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Anchorage In Primary Vs. Permanent Teeth For Rapid Maxillary Expansion In Children: Systematic Review And Meta-Analysis

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Abstract:
Background*: Rapid maxillary expansion (RME) is a widely used orthodontic technique to correct transverse maxillary deficiencies. Both primary and permanent teeth are commonly used as anchorage for this procedure. However, there is limited evidence regarding differences in skeletal and dental effects or buccal alveolar bone preservation between these anchorage types.*
Materials and Methods: *A systematic review was conducted to compare the skeletal and dental effects of RME using primary or permanent teeth as anchorage. Searches were performed in the following databases: PubMed, Web of Science, Scopus, LILACS, and OpenGrey. The risk of bias was assessed using the Rob 2.0 and Robins I tools. The certainty of evidence was evaluated according to the GRADE system, and meta-analysis was performed with R software.*
Results*: Eight studies were included in the qualitative analysis and five in the quantitative analysis. The risk of bias was low in two studies, moderate in five studies, and high in one study. The certainty of evidence was very low. It was not possible to perform a meta-analysis for the outcome "buccal alveolar bone thickness" due to the lack of available studies, which was limited to only one study. The intermolar width was greater when the anchorage used permanent teeth SMD= -1.24; 95% CI (-2.14; -0.33); p<0.01]. However, this difference may not be clinically relevant.*
Conclusion: *The evidence does not support a clear recommendation for the use of primary or permanent teeth as anchorage in RME, as no clinically relevant differences were observed in skeletal or dental effects. Primary teeth may be preferred when buccal alveolar bone preservation is a priority. Further studies are required to enhance evidence and support clinical decisions.*

Keywords: *Palatal Expansion Technique; Tooth, Deciduous; Dentition, Permanent; Alveolar Bone Loss.*

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I. Introduction

Rapid maxillary expansion (RME) is a standard procedure to increase maxillary transverse dimensions in growing patients. The conventional maxillary expansion appliance is fixed on maxillary teeth to promote the skeletal opening of the mid-palatal suture and to move the palatine shelves away from each other[1,2]. Their effects are related to force, treatment time, an interval of activation, patient's age, and they are delivered to the palatal suture, periodontium, and alveolar bone. The side effects can be lateral flexion of the alveolar processes, root resorptions, bone fenestrations, and different degrees of inclination and displacement of the anchoring teeth[3-6]. Previous investigations have shown that these effects are mainly observed when the treatment is carried out in patients with permanent dentition[7,8].

A study with computed tomography scan verified that RME reduced a mean of 0.6 mm to 0.9 mm the buccal bone thickness of supporting teeth and caused bone dehiscence on the buccal area of permanent anchorage teeth, especially if this thickness was already thin[9]. Other studies showed that RME supported by primary teeth corrects crossbite of permanent maxillary first molars with more translation and less buccal tipping than when anchoring in the permanent teeth themselves[10,11]. Devices supported by primary teeth[12] or mini implants[13] are available alternatives to minimize the RME's side effects in permanent teeth.

Although RME appears to cause buccal bone loss in supporting teeth, the clinical significance of these findings remains uncertain[14]. This systematic review seeks to compare the skeletal and dental effects of RME anchored on both primary and permanent teeth, with a primary focus on assessing the impact on buccal alveolar bone thickness. Despite our initial protocol highlighting this as a primary outcome, the emergence of significant additional secondary outcomes from the collected evidence underscored the necessity to broaden our investigation.

II. Material And Methods

Protocol and Registration

The protocol for this systematic review was registered with the National Institute for Health Research (NIHR) PROSPERO, an international prospective register of systematic reviews (Registration number: CRD4202125372). The review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[15].

Eligibility Criteria

To investigate if there are differences in anchoring the expander in primary or permanent teeth, the PICOS was: (Participants) patients with transverse maxillary deficiency (with or without posterior crossbite) treated with RME, (Intervention) RME supported by primary teeth, (Comparison) RME supported by permanent teeth, (Outcome) the primary outcome defined was buccal alveolar bone thickness. Secondary outcomes, identified based on the availability of data, included intermolar width, intercanine width, teeth inclinations, and angulations. (Studies Design) clinical trials and observational studies.

