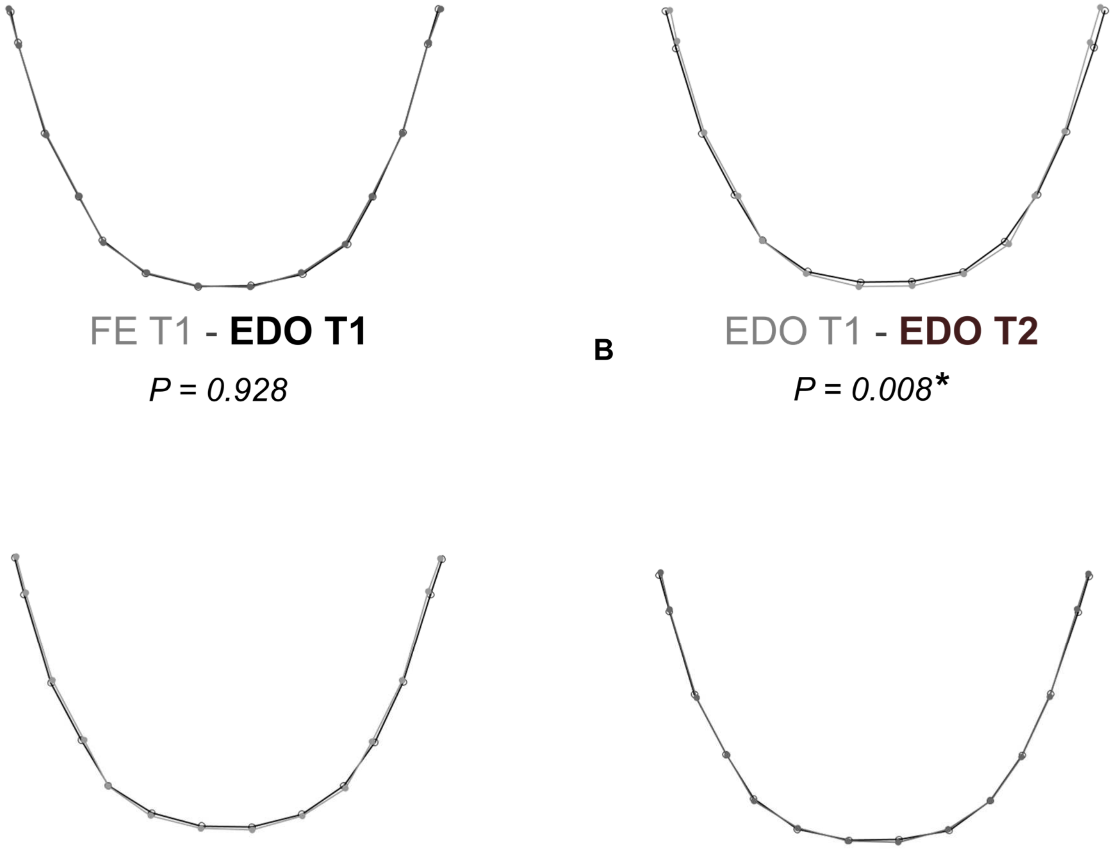

A
FE T1 - EDO T1
P = 0.943
B
EDO T1 - EDO T2
P < 0.001*
C
FE T1 - FE T2
P < 0.001*
D
FE T2 - EDO T2
P < 0.001*

Fig 6.



A FE T1 - **EDO T1**
P = 0.928

B EDO T1 - **EDO T2**
*P = 0.008**

C FE T1 **- FE T2**
P = 0.104

D FE T2 - **EDO T2**
P = 0.590

Fig 7.

Table I: Intergroup comparisons for age and sex ratio at baseline (t tests and Chi-square tests).

Variable		**EDO n=24**		**FE n=24**		***P***
		Mean	**SD**	**Mean**	**SD**	
Initial Age *(y)*		7.62	0.92	7.83	0.96	0.448†
Sex	**Feale**	13		14		0.771§
	Male	11		10		

†*t test;* §*Chi-square test.*

Table II: Baseline comparisons (t tests).

