Systematic Review

Periodontal side effects of rapid and slow maxillary expansion: *A systematic review*

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ABSTRACT

Objectives: To identify the scientific evidence that demonstrates which of the transverse maxillary treatments has the least effect on periodontal tissues.

Materials and Methods: PubMed (MEDLINE), Cochrane Library, Scopus, Web of Science, Virtual Health Library, Google Scholar, and OpenGrey were searched without restrictions. A hand search was also carried out in the reference lists of the articles selected. The related articles tool in the PubMed database was checked for each article included. Risk of bias assessment was performed using Cochrane Collaboration's Risk of Bias tool for randomized clinical trials and the ROBINS-I tool for nonrandomized studies of interventions. The GRADE tool was used to assess the quality of the evidence.

Results: After examination of the full texts, three studies were finally included. Two studies used a Haas expander with different protocols, and one study used a Haas expander compared with a quad-helix appliance. These studies evaluated periodontal parameters and periodontal indices by clinical examination with a millimeter probe, and one study examined computed tomography images. After quality assessment, two studies were considered as having a "low" risk of bias. One study was scored as having a moderate risk of bias. The evidence was graded as moderate quality for alveolar bone level, tooth displacement, and inclination and very low for all other outcomes.

Conclusions: There were no significant differences to enable a sound conclusion about which type of maxillary expansion has the least periodontal side effects. (*Angle Orthod.* 2019;89:651–660.)

KEY WORDS: Palatal expansion technique; Maxilla; Review

INTRODUCTION

Orthodontic movement is a dynamic process resulting from the application of force in which the alveolar bone is remodeled selectively by local inflammation stimuli to move the tooth,[1] modifying the supporting tissues.[2] The most common method of transverse maxilla correction is the palatal expansion technique. Depending on the frequency of activation, magnitude of the force applied, patient's age, and treatment duration, this process can be performed with different mechanisms. These produce mainly rapid maxillary expansion (RME) or slow maxillary expansion (SME).[3–6] Compared with rapid expansion, slow expansion is more closely related to dental effects than orthopedic effects.[6,7]

Both expansion protocols can cause lateral flexion of the alveolar processes, and the anchorage teeth can show different degrees of inclination change.[8] Computed tomography has shown that excessive labial tooth movements can lead to significant reductions in alveolar levels of the crestal bone, dehiscence, and gingival recession in patients treated with RME.[9] This is an orthodontic procedure that may affect periodontal health, and the orthodontist should monitor the patient regularly during treatment.[10]

There are still many controversies regarding the effects of the palatal expansion procedure on periodontal tissues. The aim of this study was to identify, by means of a systematic review of the literature, the scientific evidence that demonstrated which of the

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transverse maxillary treatments affects periodontal tissues less.

MATERIALS AND METHODS

Protocol and Registration

The study protocol was registered at the PROSPERO database (CRD42015022042). The methodology followed was based on PRISMA guidelines.[11]

Eligibility Criteria and Study Selection

Articles that evaluated the periodontal side effects obtained from RME compared with SME were included. The controlled vocabulary (MeSH terms) and the entry terms in the search strategy were defined based on the PICOS format (Table 1) as follows:

- Population (P): patients in late mixed/early permanent dentition, with mild to moderate maxillary atresia and dental crowding, using orthodontic and/or orthopedic appliances for maxillary arch expansion.
- Intervention (I): RME to correct skeletal transverse maxillary discrepancies and transverse orthodontic problems.
- Comparison (C): SME.
- Outcome (O): periodontal side effects such as bone loss, gingival recession, and plaque index.
- Study design (S): randomized or nonrandomized human clinical trials.

The exclusion criteria were the use of reverse facemask treatment, surgical and/or extraction cases, syndromic patients, and the use of only one expansion protocol.

Information Sources

The electronic databases PubMed (MEDLINE), Cochrane Library, Scopus, Web of Science, Virtual Health Library, Google Scholar, and OpenGrey were used for the search. A hand search was also carried out in the reference lists of the articles selected for any reference that could have been missed during the electronic database searches. The related articles tool in the PubMed database was checked for each article included.

The search strategy was based on English MeSH terms, using all reports containing the combination of controlled vocabulary and entry terms relating to these words and adapted for the syntax rules of each bibliographic database (Table 1). No language or publication date restrictions were applied. Searches were performed between March 29 and April 13, 2018. All relevant titles were saved in a reference manager (EndNote basic, 2016, Thomson Reuters), and duplicate hits were removed.

Study Selection

Two examiners (Dr Bastos and Dr Blagitz) performed the searches independently to identify relevant and eligible studies. Initially, articles were selected by title and abstract according to the previously described search strategy. If the article appeared to meet the inclusion criteria in the title and/or in the abstract, the full-text version of the article was retrieved for further assessment and data extraction.

Data Collection Process

The following information was extracted from the articles included (Table 2): details of the participants, intervention, evaluation, and authors' conclusion.

Results of data extraction, independently performed by two researchers, were compared. If discrepancies were unresolved, a third evaluator was consulted (Dr Aragón).

Risk of Bias in Individual Studies

Risk of bias assessment was performed by two independent reviewers (Dr Bastos and Dr Blagitz) using the Cochrane Collaboration's tool for assessing risk of bias in randomized controlled trials (RCTs)[12] and the ROBINS-I tool for assessing risk of bias in nonrandomized studies of interventions.[13] The Cochrane Collaboration's tool was used to perform quality assessment of one article included. The assessment criteria contained seven items. For each bias domain, a judgment score was given following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (http://handbook.cochrane.org).