The inclusion criteria included studies comparing types of dental anchorage (primary teeth or permanent teeth) for RME, utilizing appliances, such as Hyrax-type and Haas-type. These studies evaluated skeletal measurements (buccal alveolar bone thickness of anchoring teeth) and dental measurements (intermolar width, intercanine width, teeth inclinations and angulations). Excluded studies evaluated slow expansion appliances, hybrid expanders, expanders with differential opening, patients with craniofacial anomalies, adults, case reports, and case series. There were no limits on publication year nor language restrictions. For studies in different languages from English or Spanish, the websites https://www.onlinedoctranslator.com and https://translate.google.com.br were used.

Information sources and search strategy

Searches were conducted in databases such as PubMed, LILACS, Scopus, Web of Science, and grey literature (http://opengrey.eu). The references of the included studies were manually searched. The search was updated until June 2024, and no new studies meeting the established inclusion criteria were identified.

The descriptors were constructed and extracted from the Medical Subject Headings (MeSH) or free terms. The strategy was expanded, respecting the particularities of the different databases, as follows: "Palatal Expansion Technique"[Mesh] OR "Palatal Expansion Technique" OR "Maxillary Expansion" OR "Expansion, Maxillary" OR "Rapid palatal expansion" OR "Rapid maxillary expansion" OR "Maxillary expansion" OR "Palatal expansion” OR "Hass" OR "Hyrax" OR "RME" AND "Tooth, Deciduous"[Mesh] OR "Tooth, Deciduous" OR "Deciduous Tooth" OR "Deciduous Dentition" OR "Primary Dentition" OR "Primary Teeth" OR "Deciduous Teeth" OR "Primary teeth anchored" OR "Deciduous dentition Anchorage" OR "Primary molars" OR "Dentition, Mixed"[Mesh] OR "Dentition, Mixed" OR "Dentitions, Mixed" OR "Mixed Dentitions" OR "Dentition, Transitional" OR “Transitional Dentitions" OR "Temporary teeth vs permanent teeth" OR "Deciduous vs permanent molars" OR "Dentition, Permanent"[Mesh] OR "Dentition, Permanent".

Study selection, data items, and collection

Two authors independently screened the titles and abstracts using a reference manager (EndNote, Clarivate Analytics, Philadelphia, PA), excluding irrelevant studies at this stage. For articles where the titles or abstracts were inconclusive, the full texts were reviewed to make a decision. The studies selected after this initial screening advanced to the next stage, where the two authors independently assessed the full texts and included those that met the eligibility criteria. Disagreements were resolved through discussion, and a third investigator was consulted when necessary to reach a consensus. The following data were extracted: authors, number of participants, mean age of participants (in years), type of appliance, anchoring teeth, outcomes, and primary and secondary results.

Risk of Bias in Individual Studies

The Cochrane Risk of Bias (RoB) 2.0 tool was used to assess the risk of bias in clinical trials. The risk of bias was categorized as "high risk", "some concerns" or "low risk"[16]. For observational studies the ROBINS-I[17]. The risk of bias was categorized into "serious", "moderate", "low" or "no information". We used Risk-of-bias VISualization (Robvis) to create the bias analysis figures of the studies[18].

Assessment of the certainty of evidence

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE)[19] approach, available at https://www.gradepro.org, was used as a tool for evaluation of the certainty of evidence. The Grade has two sections: the evaluation of certainty assessment in publication bias, imprecision, indirectness, inconsistency, risk of bias, study design, and number of studies. The second section is the summary of findings which evaluates the number of participants. According to the assessment, the certainty of evidence could be rated high, moderate, low, or very low.

Data Synthesis and Summary Measures

It was not possible to perform a meta-analysis for the primary outcome buccal alveolar bone thickness due to the lack of available studies, which was limited to only one identified study. Among the secondary outcomes identified from the collected evidence, the increase in intermolar width was found to be a significant parameter. This finding was supported by continuous data available in eligible studies, which enabled the performance of a meta-analysis. A meta-analysis was applied to compare RME effects in the intermolar width comparing anchorage in primary and permanent teeth. The mean differences in the maxillary transverse measure before and immediately after the RME was applied with a 95% confidence interval. The mean active treatment time of RME (from the expander installation to the removal) applied were 5 months[20], 6 months[21], 7 months[2], 10 months[22] and 29 days[23]. The meta-analysis was of random effects and used subgroups according to methodological quality. The environment R studio[24] verified the impact of each study on the categorized value, the sensitivity and the heterogeneity (I2).