Variables			EDO n=24		FE n=24		*P*
			Mean	SD	Mean	SD	
Interincisal diastema (mm)			1.45	1.10	1.14	1.10	0.341
Arch dimensions (mm)	Maxilla	c-c	29.70	3.01	29.24	2.25	0.557
		d-d	36.29	2.22	34.78	2.21	0.051
		e-e	42.47	2.38	41.26	2.64	0.103
		6-6	49.23	2.71	47.91	2.65	0.096
		Arch length	29.27	2.64	29.39	2.27	0.865
		Arch perimeter	76.30	4.65	75.34	4.38	0.465
		Arch size	83.00	3.99	81.71	4.20	0.286
	Mandible	c-c	27.74	2.46	26.50	2.21	0.115
		d-d	33.13	2.47	31.64	1.47	0.041
		e-e	40.15	2.97	39.06	2.06	0.167
		6-6	46.03	2.68	45.36	2.42	0.373
		Arch length	25.26	1.91	24.86	1.80	0.461
		Arch perimeter	70.57	3.38	69.23	3.76	0.234
		Arch size	76.96	3.29	75.53	3.69	0.168

$P<0.05$; c, deciduous canines; d, first deciduous molars; e, second deciduous molars; 6, first permanent molars.

Table III: Intergroup comparisons of the interphase changes (*t* tests).

Variables			**EDO** n=24		**FE** n=24		***P***
			Mean (T2-T1)	SD	Mean (T2-T1)	SD	
Interincisal diastema (mm)			3.65	0.74	3.43	1.13	0.449
Arch dimensions (mm)	Maxilla	c-c	7.76	1.23	8.80	1.33	0.008*
		d-d	7.85	1.31	7.42	1.66	0.398
		e-e	6.36	0.84	4.90	0.91	<0.001*
		6-6	5.10	1.17	2.33	0.75	<0.001*
		Arch length	-0.54	0.86	-0.36	0.76	0.449
		Arch perimeter	5.14	1.56	5.33	1.40	0.662
		Arch size	9.28	1.28	7.01	1.05	<0.001*
	Mandible	c-c	-0.35	1.11	-0.05	0.67	0.324
		d-d	0.27	0.83	0.35	0.88	0.803
		e-e	0.59	0.66	0.31	0.79	0.225
		6-6	0.93	0.91	0.12	0.89	0.003*
		Arch length	-0.55	0.60	-0.52	0.60	0.844
		Arch perimeter	-0.64	0.86	-0.66	1.27	0.955
		Arch size	1.02	0.83	0.23	1.09	0.008*

*P<0.05; *Statistically significant after Holm-Bonferroni correction method; c, deciduous canines; d, first deciduous molars; e, second deciduous molars; 6, first permanent molars.*

Table IV: Intragroup and intergroup differential expansion comparisons considering deciduous canines and first permanent molars (Paired *t* tests and *t* tests).

Variables	**3-3**		**6-6**		**Intragroup comparison *P***	**Difference**		**Intergroup comparison *P***
	Mean Change	SD	Mean Change	SD		**Mean**	**SD**	
EDO	7.76	1.23	5.10	1.17	<0.001‡*	2.65	1.47	<0.001†*
FE	8.80	1.33	2.31	0.76	<0.001‡*	6.09	1.47	

†t test; ‡Paired t test; *P<0.05; c, deciduous canines; e, second deciduous molars.*

3 Discussion

4 DISCUSSION

Approximately one third of patients with maxillary constriction showed a greater transversal discrepancy in the anterior region compared to the posterior region of the arch.[15] In this regard, an individualized treatment plan should be proposed for these patients to avoid negative side effects associated with undesired under and overexpansion. The expander with differential opening and the fan-type expander are two mechanical options proposed to treat maxillary constrictions more evident in the anterior region of the arch.[10-14] The present study intended to compare the dentoskeletal effects of the EDO and the FE to elucidate the differences between both expander and guide the clinician in the expander selection.

Randomized clinical trials are considered the highest level of scientific evidence for clinical interventions.[16] The present study was developed according to the Consolidated Standards of Reporting Trials (CONSORT) statement and guidelines aiming to reach a high level of evidence with low risk of bias.[17] The orthopedic and orthodontic effects of the rapid maxillary expansion using conventional expanders were described in the deciduous, mixed and permanent dentition.[6-8,18-20] Additionally, previous studies compared the EDO and the FE with the conventional expanders in non-cleft patients using radiographs and dental models.[10,11,14] In this study, the expander with differential opening was compared with the fan-type expander in non-cleft patients in the mixed dentition using digital dental models and cone-beam computed tomography scans (CBCT).