The judgment involved recording "yes" for low risk of bias, "no" for high risk of bias, and "unclear" in the case of no, insufficient, or uncertain information about the bias involved in the domain. Of the seven bias domains, six were considered key domains, excepting blinding of participants and personnel, because the participant always knew which treatment was used, even considering similar appliances, since the activation protocol was not the same. Studies were classified as having a "low" risk of bias if there was adequate judgment of the key domains. If any of the key domains were not met, the study was classified as having a "high" risk of bias. Finally, if there was lack of information in a key domain of the study, it was judged as "unclear," and the reviewers tried to contact the paper's authors to obtain more information and allow a definitive judgment of "yes" or "no."

Table 1. Electronic Database and Search Strategy (March 29, 2018, to April 13, 2018)

Pubmed (#1 AND #2 AND #3)			
#1 (#a AND #b) **#a** ((((((((Child[MeSH Terms]) OR Child[Title/Abstract]) OR Adolescent[MeSH Terms]) OR Adolescent[Title/Abstract]) OR Young Adult[MeSH Terms]) OR Young Adult[Title/Abstract]) OR Children[Title/Abstract]) OR Adolescents[Title/Abstract]) OR Teenager[Title/Abstract]	**#1 (#a AND #b)** **#b** ((((((((((Dental Arch[MeSH Terms]) OR Dental Arch[Title/Abstract]) OR Maxilla[MeSH Terms]) OR Maxilla[Title/Abstract]) OR Molar[MeSH Terms]) OR Molar[Title/Abstract]) OR Palate[MeSH Terms]) OR Palate[Title/Abstract]) OR Transversal deficiency[Title/Abstract]) OR Transverse maxillary discrepancy[Title/Abstract]) OR Maxillary transverse constriction[Title/Abstract]) OR Orthodontic patient[Title/Abstract]) OR Orthodontic therapy[Title/Abstract]) OR Patients[Title/Abstract]	**#2** ((((((((((((((((((((((((((((((((((Tooth Movement[MeSH Terms]) OR Tooth Movement[Title/Abstract]) OR Orthodontic Appliance Design[MeSH Terms]) OR Orthodontic Appliance Design[Title/Abstract]) OR Corrective Orthodontics[MeSH Terms]) OR Corrective Orthodontics[Title/Abstract]) OR Palatal Expansion Technique[MeSH Terms]) OR Palatal Expansion Technique[Title/Abstract]) OR Maxillary Bone[Title/Abstract]) OR Maxillary Expansion[Title/Abstract]) OR Orthodontic treatment[Title/Abstract]) OR RME[Title/Abstract]) OR RPE[Title/Abstract]) OR Hyrax[Title/Abstract]) OR Haas[Title/Abstract]) OR Rapid maxillary expansion[Title/Abstract]) OR Rapid palatal expansion[Title/Abstract]) OR Rapid expansion[Title/Abstract]) OR Expansion technique[Title/Abstract]) OR Expansion protocol[Title/Abstract]) OR Lateral expansion[Title/Abstract]) OR palatal expansion[Title/Abstract]) OR Expander[Title/Abstract]) OR Expansion[Title/Abstract]) OR Maxillary[Title/Abstract]) OR Palatal[Title/Abstract]) OR Maxillae[Title/Abstract]) OR Arch[Title/Abstract]) OR Banded expanders[Title/Abstract]) OR Bonded expanders[Title/Abstract]) OR Tooth-borne expander[Title/Abstract]) OR Tooth-tissue-borne expander[Title/Abstract]) OR Acrylic-bonded appliance[Title/Abstract]) OR Fixed split acrylic appliance[Title/Abstract]	**#3** ((((((Slow maxillary expansion[Title/Abstract]) OR Slow expansion[Title/Abstract]) OR Slow palatal expansion[Title/Abstract]) OR Quad-helix[Title/Abstract]) OR SME[Title/Abstract]) OR SPE[Title/Abstract]) OR Removable expansion plate[Title/Abstract]
Scopus (#1 AND #2 AND #3)			