III. Results

Study selection and characteristics

The search strategy returned 1.712 records, excluding 597 duplicates. After the title and abstract screening, 23 studies were selected for full-text reading. Finally, eight studies[2,20,21,22,23,25,26,27] were included in the qualitative synthesis, and five[2,20,21,22,23] were included in the quantitative synthesis. The process of identifying, selecting, and excluding studies is presented in the Figure 1.

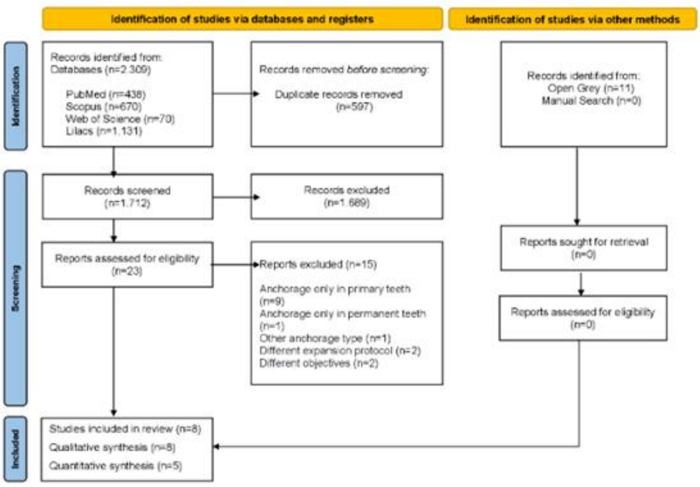

Figure 1: Flow diagram of the article selection process according to the PRISMA statement.

Two studies[20,25] were classified as clinical trials, and six[2,21,22,23,26,27] as observational studies. A total of 346 children were treated with RME, 187 had the appliance supported by primary teeth, and 169 had the appliance supported by permanent teeth. The studies originated from Italy,[2,20,21,22,25,26,27] Canada,[21] and Spain[23] and were published between 2015 and 2023. The clinical characteristics of interest of included children were maxillary atresia,[22,23,27] transverse skeletal discrepancy with unilateral or bilateral posterior crossbite[2,26] and unilateral posterior crossbite.[20,21,25] About the dentition in the beginning of the RME, all children were in the early mixed dentition, except in a single study[23] that compared mixed and young permanent dentition. To RME, the appliances used were hyrax and modified hyrax,[2,21,22,23,26] Haas, and modified Haas.[2,20,25,27] The expansion protocol ranged from 0.20 mm to 0.45 mm of daily screw activation. Just one study[23] did not report the activation protocol for RME. About the methods used to evaluate RME effects, the studies used panoramic radiographs,[27]cephalometric analysis,[25] 3D models,[20,21,25] and cone beam computed tomography (CBCT).[2,22,26] In one study the method was not reported.[23]

In the context of skeletal measurements, Digregorio et al.[26] utilized CBCT to assess the thickness of buccal alveolar bone prior to treatment (T0) and 30 days following the removal of the appliance (T1). There was significant buccal alveolar bone loss (0.73-1.25 mm) in the permanent maxillary first molars used for anchorage and no significant bone loss in primary teeth.

In terms of dental measurements, the main outcomes focused on intermolar width,[2,21,22,23] intercanine width,[20,23] and the rotations and angulations of permanent teeth.[21,25,27] Ugolini et al.[20] reported an increase in maxillary intercanine width and enhanced stability in the anterior region of the arch with appliances supported by primary teeth. Conversely, Luca et al.[22] found that RME anchored to permanent teeth resulted in a larger increase in intermolar width and more pronounced buccal tipping of the lower molars associated with upper expansion. Serafin et al.[21] observed that RME anchored to primary teeth spontaneously reduced the buccal inclination of maxillary permanent first molars, whereas anchorage to permanent molars was linked with an increase in buccal inclination, though with minimal clinical significance. In both cases, intermolar width significantly increased; however, there was no significant difference between the groups (p=0.317).