The comparisons at baseline showed no intergroup differences and confirmed the homogeneity of the sample. This results ensured an effective randomization and allocation of the patients, minimizing the risk of bias in the intergroup comparisons.[21] Additionally, the activation protocol was the same in both groups and the amount of expansion in the anterior region was also standardized to ensure a viable intergroup comparison.

Changes in arch dimensions and arch shape were assessed using digital dental models obtained from intraoral scanning. Previous studies showed the accuracy and reliability of the inter and intra-arch measurements produced from intraoral scans.[22-24] To overcome the limitations of a two-dimensional assessment of the skeletal effects of the rapid maxillary expansion, CBCT scans were used.[25] CBCT imaging allows to assess skeletal changes in craniofacial imaging analysis, demonstrating high accuracy, minimal distortion and lower radiation doses compared to helical CT.[26-29] The use of CBCT scans in this study allowed the assessment of the maxillary 3D displacements relative to the cranial base.

No important harm was caused to the participants of this study. The benefits and collateral effects of the rapid maxillary expansion were already discussed in the literature.[30-32] In 6 out of 24 patients in the FE group, posterior crossbite at the molar region was still present after the observation period. These patients were assigned for a second intervention with slow maxillary expansion after the evaluation period.

The generalizability of the results of the present study might be limited to non-cleft patients in the mixed dentition because expansion outcomes differ according to age and presence of cleft lip and palate. In addition, the generalizability of the results should be limited to similar expanders using the same activation amount and protocol.

One limitation of the study is the absence of a conventional expander group to compare the outcomes of the EDO and the FE. Further studies should compare EDO and FE with the conventional expander and evaluate the functional impact of the orthopedic differences observed after RME. A future study should also include the assessment of the tension distribution in both expanders using finite element analysis.

4 Final Considerations

4 FINAL CONSIDERATIONS

The expander with differential opening and the fan-type expander promoted a differential expansion between molar and canine region, with more intensity in patients treated with the fan-type expansion. A combination of skeletal and dental effects was observed, with greater transversal skeletal effects in patients treated with the expander with differential opening. Greater dental changes in the molar region was observed for the expander with differential opening, while patients treated with the fan-type expander demonstrated slightly greater increases in the intercanine distance and canine buccal inclination. Both expanders were capable of change the maxillary arch shape, showing distinct post-expansion arch shapes. The spontaneous mandibular dental arch changes were mild after the maxillary expansion, and the expander with differential opening promoted a slightly greater increase in the intermolar region compared to the fan-type expander. Therefore, the expander with differential opening and the fan-type expander are two viable options to treat maxillary arch constriction and posterior crossbites with very similar impact on the canine region. The decision between both appliance design should consider the required amount of expansion in the molar region and the presence of posterior crossbite including the molars.

REFERENCES

REFERENCES

1. Kutin G, Hawes RR. Posterior cross-bites in the deciduous and mixed dentitions. Am J Orthod. 1969;56:491-504.

2. da Silva Filho OG, Santamaria M, Jr., Capelozza Filho L. Epidemiology of posterior crossbite in the primary dentition. J Clin Pediatr Dent. 2007;32:73-78.

3. Silva Filho O, Freitas SF, Cavassan AO. Prevalência de oclusão normal e má-oclusão em escolares da cidade de Bauru (São Paulo). Parte I: relação sagital. Revista de Odontologia da Universidade de São Paulo. 1990;4:130-137.

4. da Silva Filho OG, Boas MC, Capelozza Filho L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofacial Orthop. 1991;100:171-179.

5. Thilander B, Wahlund S, Lennartsson B. The effect of early interceptive treatment in children with posterior cross-bite. Eur J Orthod. 1984;6:25-34.

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

7. Haas AJ. The Treatment of Maxillary Deficiency by Opening the Midpalatal Suture. Angle Orthod. 1965;35:200-217.

8. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod. 1970;57:219-255.

9. Weissheimer A, de Menezes LM, Mezomo M, Dias DM, de Lima EMS, Rizzatto SMD. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. Am J Orthod Dentofacial Orthop. 2011;140:366-376.