#1 (#a AND #b) **#a** (TITLE-ABS-KEY (**child**) OR TITLE-ABS-KEY (**adolescent**) OR TITLE-ABS-KEY (**young adult**) OR TITLE-ABS-KEY (**children**) OR TITLE-ABS-KEY (**adolescents**) OR TITLE-ABS-KEY (**teenager**))	**#1 (#a AND #b)** **#b** (TITLE-ABS-KEY (**"Transversal deficiency"**) OR TITLE-ABS-KEY (**"Transverse maxillary discrepancy"**) OR TITLE-ABS-KEY (**"Maxillary transverse constriction"**) OR TITLE-ABS-KEY (**"Orthodontic patient"**) OR TITLE-ABS-KEY (**"Orthodontic therapy"**) OR TITLE-ABS-KEY (**patients**) OR TITLE-ABS-KEY (**"Dental Arch"**) OR TITLE-ABS-KEY (**maxilla**) OR TITLE-ABS-KEY (**molar**) OR TITLE-ABS-KEY (**palate**))	**#2** ((TITLE-ABS-KEY (**"Tooth Movement"**) OR TITLE-ABS-KEY (**"Orthodontic Appliance Design"**) OR TITLE-ABS-KEY (**"Corrective Orthodontics"**) OR TITLE-ABS-KEY (**"Palatal Expansion Technique"**) OR TITLE-ABS-KEY (**"Maxillary Bone"**) OR TITLE-ABS-KEY (**"Maxillary Expansion"**) OR TITLE-ABS-KEY (**"Orthodontic treatment"**))) OR ((TITLE-ABS-KEY (**rme**) OR TITLE-ABS-KEY (**rpe**) OR TITLE-ABS-KEY (**hyrax**) OR TITLE-ABS-KEY (**haas**) OR TITLE-ABS-KEY (**"Rapid maxillary expansion"**) OR TITLE-ABS-KEY (**"Rapid palatal expansion"**) OR TITLE-ABS-KEY (**"Rapid expansion"**) OR TITLE-ABS-KEY (**"Expansion technique"**) OR TITLE-ABS-KEY (**"Expansion protocol"**) OR TITLE-ABS-KEY (**"Lateral expansion"**))) OR ((TITLE-ABS-KEY (**"palatal expansion"**) OR TITLE-ABS-KEY (**expander**) OR TITLE-ABS-KEY (**expansion**) OR TITLE-ABS-KEY (**maxillary**) OR TITLE-ABS-KEY (**palatal**) OR TITLE-ABS-KEY (**maxillae**) OR TITLE-ABS-KEY (**arch**) OR TITLE-ABS-KEY (**"Banded expanders"**) OR TITLE-ABS-KEY (**"Bonded expanders"**) OR TITLE-ABS-KEY (**"Tooth-borne expander"**))) OR ((TITLE-ABS-KEY (**"Tooth-tissue-borne expander"**) OR TITLE-ABS-KEY (**"Acrylic-bonded appliance"**) OR TITLE-ABS-KEY (**"Fixed split acrylic appliance"**)))	**#3** (TITLE-ABS-KEY (**"Slow maxillary expansion"**) OR TITLE-ABS-KEY (**"Slow expansion"**) OR TITLE-ABS-KEY (**"Slow palatal expansion"**) OR TITLE-ABS-KEY (**"Quad-helix"**) OR TITLE-ABS-KEY (**sme**) OR TITLE-ABS-KEY (**spe**) OR TITLE-ABS-KEY (**"Removable expansion plate"**))
The Cochrane Library (#1 AND #2 AND #3)			
#1 (#a AND #b) **#a** Child:ti,ab,kw or Adolescent "Young Adult":ti,ab,kw or "Young Adult":ti,ab,kw or Children:ti,ab,kw or Adolescents or Teenager:ti,ab,kw	**#1 (#a AND #b)** **#b** "Dental Arch" or Maxilla Molar Palate:ti,ab,kw or Molar or Palate:ti,ab,kw or "Transversal deficiency" or "Transverse maxillary discrepancy":ti,ab,kw or "Maxillary transverse constriction" or "Orthodontic patient":ti,ab,kw or "Orthodontic therapy" or Patients:ti,ab,kw	**#2** "Tooth Movement" or "Orthodontic Appliance Design" or "Corrective Orthodontics" or "Palatal Expansion Technique" or "Maxillary Bone" or "Maxillary Expansion":ti,ab,kw or "Orthodontic treatment" or RME or RPE or Hyrax or Haas or "Rapid maxillary expansion":ti,ab,kw or "Rapid palatal expansion" or "Rapid expansion" or "Expansion technique" or "Expansion protocol" or "Lateral expansion" or "palatal expansion":ti,ab,kw or Expander or Expansion or Maxillary or Palatal or Maxillae or Arch:ti,ab,kw or "Banded expanders" or "Bonded expanders" or "Tooth-borne expander" or "Tooth-tissue-borne expander" or "Acrylic-bonded appliance" or "Fixed split acrylic appliance":ti,ab,kw	**#3** "Slow maxillary expansion" or "Slow expansion":ti,ab,kw or "Slow palatal expansion" or "Quad-helix":ti,ab,kw or SME:ti,ab,kw or SPE:ti,ab,kw or "Removable expansion plate":ti,ab,kw
Web of Science (#1 AND #2 AND #3)			
