Annals Journal of Dental and Medical Assisting
2025, Volume 5, Issue 1, Page No: 32-42

Available online at: www.tsdp.net

ISSN: 3062-3510

Original Article

Comparison of Skeletal and Dental Outcomes Following Bone-Borne versus Tooth-Borne Surgically Assisted Rapid Palatal Expansion in Patients with Maxillary Transverse Deficiency: A Systematic Review and Meta-Analysis

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Received: 12 October 2024; **Revised:** 15 February 2025; **Accepted:** 15 February 2025

ABSTRACT

This review aimed to evaluate and compare the skeletal and dental changes resulting from bone-borne (BB) versus tooth-borne (TB) surgically assisted rapid palatal expansion (SARPE) in patients with maxillary transverse deficiency (MTD). Eligible studies included randomized controlled trials, non-randomized trials, and cohort studies. A systematic search of PubMed®, Dentistry & Oral Sciences Source, CINAHL Plus, and Cochrane CENTRAL was performed for publications up to January 2023. Outcomes were calculated using weighted mean differences with 95 percent confidence intervals (CIs), and study heterogeneity was examined with Cochran's I^2 test. Meta-analyses were conducted using RevMan v5.3.5.22. Seven studies, comprising a total of 249 participants who received SARPE with either BB or TB devices, were included in the review. Skeletal expansion in the first premolar and first molar regions was reported in five studies, revealing no significant difference between BB and TB approaches (mean difference: −0.16; 95 percent CI: −0.34 to 0.67). For dental expansion, all seven studies were analyzed, again showing no statistically significant differences between the groups (mean difference: −0.29; 95 percent CI: −0.77 to 0.19). Overall, the evidence indicates that both BB and TB SARPE appliances produce similar skeletal and dental expansion outcomes in patients with maxillary transverse deficiency, with no clear advantage of one approach over the other.

Keywords: Bone-borne, Surgically assisted rapid palatal expansion, Tooth-borne, SARPE

How to Cite This Article: Su-Yeon O, Chang SJ, Lim CY. Comparison of Skeletal and Dental Outcomes Following Bone-Borne versus Tooth-Borne Surgically Assisted Rapid Palatal Expansion in Patients with Maxillary Transverse Deficiency: A Systematic Review and Meta-Analysis. Ann J Dent Med Assist. 2025;5(1):32-42. https://doi.org/10.51847/wHmSdJ9oN0

Introduction

Maxillary transverse deficiency (MTD) is a commonly encountered condition in orthodontic practice [1–3]. Proffit and White reported that approximately 30% of adult orthodontic patients present with MTD [4]. Its prevalence ranges from 8% to 18% in children and around 10% in adults [5–7]. In specific populations, studies have found varying prevalence rates: 0.3% in primary dentition in Argentina [8], 15.6% in Turkey [9], 5.5% in India [10], and 10.4% in South Africa [11]. Evidence also suggests a higher occurrence of MTD among females compared to males [12].

MTD can result in reduced intercanine and intermolar widths, unilateral or bilateral posterior crossbites, and narrow, deep palatal vaults [13, 14]. These structural changes may contribute to dental crowding, enlarged buccal corridors, non-carious cervical tooth wear, periodontal issues, and imbalances in facial musculature [15–17]. Achieving a normal transverse skeletal relationship is essential to prevent these complications and to establish stable occlusion [18].

In adolescents, rapid maxillary expansion (RME) is widely regarded as the most effective orthodontic method to correct transverse discrepancies [19, 20]. This technique works by opening the midpalatal suture and widening the maxillary arch [21]. However, in adults, the midpalatal suture and adjacent articulations tend to be more fused, reducing skeletal responsiveness and increasing reliance on dental movement [22]. Use of conventional expansion appliances in skeletally mature patients can lead to undesired outcomes such as dental tipping, alveolar dehiscence, periodontal damage, root resorption, and instability of the results [23, 24]. To address these challenges, surgically assisted rapid palatal expansion (SARPE) is indicated in non-growing patients [25].