10. 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;74:184-194.

11. Corekci B, Goyenc YB. Dentofacial changes from fan-type rapid maxillary expansion vs traditional rapid maxillary expansion in early mixed dentition. Angle Orthod. 2013;83:842-850.

12. Cozza P, De Toffol L, Mucedero M, Ballanti F. Use of a modified butterfly expander to increase anterior arch length. J Clin Orthod. 2003;37:490-495.

13. Garib D, Garcia L, Pereira V, Lauris R, Yen S. A rapid maxillary expander with differential opening. J Clin Orthod. 2014;48:430-435.

14. de Medeiros Alves AC, Janson G, Mcnamara Jr JA, Lauris JRP, Garib DG. Maxillary expander with differential opening vs Hyrax expander: A randomized clinical trial. Am J Orthod Dentofacial Orthop. 2020;157:7-18.

15. Belluzzo RHL, Faltin Junior K, Lascala CE, Vianna LBR. Maxillary constriction: are there differences between anterior and posterior regions? Dental Press J Orthod. 2012;17:1-6.

16. Concato J, Shah N, Horwitz RI. Randomized, controlled trials, observational studies, and the hierarchy of research designs. N Engl J Med. 2000;342:1887-1892.

17. Schulz KF, Altman DG, Moher D, Group C. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMC Med. 2010;8:18.

18. Lagravère MO, Heo G, Major PW, Flores-Mir C. Meta-analysis of immediate changes with rapid maxillary expansion treatment. J Am Dental Assoc. 2006;137:44-53.

19. Lagravere MO, Major PW, Flores-Mir C. Long-term dental arch changes after rapid maxillary expansion treatment: a systematic review. Angle Orthod. 2005;75:155-161.

20. Lagravere MO, Major PW, Flores-Mir C. Long-term skeletal changes with rapid maxillary expansion: a systematic review. Angle Orthod. 2005;75:1046-1052.

21. Berger VW, Exner DV. Detecting selection bias in randomized clinical trials. Control Clin Trials. 1999;20:319-327.

22. Aragon ML, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review. Eur J Orthod. 2016;38:429-434.

23. Hack GD, Patzelt S. Evaluation of the accuracy of six intraoral scanning devices: an in-vitro investigation. ADA Prof Prod Rev. 2015;10:1-5.

24. Camardella LT, Breuning H, de Vasconcellos Vilella O. Accuracy and reproducibility of measurements on plaster models and digital models created using an intraoral scanner. J Orofac Orthop. 2017;78:211-220.

25. Bazargani F, Feldmann I, Bondemark L. Three-dimensional analysis of effects of rapid maxillary expansion on facial sutures and bones. Angle Orthod. 2013;83:1074-1082.

26. Loubele M, Van Assche N, Carpentier K, Maes F, Jacobs R, van Steenberghe D et al. Comparative localized linear accuracy of small-field cone-beam CT and multislice CT for alveolar bone measurements. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;105:512-518.

27. Ludlow JB, Laster WS, See M, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy in cone beam computed tomography images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;103:534-542.

28. Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. J Periodontol. 2006;77:1261-1266.

29. 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;134:8. e1-8. e11.

30. De Felippe NL, Da Silveira AC, Viana G, Smith B. Influence of palatal expanders on oral comfort, speech, and mastication. Am J Orthod Dentofacial Orthop. 2010;137:48-53.

31. Gecgelen M, Aksoy A, Kirdemir P, Doguc DK, Cesur G, Koskan O et al. Evaluation of stress and pain during rapid maxillary expansion treatments. J Oral Rehabil. 2012;39:767-775.

32. Needleman HL, Hoang CD, Allred E, Hertzberg J, Berde C. Reports of pain by children undergoing rapid palatal expansion. Pediatr Dent. 2000;22:221-226.

APPENDIXES

APPENDIX A - Declaration of exclusive use of the article 1 in thesis.

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article *"Maxillary dentoskeletal outcomes of the expander with differential opening and the fan-type expander: a randomized clinical trial"* will be included in Thesis of the student Camila da Silveira Massaro and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, February 26th, 2020.