#1 (#a AND #b) **#a** **Tópico:** (Child) *OR* **Tópico:** (Adolescent) *OR* **Tópico:** ("Young Adult") *OR* **Tópico:** (Children) *OR* **Tópico:** (Adolescents) *OR* **Tópico:** (Teenager)	**#1 (#a AND #b)** **#b** **Tópico:** ("Dental Arch") *OR* **Tópico:** (Maxilla) *OR* **Tópico:** (Molar) *OR* **Tópico:** (Palate) *OR* **Tópico:** ("Transversal deficiency")*OR* **Tópico:** ("Transverse maxillary discrepancy") *OR* **Tópico:** ("Maxillary transverse constriction") *OR* **Tópico:**("Orthodontic patient") *OR* **Tópico:** ("Orthodontic therapy") *OR* **Tópico:** (Patients)	**#2** **Tópico:** ("Tooth Movement") *OR* **Tópico:** ("Orthodontic Appliance Design") *OR* **Tópico:**("Corrective Orthodontics") *OR* **Tópico:** ("Palatal Expansion Technique") *OR* **Tópico:** ("Maxillary Bone") *OR* **Tópico:** ("Maxillary Expansion") *OR* **Tópico:** ("Orthodontic treatment") *OR* **Tópico:** (RME) *OR* **Tópico:** (RPE) *OR* **Tópico:** (Hyrax) *OR* **Tópico:** (Haas) *OR* **Tópico:** ("Rapid maxillary expansion")*OR* **Tópico:** ("Rapid palatal expansion") *OR* **Tópico:** ("Rapid expansion") *OR* **Tópico:** ("Expansion technique") *OR* **Tópico:** ("Expansion protocol") *OR***Tópico:** ("Lateral expansion") *OR* **Tópico:** ("palatal expansion") *OR* **Tópico:**(Expander) *OR* **Tópico:** (Expansion)*OR* **Tópico:** (Maxillary) *OR* **Tópico:**(Palatal) *OR* **Tópico:** (Maxillae) *OR* **Tópico:** (Arch) *OR* **Tópico:** ("Banded expanders") *OR* **Tópico:** ("Bonded expanders") *OR* **Tópico:** ("Tooth-borne expander") *OR* **Tópico:** ("Tooth-tissue-borne expander") *OR* **Tópico:**("Acrylic-bonded appliance") *OR* **Tópico:** ("Fixed split acrylic appliance")	**#3** **Tópico:** ("Slow maxillary expansion") *OR* **Tópico:**("Slow expansion") *OR* **Tópico:** ("Slow palatal expansion") *OR* **Tópico:** ("Quad-helix") *OR* **Tópico:** (SME) *OR* **Tópico:** (SPE) *OR* **Tópico:** ("Removable expansion plate")
Virtual Health Library (#1 AND #2 AND #3)			
#1 (#a AND #b) **#a** (tw:(Child)) OR (tw:(Adolescent)) OR (tw:("Young Adult")) OR (tw:(Children)) OR (tw:(Adolescents)) OR (tw:(Teenager))	**#1 (#a AND #b)** **#b** (tw:("Dental Arch")) OR (tw:(Maxilla)) OR (tw:(Molar)) OR (tw:(Palate)) OR (tw:("Transversal deficiency")) OR (tw:("Transverse maxillary discrepancy")) OR (tw:("Maxillary transverse constriction")) OR (tw:("Orthodontic patient")) OR (tw:("Orthodontic therapy")) OR (tw:(Patients))	**#2** (tw:((tw:("Tooth Movement")) OR (tw:("Orthodontic Appliance Design")) OR (tw:("Corrective Orthodontics")) OR (tw:("Palatal Expansion Technique")) OR (tw:("Maxillary Bone")) OR (tw:("Maxillary Expansion")) OR (tw:("Orthodontic treatment")) OR (tw:(RME)) OR (tw:(RPE)) OR (tw:(Hyrax)) OR (tw:(Haas)) OR (tw:("Rapid maxillary expansion")) OR (tw:("Rapid palatal expansion")) OR (tw:("Rapid expansion")) OR (tw:("Expansion technique")) OR (tw:("Expansion protocol")) OR (tw:("Lateral expansion")) OR (tw:("palatal expansion")) OR (tw:(Expander)) OR (tw:(Expansion)) OR (tw:(Maxillary)) OR (tw:(Palatal)) OR (tw:(Maxillae)) OR (tw:(Arch)) OR (tw:("Banded expanders")) OR (tw:("Bonded expanders")) OR (tw:("Tooth-borne expander")) OR (tw:("Tooth-tissue-borne expander")) OR (tw:("Acrylic-bonded appliance")) OR (tw:("Fixed split acrylic appliance"))))	**#3** (tw:((tw:("Slow maxillary expansion")) OR (tw:("Slow expansion")) OR (tw:("Slow palatal expansion")) OR (tw:("Quad-helix")) OR (tw:(SME)) OR (tw:(SPE)) OR (tw:("Removable expansion plate"))))
Google Scholar			
child AND "Transverse maxillary discrepancy" AND "Rapid maxillary expansion" AND "Slow maxillary expansion"			
Open Grey			
child AND maxillary AND expansion			