According to the protocol, we included studies that analyzed the primary outcome and important secondary outcomes found throughout the review process. Table 1 shows additional characteristics of included studies.

Table 1: Summary of the data from included studies.

Authors	Sample Size (Mean age + SD)	Appliance Design	Anchor Teeth	Outcomes	Results
Digregório et al.[26]	37 patients Group E: (8.8 ± 1.1) Group 6: (13.9 ± 1.3)	Hyrax	Group E: primary molars Group 6: permanent molars	Buccal bone thickness	Reduction in buccal bone thickness Group E: - 0.43mm (16MRP) * - 0.51mm (26 MRP) Group 6: - 0.73mm (min) (16MRP) * - 1.25mm (max) (16 DRP) *
Fastuca et al.[2]	44 patients (8.0 ± 1.0)	Hyrax Modified Hyrax Modified Hass	HX-6: permanent molars HX-E: primary molars HS-E: primary molars	Intermolar width	Increased intermolar width HX-6: +5.34 mm* HX-E: +3.71mm* HS-E: +4.34 mm*
Lázaro et al.[23]	35 patients (10.0 ± 1.6)	Hyrax Modified Hyrax	Group I: permanent molars Group II: primary molars	Intermolar width Intercanine width	Increased intermolar width Group I: +7.6 mm± 2.42 mm* Group II: +5.2 mm ± 1.39 mm* Increased intercanine width Group I: +2.9 mm ± 1.64 mm* Group II: +4.5 mm± 1.7 mm*
Luca et al.[22]	12 patients Group I: (10.1) Group II: (9.3)	Hyrax	Group I: permanent molars Group II: primary molars	Intermolar width	Increased intermolar width Group I: 3.20 mm to 3.59 mm* Group II: 3.29 mm to 3.54 mm*
Ugolini et al.[20]	70 patients (8.4 ± 1.1)	Hass	Group 6: permanent molars Group E: primary molars	Intermolar width Intercanine width	Intermolar width Group E: 29.2 mm to 33.5 mm* Group 6: 29.9 mm to 35.7 mm* Intercanine width Group E: 28.7 mm to 32.9 mm* Group 6: 27.8 mm to 31.1 mm*
Cerruto et al.[25]	70 patients (8.4 ± 1.1)	Hass	Group 6: permanent molars Group E: primary molars	Molar rotation angle Incisor rotation angle	MRA Group 6: (-6.6°) * Group E: (-6.1°) * U1RA Group 6: (+13.4°) *Group E:(+8.9°) * U2RA Group 6:(+11.5°) *Group E:(+18.2°) *
Ugolini et al.[27]	137 patients Group 6 - (8.2± 1.6) Group E – (7.9± 1.2) CG – (7.6± 1.1)	Hass	Group 6- permanent molars. Group E - primary molars. CG - no treatment	Angulation of permanent maxillary canines	Group 6: α right (11.8° to 7.5°)[a], α left (13.5° to 9.6°)[b]. Group E: α right (14.0° to 10.6°)[a], α left (9.3° to 13.6°)[b].

Serafin et al.[21]	40 patients Group 6: 12.6 ± 1.8 Group E: 8.4 ± 1.1)	Hyrax	Group 6: permanent molars Group E: primary molars	Intermolar width Buccolingual inclination	Intermolar width Group 6 - 41.93 mm to 44.74 mm* Group E - 43.5 mm to 46.75 mm* Buccolingual inclination Crossbite Group 6 – increased (+2.39°) * Group E – decreased (-2.67°) No crossbite Group 6 - increased (+0.57°) Group E – decreased (-3.49°) *

*Significance level p<0.05; Mesiobuccal root of maxillary right permanent first molar (16MRP); Mesiobuccal root of maxillary left first permanent molar (26MRP); Distobuccal root of maxillary right permanent first molar (16DRP); CG, control group; [a] Significant when compared to CG right; [b] Significant when compared to CG left; MRA, Molar rotation angle; U1RA, Upper central rotation angle; U2RA, Upper lateral rotation angle.