Camila da Silveira Massaro — Signature

Daniela Gamba Garib Carreira — Signature

APPENDIX B - Declaration of exclusive use of the article 2 in thesis.

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article "Dental arch comparison between expander with differential opening and fan-type expander: a randomized clinical trial" will be included in Thesis of the student Camila da Silveira Massaro and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, February 26th, 2020.

Camila da Silveira Massaro

Signature

Daniela Gamba Garib Carreira

Signature

ANNEXES

ANNEX A – Research Institutional Board approval (page 1 of 3).

USP - FACULDADE DE ODONTOLOGIA DE BAURU DA USP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado

Pesquisador: Camila da Silveira Massaro

Área Temática:

Versão: 1

CAAE: 71648917.6.0000.5417

Instituição Proponente: Universidade de Sao Paulo

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.222.973

Apresentação do Projeto:

O objetivo desse estudo será comparar, por meio de modelos digitais e tomografia computadorizada cone-beam (TCCB), os efeitos dentoalveolares e esqueléticos do expansor maxilar com abertura diferencial e em leque, em pacientes ortodônticos na fase de dentadura mista. Material e métodos: Será proposto um ensaio clínico randomizado, no qual serão selecionados 48 indivíduos, de ambos os sexos, idade entre 7 e 11 anos e com atresia maxilar. Os pacientes serão alocados em dois grandes grupos experimentais. O primeiro grupo será composto por 24 indivíduos que serão submetidos à expansão rápida da maxila com o expansor com abertura diferencial (GED). O segundo grupo será composto por 24 indivíduos que serão submetidos à expansão rápida da maxila com o expansor com abertura em leque (GEL). Em 12 pacientes de cada grupo (subgrupos imediatos), a TCCB será realizada antes do início do tratamento e imediatamente após a expansão rápida da maxila. Nos demais 12 pacientes de cada grupo (subgrupos tardios), a TCCB será obtida antes do tratamento e 6 meses após a expansão rápida da maxila. Para todos os pacientes, modelos de estudo serão obtidos antes do início do tratamento e após o período de contenção.

Objetivo da Pesquisa:

O objetivo do presente estudo será comparar os efeitos dentoalveolares e esqueléticos do

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ANNEX A – Research Institutional Board approval (page 2 of 3).

USP - FACULDADE DE ODONTOLOGIA DE BAURU DA USP

Continuação do Parecer: 2.222.973

expansor ortopédico com abertura diferencial e do expansor com abertura em leque, em pacientes ortodônticos na fase de dentadura mista.

Avaliação dos Riscos e Benefícios:

Descritos adequadamente na Plataforma Brasil, no Projeto e no TCLE.

Comentários e Considerações sobre a Pesquisa:

Trata-se de um Projeto de Doutorado bastante interessante, está descrito adequadamente e bem delineado.

Considerações sobre os Termos de apresentação obrigatória:

Todos os termos estão adequados.

Conclusões ou Pendências e Lista de Inadequações:

Projeto aprovado sem restrições de ordem ética.

Considerações Finais a critério do CEP:

Esse projeto foi considerado APROVADO na reunião ordinária do CEP de 09.08.2017, com base nas normas éticas da Resolução CNS 466/12. Ao término da pesquisa o CEP-FOB/USP exige a apresentação de relatório final. Os relatórios parciais deverão estar de acordo com o cronograma e/ou parecer emitido pelo CEP. Alterações na metodologia, título, inclusão ou exclusão de autores, cronograma e quaisquer outras mudanças que sejam significativas deverão ser previamente comunicadas a este CEP sob risco de não aprovação do relatório final. Quando da apresentação deste, deverão ser incluídos todos os TCLEs e/ou termos de doação assinados e rubricados, se pertinentes.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_948098.pdf	19/07/2017 15:58:33		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_de_assentimento.pdf	19/07/2017 15:57:17	Camila da Silveira Massaro	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	19/07/2017 15:50:04	Camila da Silveira Massaro	Aceito
Declaração de	Carta_de_encaminhamento.pdf	19/07/2017	Camila da Silveira	Aceito

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ANNEX A – Research Institutional Board approval (page 3 of 3).