Table 2. Description of Studies Included

		Participants			Intervention		Evaluation		
Author, year	Study design	N, age, sex	Group allocation	Condition	Orthodontic device	Activation protocol	Survey method	Measurements investigated	Authors' conclusions
Brunetto et al. (2013)	RCT	33 children (18 girls, 15 boys; mean age 9 years).	RME group: n = 17 (10 girls, 7 boys; mean age 8.9 years). SME group: n = 16 (8 girls, 8 boys; mean age 9 years).	Clinical maxillary transverse deficiency and intertransitory period of the mixed dentition (mean age between 7 and 10 years).	Tooth-tissue-borne palatal expander recommended by Haas.	RME group: a half turn (0.4 mm) per day. A full turn on the first day. SME group: a half turn (0.4 mm) weekly.	CBCT examination before orthodontic treatment (T1) and between 1 and 7 days after stabilization of the screw (T2). The appliances were not removed for the T2 examinations.	Alveolar bone height and thickness, tooth inclination, tooth displacement and inclination.	RME group had greater teeth inclinations and SME group had greater bodily movement of the teeth (maxillary first permanent molars). Loss and reduction of height and thickness of bone were detected in both groups, with greater intensity and significance in the SME group. Changes in the frequency of activation of the palatal expander might influence the dental and periodontal side effects of maxillary expansion treatment.
Greenbaum and Zachrisson (1982)	Non-randomized clinical trial.	61 patients (89 with the control group); 42 females (65 with the control group); 19 males (24 with the control group).	RME group: n = 28 (17 females, 11 males; mean age 13.2 ± 1.9 years). SME group: n = 33 (25 females, 8 males; mean age 12.3 ± 2.0 years). Control group: n = 28 (23 females, 5 males; mean age 14.3 ± 2.4 years).	Narrow maxillary arch, initiation of treatment prior to the age of 21 years, completion of active orthodontic treatment consisting of a light-wire edgewise appliance and no restorations on maxillary first permanent molar buccal surfaces.	RME group: tissue-borne, fixed, split acrylic appliance. SME: quad-helix appliance.	Immediately after cementation: 1/4 turn each 5 min, for 15 min. The parent should turn the screw 1/4 turn in the morning and 1/4 turn in the evening. The patient was observed at 7-, 10-, 14-, 18- and 21-day intervals. RME group: the appliance was retained for a minimum of 3 months. SME group: the appliance was retained for 3–6 months. Control group: no palatal expansion during the treatment.	Clinical and periodontal examination with machined and calibrated periodontal probe.	Alveolar bone height, attachment level, probing depth and width of keratinized gingiva. Examination for possible furcation involvement with the probe and level of crestal bone.	Both lateral expansion groups exhibited minimal differences in periodontal conditions when compared to the control group. Based on the results, it is difficult to offer recommendations as to the preferred choice of treatment to correct a maxillary lateral deficiency.
Mummolo et al. (2014)	Non-randomized pilot study.	20 patients (11 girls, 9 boys; mean age 6.3 years).	RME group: n = 10 (5 girls, 5 boys; mean age 6.3 years). SME group: n = 10 (6 girls, 4 boys; mean age 6.3 years).	No dental diseases, a constriction of the upper jaw, good general health, probing depth values not exceeding 3 mm in the whole dentition, no radiographic evidence of periodontal bone loss and normal gingival biotype.	The Haas expander was anchored to the second deciduous molars with bands and bonded to the deciduous canines using acrylic resin.	RME group: 0.25 mm activated by the operator and 0.25 mm activated by the parent. Then, it was activated once in the morning and once in the evening (0.5 mm total daily activation) for 20 days (T1). After the active therapy, the screw was fixed and remained in retention therapy for 5 months (T2). SME group: twice a week (0.5 mm total weekly activation) (T1). After 3 months of active therapy, there was a period of 3 months for retention (T2).	Clinical and periodontal examination with periodontal probe.	Plaque index, papillary bleeding index and pocket probing depth.	Both rapid and slow expansion treatments present a potential irritation effect on the periodontium. There are no long-term benefits that might be referred unequivocally to one of the two treatments in terms of periodontal consequences, as demonstrated by the lack of significant differences between the two groups at the retention period (T2).

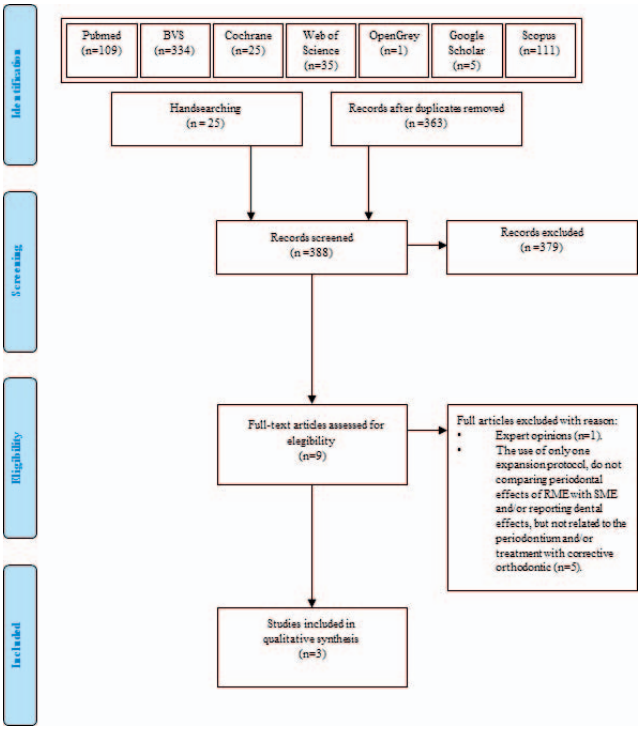

Figure 1. Flow diagram of study identification.

The ROBINS-I tool is made of seven domains through which bias might be introduced. Each domain was scored as low, moderate, serious, or critical risk of bias. If there was no clear indication that the study was at serious or critical risk of bias, and there was a lack of information in one or more domains, the study was judged as having "no information." The overall risk of bias of the study was scored as serious if serious risk of bias was scored in at least one domain. If not, the study received a moderate risk of bias in the overall evaluation. If all evaluations of the study were classified as low risk of bias, then low risk was the final evaluation of the study included.

During the period of study, if disagreements were unresolved between the reviewers, a third evaluator was consulted (Dr Aragón).

Summary Measures

Measurements of continuous data were in millimeters[5,8,10] and degrees,[8] and categorical data and scores[10] were collected for some selected clinical indices,[10] cone-beam computerized tomography images,[8] and periodontal and clinical examinations.[5]

Synthesis of Results

Data collected were synthetized in a descriptive table. A meta-analysis was planned if there was relative homogeneity of the data and the methods for obtaining it, for each selected article.