Risk of bias of the included studies

The risk of bias for clinical trials and observational studies are in Figures 2 and 3, respectively.

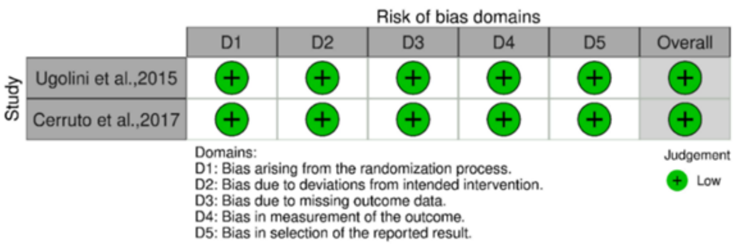

Figure 2: Quality assessment of the randomized clinical trials, according to ROB 2.0 tool.

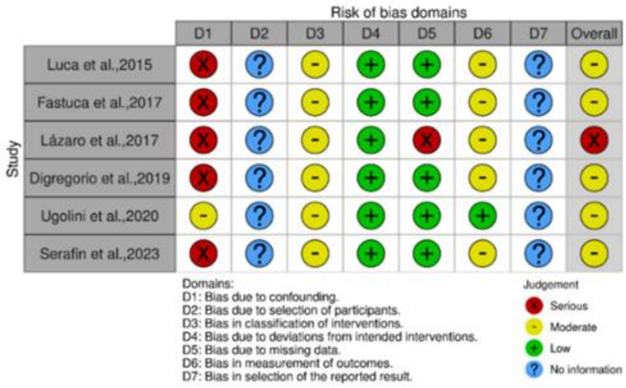

Figure 3: Quality of the observational studies, according to ROBINS-I quality assessment scale.

The clinical trial[20,25] presented low risk. Five observational studies[2,21,22,23,26] showed a high risk of bias in at least one domain, due to the lack of management of the confounding factors. In all studies, there was minimal or no information about the beginning of the observation or of the intervention done. When considering the classification of interventions, a moderate risk of bias was identified because of being retrospective. Relating to the missing data, one study[23] presented high risk of bias. About the measurement of results, one study[27] showed low risk, while the others [2,21,22,23,26] presented a moderate risk of bias.

Assessment of the certainty of evidence

For the primary outcome (buccal alveolar bone thickness), we found only one study.[26] For the secondary outcome (intermolar width), we assessed the certainty of the evidence of the studies included in the meta-analysis[2,20,21,22,23] according to the study design. By categorizing the studies according to their design, we sought to ensure a transparent and systematic evaluation of the evidence, ensuring that the methodological distinctions in the types of studies were appropriately reflected in our overall analysis of the intermolar width outcome. Table 2 shows the complete information on evaluation of certainty of evidence.

Table 2: Assessment of the certainty of the evidence.

Variable	Certainty assessment							№ of patients		Certainty
Outcome	N	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other	Intervention	Comparison	
Buccal bone thickness	1	observational studies	serious[a]	not serious	very serious[b]	not serious	none	21	16	⊕◯◯◯ Very low
Intermolar width	4	observational studies	serious[c]	not serious	serious[d]	not serious	none	63	53	⊕◯◯◯ Very low
Intermolar width	1	randomised trials	not serious	not serious	very serious[e]	not serious	none	35	35	⊕⊕◯◯ Low

[a] The certainty of the evidence has been downgraded by one level. The study moderate risk of bias. [b] The certainty of the evidence has been downgraded by two level. The number of individuals is lower than the optimal information size. [c] The certainty of the evidence has been downgraded by one level. The studies are at moderate and serious risk of bias. [d] Small sample sizes and design for observational studies. [e] The certainty of the evidence has been downgraded by two level. The number of individuals is lower than the optimal information size.

Quantitative synthesis of data

When comparing the intermolar width increase with anchorage in primary or permanent teeth, five of the selected studies[2,20,21,22,23] when grouped, showed a more intermolar width increase when anchorage was done in permanent teeth (MD=-1.24 [CI95%= -2.14; -0.33]). Heterogeneity was considered high (I2 = 77%) (Figure 4). Subgroup analysis showed no difference between groups according to the risk of bias.