USP - FACULDADE DE ODONTOLOGIA DE BAURU DA USP

Continuação do Parecer: 2.222.973

Instituição e Infraestrutura	Carta_de_encaminhamento.pdf	15:31:28	Massaro	Aceito
Folha de Rosto	Folha_de_rosto.pdf	19/07/2017 15:22:34	Camila da Silveira Massaro	Aceito
Declaração de Pesquisadores	Declaracao_de_Compromisso.pdf	18/07/2017 21:02:12	Camila da Silveira Massaro	Aceito
Outros	Questionario_tecnico_do_pesquisador.pdf	18/07/2017 20:55:16	Camila da Silveira Massaro	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_de_pesquisa.pdf	18/07/2017 20:49:26	Camila da Silveira Massaro	Aceito
Orçamento	Orcamento.pdf	18/07/2017 20:48:33	Camila da Silveira Massaro	Aceito
Cronograma	Cronograma.pdf	18/07/2017 20:44:50	Camila da Silveira Massaro	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

BAURU, 16 de Agosto de 2017

Assinado por:
Ana Lúcia Pompéia Fraga de Almeida
(Coordenador)

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ANNEX B – Informed consent for children.

Universidade de São Paulo
Faculdade de Odontologia de Bauru

Departamento de Odontopediatria, Ortodontia e
Saúde Coletiva

<u>Termo de Assentimento</u>

Você está sendo convidado (a) a participar da pesquisa **"Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado".** Essa pesquisa será realizada pela Drª. Camila da Silveira Massaro, aqui na Faculdade de Odontologia de Bauru da Universidade de São Paulo (FOB-USP). Caso concorde em participar, é importante que você saiba que os atendimentos serão aqui na clínica de Ortodontia desta faculdade (FOB-USP). Assim como você, o seu responsável também será informado sobre a sua participação neste estudo.

O aparelho será colocado no seu céu da boca, ficará apoiado nos dentes de trás e fará uma expansão (abertura) do seu arco superior (de cima). Com isso, vamos corrigir a sua mordida.

Para fazer o seu tratamento, vamos tirar algumas fotos e fazer um exame para ver a posição dos seus ossos do rosto. Quando começarmos o tratamento, vamos fazer uma cópia dos seus dentes de cima (molde) para poder fazer o seu aparelho. O aparelho que você vai usar se chama expansor, e será fixo (você não poderá tirar e colocar o aparelho). Não se preocupe que eu explicarei em detalhes para o seu responsável a forma correta de mexer no seu aparelho.

É muito importante você escovar e limpar muito bem os seus dentes e o seu aparelho. Você ficará de aparelho por 1 ano. Se você sentir qualquer incômodo, você pode me falar. Participando da pesquisa, você receberá tratamento de graça e iremos corrigir a posição dos seus dentes, o que deixará seu sorriso mais bonito e sua mordida mais saudável. Ninguém saberá que você está participando da pesquisa.

Se você tiver alguma dúvida, pode me perguntar a qualquer momento. Se você não quiser, não precisa participar da pesquisa. Não terá nenhum problema e você receberá atendimento da mesma forma. Se você não tiver o desejo de participar, pode pintar a carinha triste.

Sendo assim, após me explicarem ou ter lido e entendido todas as informações deste texto, eu, ____ aceito participar da pesquisa "**Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado"**, pintando a carinha feliz.

Entendi as coisas ruins e as coisas boas que podem acontecer.

Entendi que posso dizer "sim" e participar, mas que, a qualquer momento, posso dizer "não" e desistir. Ninguém vai ficar bravo.

Bauru, ____ de ______________ de _______.

______________________________	______________________________
Camila da Silveira Massaro **Pesquisador responsável**	**Assinatura do menor**

SIM, EU CONCORDO!

NÃO, EU NÃO CONCORDO!

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ANNEX C- Informed consent for legal guardians of children (front).