Evaluation of the Level of Evidence

The level of evidence was calculated using the Grading of Recommendations, Assessment, Development and Evaluation Pro software (GRADEpro Guideline Development Tool, available online at gradepro.org.). It grades the quality of evidence in four levels: very low, low, moderate, and high. "High quality" suggests that the true effect lies close to the estimate of the effect. "Very low quality" suggests that there is very little confidence in the effect estimate, and the estimate reported can be substantially different from what was measured. This tool considers five aspects for rating the quality of evidence.[14]

RESULTS

Study Selection

After the database screening, 620 articles were selected: 109 from PubMed, 334 from BVS, 25 from the Cochrane Library, 35 from Web of Science, one from OpenGrey, five from Google Scholar, and 111 from Scopus. After the duplicate studies were removed, 388 studies were identified. After title screening, nine studies remained for further careful examination of the abstracts. The full texts of these nine studies were assessed to check if they were eligible. Among them, six were excluded. The reasons for exclusions were as follows: expert opinion ($n = 1$),[15] the use of only one expansion protocol, not comparing periodontal side effects of RME with SME, and/or reporting dental effects, but not related to the periodontium and/or corrective orthodontic treatment ($n = 5$).[6,16–19] Therefore, three articles were finally included and selected for qualitative analysis of risk of bias. The flow diagram (Figure 1) illustrates the results of the search, summarizing the process of identifying, including, and excluding studies.

Study Characteristics

The characteristics of the three studies selected are listed in Table 2. Among them, there was an RCT,[8] a nonrandomized pilot study,[10] and a non-RCT.[5]

Regarding the type of orthodontic appliance, two studies used a Haas expander, changing the activation protocol to differentiate RME from SME.[8,10] The other study used a Haas expander for RME and a quad-helix appliance for SME.[5]

Concerning the measures used, one study evaluated the level of marginal alveolar bone by clinical examination with a millimeter probe, bone insertion, probing depths, width of keratinized gingiva, furcation

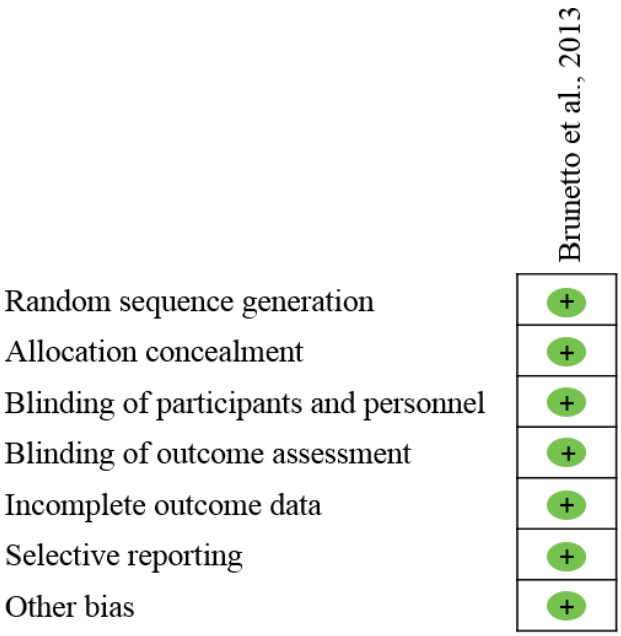

Figure 2. Summary of the risk of bias assessment according to the Cochrane Collaboration's tool, used to record the risk of bias of one article classified as a RCT.

involvement, and height of the bone crest.[5] The second study used the same method and evaluated plaque index, papillary bleeding index, and probing depth.[10] The third study, using computed tomography images, evaluated the alveolar height, bone thickness, displacement, and tooth inclination.[8]

The number of patients included in these studies ranged from 20 to 61 participants. The age range of the participants included in the clinical trials was similar, between 6.3 years and 13.2 years.

When evaluating the three articles, one[8] reported sample loss and the reasons for it, with a loss of 39.9% for RME and 48.4% for SME. In one study,[5] there was evaluation of patients' medical records, seeking information on age at the start of treatment and at the time of evaluation, premolar extraction, and facial type, among others.

Risk of Bias Within Studies

Assessment of risk of bias of the studies included in this systematic review was performed using the Cochrane Collaboration's tool in RCTs (Figure 2) and the ROBINS-I tool in nonrandomized studies of interventions (Table 3).

One full-text study reported the method of randomization employed and how the allocation concealment was performed. This study[8] was considered as having a "low" risk of bias according to the Cochrane Collaboration's tool, even for blinding of outcome assessment, because it was clear that the periodontal evaluation was performed by a blind operator.

In the other two articles,[5,10] the randomization method used for sample selection was not declared, and this information was confirmed after contact by email with the authors.[8,10] Because of this, the risk of bias followed the protocol recommended by the ROBINS-I tool. One article was scored as having a low risk of bias.[10] For the other one, as information on bias in the measurement of outcomes was not clear, the overall classification was moderate risk of bias.[5]

The articles presented appropriate statistical tests for the data analyzed, and they did not have any other data that could lead to an increase in the risk of bias.

Results of Individual Studies

Two studies did not find significant differences in periodontal changes between the two expansion treatments,[5,10] and one reported increased periodontal bone loss with changes in height and thickness for slow expansion.[8]

A summary of the description of the studies included and evaluated is presented in Table 2.