SARPE is a reliable method for treating MTD in skeletally mature individuals [25]. The procedure involves performing osteotomies to release sutural resistance, followed by placement and activation of an expander to achieve the desired expansion [26]. Depending on practitioner preference, expanders can be classified as bone-borne (BB) or tooth-borne (TB) [27].

TB expanders are attached to teeth without additional surgical intervention and generally provide satisfactory results [28]. However, the forces are transmitted through the dentition, which may compromise control over relapse during the consolidation period [29, 30]. Additionally, TB appliances are associated with dental tipping, alveolar bone dehiscence, and potential periodontal damage [29]. To overcome these limitations, Mommaerts introduced the BB SARPE technique, which transmits forces directly to the palatal bone, producing more skeletal and fewer dental effects [31, 32]. BB expanders also improve stability of the expanded segments during consolidation [33].

Previous systematic reviews have explored skeletal and dental outcomes after SARPE [26, 34]. However, these reviews were limited by insufficient data on anterior expansion and a lack of comparative designs. Given the inconsistent or unclear results from available randomized controlled trials (RCTs) comparing BB and TB SARPE [28, 32], a comprehensive systematic review and meta-analysis was warranted to provide stronger evidence.

Objectives

This review aimed to consolidate the existing evidence and generate high-quality data to address the following research question: Do bone-borne expanders produce different skeletal and dental effects compared to tooth-borne expanders in patients with maxillary transverse deficiency?

Materials and Methods

Eligibility criteria

This systematic review was designed following the PICOS framework (Population, Intervention, Comparison, Outcomes, Study design). The population included orthodontic patients who had undergone SARPE. Bone-borne (BB) expanders were treated as the intervention group, while tooth-borne (TB) expanders served as the comparison group. The main outcomes assessed were changes in skeletal and dental structures.

The review considered randomized controlled trials (RCTs), non-RCTs, and cohort studies. Publications such as case reports, case series, narrative reviews, case–control studies, single-arm longitudinal studies, and animal experiments were excluded.

Search strategy

An extensive literature search was performed in PubMed®, CINAHL Plus, Cochrane Central Register of Controlled Trials (CENTRAL), and Dentistry & Oral Sciences Source for articles published up to January 2023. Grey literature, unpublished studies, and Google Scholar were also manually screened. The search employed the following Medical Subject Headings (MeSH) and keywords: (“Orthodontics”[MeSH] OR orthodontic* OR dental OR dentistry) AND (skeletal OR soft tissue OR airway OR suture opening comparison) AND (“Surgically assisted rapid maxillary expansion” OR “mini-screw assisted rapid palatal expansion” OR SARPE OR SARME OR “surgically assisted rapid palatal expansion” OR MARPE OR “bone-anchored rapid palatal expansion”).

Study selection and data extraction

Studies reporting skeletal and dental outcomes in RCTs, non-RCTs, or cohort designs were eligible. After completing the database search, all results were imported into EndNote™ X9.2 (Clarivate, Philadelphia, USA) for organization. Two authors (LK and HQ) independently screened the studies in a two-step process. First, titles and abstracts were evaluated for relevance. Next, full texts of potentially eligible studies were reviewed. Any disagreements were resolved by a third author (WI), who independently re-evaluated the studies. The agreement between reviewers was high (intraclass correlation coefficient (ICC) = 0.88). Data were extracted into a standardized form, and all discrepancies were cross-checked against the original publications to ensure accuracy **(Figure 1)** [35].