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Universidade de São Paulo
Faculdade de Odontologia de Bauru
Departamento de Odontopediatria, Ortodontia e Saúde Coletiva

Termo de Consentimento Livre e Esclarecido (Ao responsável do menor)

O menor sob sua responsabilidade está sendo convidado a participar como voluntário da pesquisa intitulada **"Expansor maxilar com abertura diferencial versus com abertura em leque: um ensaio clínico randomizado".** Essa pesquisa científica será realizada pela ortodontista Camila da Silveira Massaro, Doutoranda em Ortodontia na Faculdade de Odontologia de Bauru da Universidade de São Paulo, sob orientação da Profª. Drª. Daniela Gamba Garib Carreira e terá como objetivo avaliar, por meio de modelos dentários e de tomografias, os efeitos de dois tipos de aparelhos expansores (aparelhos fixos, posicionados no céu da boca) em indivíduos dos 7 aos 11 anos de idade. O aparelho terá a função de expandir (abrir) o arco superior (de cima), que encontra-se atrésico (muito fechado). A finalidade deste aparelho será proporcionar um bom relacionamento entre os arcos dentários, corrigindo a forma do arco superior (de cima) e a "mordida cruzada posterior" presente. Correta higiene bucal e cuidados com alimentos duros serão importantes para a manutenção da saúde bucal e do aparelho em boas condições. Você e o menor sob sua responsabilidade serão orientados durante todo o tratamento sobre os cuidados necessários e sobre eventuais questionamentos.

Serão realizados no (na) seu (sua) filho (a) dois escaneamentos (uma filmagem dos dentes) das arcadas dentárias superior (de cima) e inferior (de baixo): uma antes e outra após o tratamento. Serão realizados também dois exames de tomografias computadorizadas de feixe cônico. O primeiro será realizado no início do tratamento para todos os pacientes e o segundo poderá ser logo após a fase de ativação do aparelho ou 6 meses após o término das ativações, de acordo com o grupo sorteado. Esse exame complementar realizado antes e após o tratamento ortodôntico possibilita informações necessárias para a realização do planejamento do tratamento ortodôntico e avaliação dos efeitos dos aparelhos em toda a face do paciente. Por fim, durante todo o acompanhamento da terapia serão realizadas também algumas fotografias intrabucais (frontal, lateral do sorriso e oclusal) e extrabucais (frente e lateral da face), para complementar a avaliação acima descrita.

Fotografias são procedimentos rápidos e fazem parte da rotina odontológica. O procedimento de escaneamento dos arcos dentários é um método simples e apresenta mínimo desconforto e nenhum risco para o menor. A realização do exame de tomografia é bastante simples e a exposição à radiação recebida justifica-se pelo benefício que este tratamento trará, pois o tratamento promoverá ganho ortopédico e ortodôntico consideráveis. Se acontecer algum tipo de desconforto durante qualquer um dos procedimentos, o profissional saberá como alivia-o imediatamente.

O tempo total de tratamento será de 1 ano. Todos os procedimentos clínicos serão realizados pelo próprio pesquisador responsável, na clínica de Ortodontia da Faculdade de Odontologia de Bauru, Universidade de São Paulo. Ao participar desta pesquisa, o menor sob sua responsabilidade receberá como benefícios a gratuidade do planejamento ortodôntico, do tratamento das suas más oclusões (posicionamento incorreto dos dentes), do acompanhamento clínico, e, caso apresentem a necessidade de algum outro tratamento bucal, serão encaminhados para o sistema de Triagem da Faculdade de Odontologia de Bauru para serem posteriormente encaminhados a outros Departamentos. Se houver suspeita de qualquer alteração médica ou psicológica, os responsáveis serão orientados a buscar tratamento e acompanhamento adequado para o menor. Ao final do estudo, os participantes terão garantido o acompanhamento e/ou tratamento ortodôntico complementar (se necessário). Não será oferecida remuneração, auxílio para alimentação ou transporte até o local nos dias de atendimento. É garantida a indenização em casos de danos que ocorram decorrentes dos procedimentos empregados nesta pesquisa.

Após a instalação do aparelho, o menor pode sentir algum tipo de desconforto, porém suportável, na região do palato e nos dentes de apoio. Os desconfortos que o (a) seu (sua) filho (a) pode sentir consistem em sensações de pressão variadas, porém suportáveis, na região dos dentes póstero-superiores (de cima e de trás), da região entre os incisivos centrais superiores (os dentes de cima e da frente), na região do nariz e na área entre os olhos. A expansão maxilar é bem documentada na literatura e os riscos existentes com a realização do procedimento estudado são mínimos e limitam-se a possíveis quebras dos parafusos expansores, durante o procedimento de ativação do aparelho. Nesses casos, um novo aparelho será confeccionado e instalado sem custos para o (a) senhor (a) ou seu (sua) filho (a).