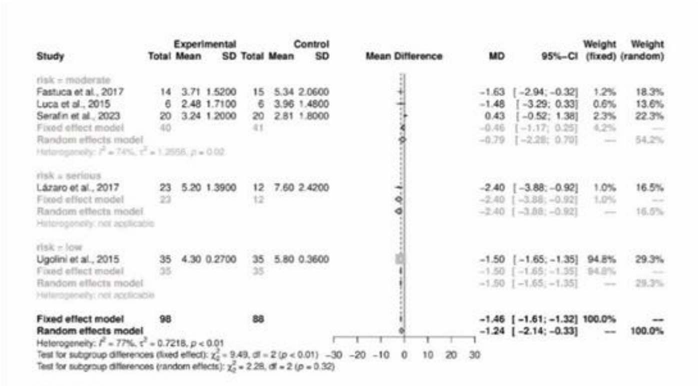

Figure 4: Forest plot of meta-analysis comparing intermolar width.

To verify the impact, in the grouped value, of removing each one of the studies, a sensitivity analysis was also performed (Figure 5). We observed that the removal of study[21] resulted in a reduction of heterogeneity to zero and an increase in the favorable intermolar width difference with anchorage in permanent teeth.

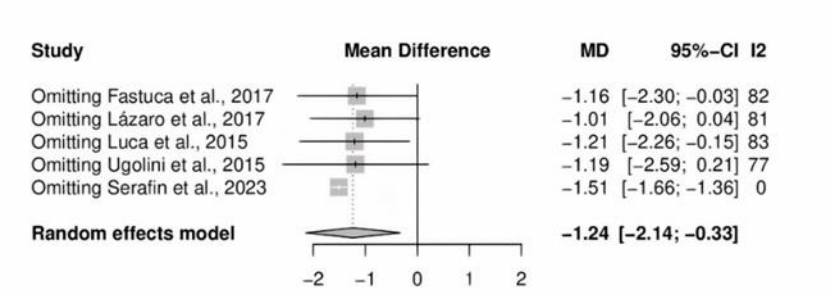

Figure 5: Forest plot of sensitivity analysis.

IV. Discussion

As far as we know, this is the first systematic review comparing the skeletal and dental effects of RME when supported by primary versus permanent teeth. Lo Giudice et al.[14] evaluated the periodontal effects of RME but did not compare the anchorage teeth in children. After the data basis search, eight studies[2,20,21,22,23,25,26,27] were included. It was impossible to perform a meta-analysis to the outcome "buccal alveolar bone thickness" since only one study evaluated it.[26] Therefore, a meta-analysis of a clinically relevant secondary outcome, the intermolar width, was performed with five studies.[2,20,21,22,23]

To assess the primary outcome, Digregorio et al.[26] conducted a comparison of RME anchored on primary teeth and permanent teeth. The study was assigned a very low quality of evidence rating according to the GRADE system, due to serious concerns about the risk of bias and the indirectness of evidence. Additionally, the clinical implications of these results remain uncertain without further clinical trials to assess how periodontal soft tissues react to the use of the expander. Moreover, diminished tissue thickness following lateral expansion may result in gingival recession, bony dehiscence, or buccally displaced teeth over the long term. Clinical trials and long-term prospective observational studies are essential to examine bone loss and gingival effects of RME, and to contrast these effects among different anchorage teeth.