Table 3. Risk of Bias According to the Cochrane Collaboration's Tool and ROBINS-I

Cochrane	Brunetto et al. (2013)	ROBINS-I	Mummolo et al. (2014)	Greenbaum and Zachrisson (1982)
Participants	33	Participants	20	61/89 (with/without control group)
Domain		Domain		
Random sequence generation	Low	Bias due to confounding	Low	Low
Allocation concealment	Low	Bias in selection of participants into the study	Low	Low
Blinding of participants and personnel	Low	Bias in measurement of interventions	Low	Low
Blinding of outcome assessment	Low	Bias due to departures from intended interventions	Low	Low
Incomplete outcome data	Low	Bias due to missing data	Low	Low
Selective reporting	Low	Bias in measurement of outcomes	Low	Moderate
Other	Low	Bias in selection of the reported result	Low	Low
		Overall	Low	Moderate

Table 4. GRADE Evidence Profile Table: Should RME Versus SME Be Used for Maxillary Atresia?

Certainty Assessment									
No. of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations	Impact	Certainty	Importance
Alveolar bone level (assessed with CBCT, mm)									
1	Randomized trials	Not serious	Not serious	Not serious	Serious[a]	None	Loss and reduction of height and thickness of bone were detected in both groups, with greater intensity and significance in the SME group.	⊕⊕⊕○ MODERATE	CRITICAL
Alveolar bone height (assessed with clinical and periodontal examination with machined and calibrated periodontal probe, mm)									
1	Observational studies	Serious[b]	Not serious	Not serious	Serious[a]	None	Both lateral expansion groups exhibited minimal differences in periodontal conditions. It is difficult to offer recommendations as to the preferred choice of treatment to correct a maxillary lateral deficiency because both approaches may be considered to be within an acceptable range.	⊕○○○ VERY LOW	IMPORTANT
Tooth displacement and inclination (assessed with CBCT, mm and degrees)									
1	Randomized trials	Not serious	Not serious	Not serious	Serious[a]	None	RME group had greater teeth inclinations and SME group had greater bodily movement of the teeth (maxillary first permanent molars).	⊕⊕⊕○ MODERATE	CRITICAL
Probing pocket depth (assessed with clinical and periodontal examination with periodontal probe, mm)									
2	Observational studies	Serious[c]	Not serious	Not serious	Serious[a]	None	None of the studies showed significant differences in periodontal conditions in the RME and SME groups. Both expansion protocols present a potential irritation effect on the periodontium.	⊕○○○ VERY LOW	IMPORTANT

[a] Narrative synthesis was conducted, and the estimates are not precise.
[b] The information on the bias in the measurement of outcomes was not clear according to ROBINS-I.
[c] In one of the two studies, the information on bias in the measurement of outcomes was not clear according to ROBINS-I.

Synthesis of Results

Because of the heterogeneity of the periodontal evaluation methods employed and the units of measurement (continuous and categorical data) used in the related articles found, the conduct of a meta-analysis was not justified and would not have allowed meaningful comparisons. Only simple and descriptive comparisons are reported.

Assessment of the Quality of Evidence

The GRADE evidence profile table is described in Table 4. For the outcome alveolar bone level (height and thickness) and tooth displacement and inclination,

the GRADE quality of evidence was graded as moderate because of "serious" limitations in imprecision, because a narrative synthesis was conducted, because of the impossibility of performing meta-analysis, and because the estimates are not precise. In all other outcomes, the GRADE quality of evidence was judged as very low due to "serious" limitations in imprecision and risk of bias, since the information on bias in the measurement of outcomes was not clear in these observational studies.

DISCUSSION

Maxillary atresia can be skeletal, dental, or a combination of both problems. Depending on the diagnostic etiology, correction demands the use of different appliances, used for correction via orthodontic or orthopedic maxillary expansion.[18] Some recent systematic reviews[20,21] studied the difference in effectiveness of dental arch correction between RME and SME, and there was no strong evidence of differences between the two protocols.

When the periodontal side effects of maxillary expansion are considered, it is important to monitor the periodontal tissues affected by the procedure,[10] since the components of fixed orthodontic appliances can cause an imbalance of oral flora,[7] leading to the appearance and accumulation of cariogenic and/or periodontopathic bacteria.[22] In addition, both RME and SME lead to bodily or tooth inclination movement through the alveolar process, approximating anatomical limits[8] and causing damage to the periodontium and compromising tooth longevity in the oral cavity.[5]

Even against information that proves damage to the periodontal structures,[8,9] it is not clear in the literature which one of the two maxillary expansion protocols leads to a greater commitment in these terms, which would help the clinician to select the more appropriate treatment for gingival and alveolar bone health. Thus, this systematic review was conducted to synthesize the related information available. The small number of articles included in this study, combined with different methods of evaluating periodontal structures, made it impossible to carry out a meta-analysis, even considering that all of the included studies performed the same comparison in periodontal terms, exactly according to the purpose of the study, between RME and SME.

Summary of Evidence

Statistical differences were found when comparing the measurements and the periodontal indices obtained in the RME and SME groups for the main variables in the studies selected.[5,8,10] However, none could be considered clinically relevant, since there was no definitive conclusion about which type of expansion was appropriate regarding the periodontal aspects.