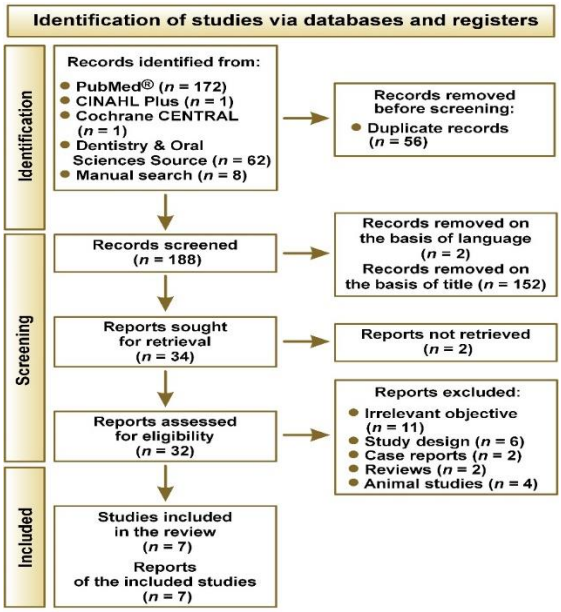

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)35 flowchart of the study

CENTRAL – Central Register of Controlled Trials.

Effect measures and data synthesis

The analysis focused on systematically evaluating skeletal and dental modifications, particularly in the regions of the canines, first premolars, and first molars. Individual study results were carefully examined and summarized for these specific regions. For numerical data, a meta-analysis was carried out using Review Manager (RevMan) version 5.4 (Cochrane Collaboration, London, UK). The I^2 statistic was applied to assess the degree of heterogeneity across studies, and both fixed- and random-effects models were employed to estimate pooled effect sizes.

Risk of bias assessment

For randomized controlled trials (RCTs), the Cochrane Risk of Bias tool (RoB 2.0) [36] was used. This tool evaluates several domains to classify RCTs as having low, unclear, or high risk of bias. Non-RCTs and cohort studies were appraised using the Newcastle–Ottawa Scale (NOS) [37] to determine study quality.

Certainty of evidence

The overall strength of evidence for the review was determined using the GRADE framework (Grading of Recommendations Assessment, Development, and Evaluation) [38]. This approach considers study design, risk of bias, inconsistency, imprecision, and indirectness of the outcomes. Based on these criteria, evidence was categorized as very low, low, moderate, or high quality **(Table 1)**.

Table 1. Assessment of the quality of the evidence using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach

Studies, n	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Summary of findings			
							patients, n		relative effect	certainty of evidence
							BB	TB		
5	RCT/non-RCT	not serious	not serious	not serious	not serious	none	86/170 (50.6%)	84/170 (49.4%)	not estimable	⊕⊕⊕⊕ high
2	cohort studies	not serious	not serious	not serious	not serious	none	35/79 (44.3%)	44/79 (55.7%)	not estimable	⊕⊕ low

RCT – randomized control trial; BB – bone-borne; TB – tooth-borne; CI – confidence interval.

Results

Study selection and characteristics

The database search initially retrieved 244 records. After removing duplicates, 188 articles remained. Screening based on titles, abstracts, and language criteria further narrowed the pool to 34 studies. A full-text review of these articles identified 7 studies that met the inclusion criteria for the systematic review and meta-analysis, as illustrated in **Figure 1**. Among the selected studies, 4 were RCTs, 1 was a non-RCT, and 2 were cohort studies. All included studies evaluated and compared the skeletal and dental outcomes of SARPE using bone-borne (BB) versus tooth-borne (TB) expanders. A detailed overview of each study is provided in **Table 2**.

Table 2. Summary of Studies Included in the Review

Study	Design	Sample Size	Surgical Technique	Expander Type	Primary Outcome	Secondary Outcome	Outcome Measurement