Concerning the secondary outcome, Fastuca et al.[2] assessed the impact on intermolar width in 44 patients, who were categorized into three groups (Hyrax anchored by permanent molars, Hyrax anchored by primary molars, and Haas anchored by primary molars). Significant differences were observed in measurements taken before and seven months following RME, however, no distinctions were found among the groups. Luca et al.[22] conducted a comparison involving six patients undergoing RME anchored by permanent maxillary first molars and another six with RME anchored by primary maxillary second molars. RME anchored by permanent teeth was associated with a notable increase in intermolar width and buccal tipping of the permanent mandibular first molars. Utilizing primary teeth for anchorage resulted in a more substantial increase in skeletal intermolar width and a greater inclination of the permanent maxillary first molars. The activation rates of 0.20 mm per day[22] and 0.40 mm per day[2] might have influenced these outcomes, suggesting that a slower activation speed leads to more pronounced dental effects.[22]

The single clinical trial of this systematic review evaluated maxillary and mandibular widths after RME using digital casts. Ugolini et al.[20] compared 35 patients where RME was anchored to the primary maxillary second molars against 35 others anchored to the permanent maxillary first molars. Anchorage in the primary maxillary second molars resulted in greater anterior dimensions of the dental arch. The increased expansion observed with primary molars may be attributed to the anterior positioning of the screw, leading to more skeletal expansion. The greater the skeletal effects, the more stable the results in the long term.[28] In a subsequent study derived from this clinical trial, Cerruto et al.[25] examined the radiographic and dental arch changes induced by RME using a Haas appliance. Employing primary maxillary second molars for RME anchorage resulted in a more favorable spontaneous alignment of the incisors than with appliances anchored to permanent molars. These outcomes were likely due to the enhanced expansion in the anterior region of the dental arch when RME is supported by primary teeth.

The risk of bias in clinical trial[20,25] was low. The six observational studies ranged from moderate risk[2,21,22,26,27] to high risk.[23] The main limitations were the retrospective design and the lack of management of confounding factors. The analysis identified confounding factors, including different diagnoses for the indication of RME, variations in the amount of expander screw activation, differences in patient age, treatment duration, as well as the use of samples from dental departments, mainly from Italy,[2,21,26,27] with a similar team of coauthors based on specific research interests. One study[23] classified as high risk presented methodological flaws, which may compromise the reliability of the presented results.

Continuous data from five eligible studies[2,20,21,22,23] supported a meta-analysis for the outcome of intermolar width. The meta-analysis showed a favorable difference in favor of using permanent teeth to anchor RME, with a mean difference of -1.24 (95%CI: -2.14 to -0.33). The exclusion of the study by Serafin et al.[21] resulted in a reduction of heterogeneity to zero, indicating its potential role as a significant source of variability in the results. Considering the potential sources of heterogeneity, we emphasize the impact of the small sample size and the use of nonparametric tests in the analysis of continuous data. This methodological choice may have influenced the consistency of the data, especially when combined with studies[2,20,22] that used parametric methods.

While the studies included in the meta-analysis[2,20,21,22,23] are significant in their own right, they are not sufficient to answer a clinical question. The distinction between the designs of the studies analyzed for the secondary outcome of intermolar width and their respective evidence quality according to GRADE illustrates the complexity in interpreting the available data and underscores the importance of cautiously interpreting these results. To obtain reliable clarifications on these issues, future research is indispensable, ideally through meticulously planned randomized clinical trials. Among the limitations identified in this study, the most critical is the scarcity of research addressing the primary outcome buccal alveolar bone thickness. Additionally, there was a predominance of short-term observational studies focused on the secondary outcome, limiting the depth of the analysis.

RME is a classic treatment in pediatric orthodontics. The decision to anchor the appliance in primary or permanent teeth seems to vary according to the clinician's preference. Our literature review highlights the need for studies that provide comparative data on the effects of RME on periodontal tissues, depending on the type of anchorage used. This is important because there are current doubts about the skeletal benefits and the preservation of alveolar bone plates when incorporating skeletal anchorage in children.[29]

Our findings have clinical implications. Given the absence of differences in skeletal and dental effects between anchorage in primary and permanent teeth, clinicians can personalize RME treatment based on the individual characteristics of each patient, such as age, stage of dental development, and degree of maxillary constriction. Primary teeth may be preferred in situations where the preservation of alveolar bone is crucial, especially in children at risk of periodontal problems.

V. Conclusion

Currently, there is no evidence-based recommendation to support the choice between primary or permanent teeth as anchorage for RME in children. Considering the preservation of alveolar bone, we suggest that primary teeth may be a preferable option in specific situations, especially in children at risk for periodontal problems. Future studies are needed to provide more detailed comparative data that can better inform clinical choices.

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