Three articles were included in this systematic review, and methodological issues were identified. Regarding classification of the articles and their score for the Cochrane Collaboration's tool, one study was rated as having a low risk of bias for all key areas, mainly because there was an adequate method of randomization and allocation.[8] The other two articles were scored as having low and moderate risk of bias according to the ROBINS-I tool.[5,10]

The quality of evidence of clinical outcomes was also graded using the GRADE tool. The evidence scored for the alveolar bone level outcome, which included alveolar bone height and thickness, was moderate for the RCT study and very low for the observational study, since it was not possible to conduct a meta-analysis and narrative synthesis was conducted, and the estimates are not precise. The imprecision evaluation was classified as "serious." A moderate evidence was scored for tooth displacement and inclination, again because of a "serious" imprecision. For potential periodontal irritation effects, there was a "serious" evidence level for imprecision and the risk of bias outcome, since the information on bias in the measurement of outcomes was not clear in the ROBINS-I tool for one article.[5]

Heterogeneity was observed for the periodontal evaluation methods and units of measurement used (continuous and categorical data). In the study by Mummolo et al.,[10] clinical periodontal indices were used to assess gingival and periodontal health. Statistical differences occurred between rapid and slow maxillary groups when considering plaque index and papillary bleeding index, suggesting that the palatal expander, as well as fixed orthodontic appliances in adolescents, caused irritation side effects in the periodontium.[23] Greenbaum and Zachrisson[5] measured periodontal parameters, such as alveolar bone height, attachment level, probing depth, and width of keratinized gingiva in millimeters, comparing rapid and slow maxillary groups with a control group not undergoing expansion. They concluded that, even with statistically significant differences for most of the variables included, with more damage resulting from the rapid protocol, the differences were not substantial enough to warrant a better treatment for maxillary atresia correction. Finally, Brunetto et al.[8] took cone-beam computerized tomography images to evaluate, quantitatively, periodontal aspects related to the expansion protocol, such as buccal displacement of the maxillary first permanent molars, which was greater for the slow protocol; inclination movement of anchorage teeth, which was more intense for the rapid protocol; and bone loss, detected in both groups but

with a more significant result for slow expansion. The authors concluded that the activation frequency of the palatal screw might have influenced dental and periodontal aspects and that there were differences in dental movements and periodontal side effects between RME and SME. The inclination movements of supporting teeth in RME were in agreement with another cone-beam computerized tomography study,[9] which showed reduced buccal bone plate and increased lingual bone plate thickness of supporting teeth, as well as bone dehiscence on the buccal aspect of anchorage teeth. All of these features were demonstrative of tooth inclination movement.

The main conclusion of the studies selected was that it is necessary to standardize the methods of measurement as well as to randomize the sample to obtain a sound conclusion. This would make studies more clinically effective and able to help in decision making about which type of expansion is less harmful to the periodontal tissues.

Limitations

One article included in this systematic review[8] had a 39.9% sample loss in the RME group and 48.4% sample loss for the slow protocol. Even considering high values of sample loss, the power of analysis of variance was calculated, and a value of 76% was obtained for intergroup comparison. Therefore, the article was rated as having a low risk of bias in this domain.

Another factor to be considered is the use of the same appliance, with a different activation protocol, in two studies.[8,10] Perhaps using a such a bulky appliance for a slow expansion protocol was excessive, since plaque accumulation and difficulties in oral hygiene can contribute to further damage of periodontal tissues and supporting teeth. However, this gave a more reliable finding of the approach itself.

Besides the type of expansion and the appliance selected, which teeth are banded must be considered as an important variable, since the process of deciduous tooth exfoliation can affect the interpretation of results. It is known that when expansion treatment is performed in the deciduous or mixed dentition, with bands on the deciduous molars, the result is better because the orthopedic effect is more favorable at early ages.[24] However, deciduous canines and molars, the anchorage teeth, can be involved in periodontal terms. In this instance, the permanent teeth would erupt in an area with new bone, reestablishing the alveolar area.[9]

In this systematic review, two studies used an expander appliance anchored to the first permanent molars.[5,8] The third study used a Haas expander anchored to the second deciduous molars with bands and bonded to the deciduous canines using acrylic resin.[10] However, contradictorily, one of the periodontal indices, pocket probing depth, was measured at the first permanent molar.

Other important variables to be evaluated in more powerful, future research, that could affect the results are age at the initiation of treatment and at examination, extraction cases, sagittal movement of the maxillary first molar during treatment, the length of time in bands and retention, and the duration of the postretention period.[5] Thus, a representative random sample, standardization of the appliance and anchoring teeth, age range, and a consistent method of evaluation are necessary for future studies to provide more sound clinical evidence.

Clinical Considerations

The lack of sufficient evidence makes it impossible to indicate which type of expansion protocol should be preferred. Perhaps the choice depends on the main desired effect (orthopedic or orthodontic) rather than on the appliance that would be less harmful to the periodontal tissue.

CONCLUSIONS

- Based on evaluation of the studies that met the inclusion criteria, there were no significant or clinical differences to permit a sound conclusion about what type of maxillary expansion, rapid or slow, is more appropriate regarding periodontal health.
- The studies selected assessed only two types of appliance (the Haas expander and, to a lesser degree, the quad-helix appliance) and had different evaluation methods, requiring further randomized clinical studies with adequate sample size, random sequence generation, and concealment of participant allocation to increase the strength of evidence for comparing the periodontal side effects caused by different maxillary expansion protocols.
- The quality of the evidence was graded as moderate for the outcome variables for alveolar bone level and tooth displacement and inclination. All other outcomes were graded as very low quality.

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