Esse tratamento requisitará muita colaboração do (a) seu (sua) filho (a) e da família, pois o sucesso da terapia somente será possível com o retorno mensal, correta realização das ativações do aparelho e adequada higiene oral, conforme será orientado a vocês durante todo o tratamento.

É importante que você saiba que sua privacidade será respeitada, ou seja, o nome do seu filho (a) ou qualquer outro dado que possa, de qualquer forma, identificá-lo, será mantido em sigilo. Além disso, o menor

Rubrica do Participante da Pesquisa :

Rubrica do Pesquisador Responsável:

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ANNEX C- Informed consent for legal guardians of children (verso).

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Universidade de São Paulo
Faculdade de Odontologia de Bauru

Departamento de Odontopediatria, Ortodontia e Saúde Coletiva

receberá um termo como este o convidando a participar desta pesquisa e que, caso ele recuse o convite, a vontade dele será prevalecida, mesmo que o Sr(a) (pais/responsável legal) permita sua participação. O menor poderá deixar de participar da pesquisa a qualquer momento sem sofrer prejuízos, retirando, então, seu consentimento, sem precisar justificar.

A **pesquisadora** envolvida com a referida pesquisa é **Camila da Silveira Massaro** e com ela você poderá manter contato via **e-mail** (camilamassaro@usp.br) ou **telefone** (14) 98165 8166.

É assegurado o esclarecimento de dúvidas durante toda pesquisa, bem como será garantido o livre acesso a todas as informações e esclarecimentos adicionais sobre o estudo.

Pelo presente instrumento que atende às exigências legais, o(a) Sr.(a) ____, responsável pelo menor ____, portador da cédula de identidade ____________________, após leitura minuciosa das informações constantes neste TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO, devidamente explicada pelos profissionais em seus mínimos detalhes, ciente dos serviços e procedimentos aos quais será submetido, não restando quaisquer dúvidas a respeito do lido e explicado, DECLARA e FIRMA seu CONSENTIMENTO LIVRE E ESCLARECIDO concordando em participar da pesquisa proposta. Fica claro que o participante da pesquisa, pode a qualquer momento retirar seu CONSENTIMENTO LIVRE E ESCLARECIDO e deixar de participar desta pesquisa e ciente de que todas as informações prestadas tornar-se-ão confidenciais e guardadas por força de sigilo profissional (Art 9° do Código de Ética Odontológica).

Por fim, como pesquisador responsável pela pesquisa, DECLARO o cumprimento do disposto na Resolução CNS nº 466 de 2012, contidos nos itens IV.3 e IV.5.a e, na íntegra com a resolução CNS nº 466 de dezembro de 2012.

Por estarmos de acordo com o presente termo o firmamos em duas vias igualmente válidas (uma via para o participante da pesquisa e outra para o pesquisador) que serão rubricadas em todas as suas páginas e assinadas ao seu término, conforme o disposto pela Resolução CNS nº 466 de 2012, itens IV.3.f e IV.5.d.

Bauru, ____ de _____________ de ______.

______________________________	______________________________
Camila da Silveira Massaro **Pesquisadora responsável**	**Assinatura do responsável pelo menor**

O **Comitê de Ética em Pesquisa – CEP**, organizado e criado pela **FOB-USP**, em 29/06/98 (**Portaria GD/0698/FOB**), previsto no item VII da Resolução nº 466/12 do Conselho Nacional de Saúde do Ministério da Saúde (publicada no DOU de 13/06/2013), é um Colegiado interdisciplinar e independente, de relevância pública, de caráter consultivo, deliberativo e educativo, criado para defender os interesses dos participantes da pesquisa em sua integridade e dignidade e para contribuir no desenvolvimento da pesquisa dentro de padrões éticos.

Qualquer denúncia e/ou reclamação sobre sua participação na pesquisa poderá ser reportada a este CEP:

Horário e local de funcionamento:
Comitê de Ética em Pesquisa
Faculdade de Odontologia de Bauru-USP - Prédio da Pós-Graduação (bloco E - pavimento superior), de segunda à sexta-feira, no horário das **13h30 às 17 horas**, em dias úteis.
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