Landes *et al.* [32]	RCT	Total: 50 (BB: 24, TB: 26)	Bipartite median or tripartite paramedian osteotomy	BB: TPD & MWD TB: HE	Skeletal and dental expansion in first and second premolars and molars	Dental tipping, vestibular bone resorption	CBCT
Koudstaal *et al.* [39]	RCT	Total: 46 (BB: 25, TB: 21)	Le Fort I with midline osteotomy	BB: TPD & BAD TB: HE	Skeletal and dental expansion in first premolars and first molars; dental expansion in canines	Dental tipping	3D scanned cast models
Laudemann *et al.* [40]	Cohort	Total: 34 (BB: 18, TB: 16)	Le Fort I with midline osteotomy	BB: TPD & MWD TB: HE	Dental expansion in canines, first premolars, and first molars	Dental tipping, attachment loss	3D scanned cast models
Nada *et al.* [41]	Cohort	Total: 45 (BB: 17, TB: 28)	Le Fort I with midline osteotomy	BB: TPD TB: HE	Skeletal and dental expansion in first premolars and first molars; dental expansion in canines	None	CBCT
Zandi *et al.* [28]	RCT	Total: 30 (BB: 15, TB: 15)	Le Fort I with midline osteotomy	BB: TPD TB: HE	Skeletal and dental expansion in first premolars and first molars; nasal floor width	None	CBCT
Kayalar *et al.* [42]	RCT	Total: 20 (BB: 10, TB: 10)	Le Fort I with midline osteotomy	BB: Hybrid RME TB: HE	Skeletal and dental expansion in first premolars and first molars	Dental tipping, root resorption, vestibular bone resorption	CBCT
Barone *et al.* [43]	Non-RCT	Total: 24 (BB: 12, TB: 12)	Le Fort I with midline osteotomy	BB: BAD TB: HE	Dental expansion in canines, first premolars, and first molars	None	Three-dimensional digital models of casts

TPD – transpalatal distractor; MWD – maxillary widening device; HE – Hyrax expander; BAD – bone-anchored device; RME – rapid maxillary expander; CBCT – cone-beam computed tomography.

Evaluation of bias within and across studies

The RoB 2.0 tool, covering five domains, was applied to assess bias in the RCTs. All trials demonstrated low risk in domains 3 and 5. For domains 1 and 4, Koudstaal *et al.* [39] and Kayalar *et al.* [42] were judged to have low risk, whereas Landes *et al.* [32] and Zandi *et al.* [28] showed high risk. In summary, two of the studies [39, 42] presented some concerns regarding bias, while the remaining trials were considered at high risk **(Figure 2)** [28, 32].

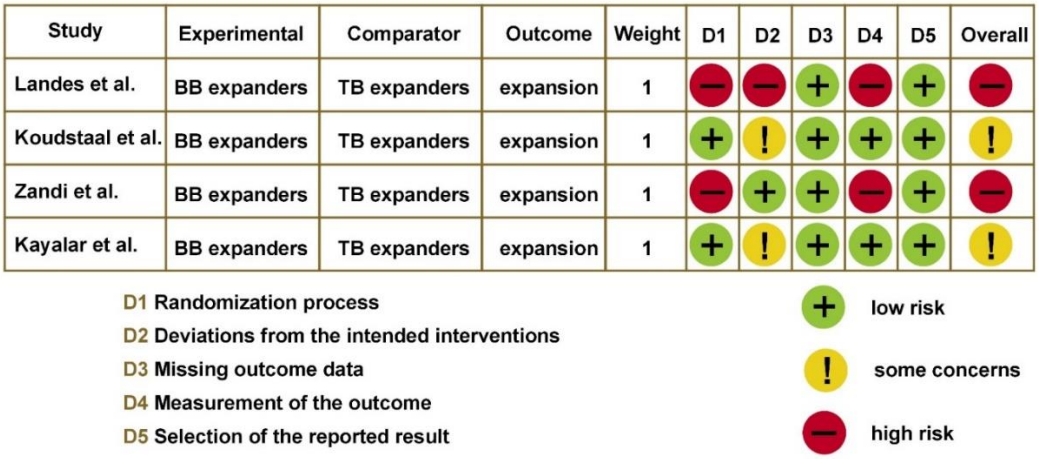

Figure 2. Evaluation of bias risk in randomized controlled trials using the Cochrane RoB 2.0 tool
BB – bone-borne; TB – tooth-borne

The Newcastle–Ottawa Scale [40, 41, 43] was applied to evaluate the methodological quality of three studies, and the results showed that each study achieved a favorable level of evidence **(Table 3)**.

Table 3. Quality assessment of non-randomized and cohort studies using the Newcastle–Ottawa Scale

Study	Sample size	Selection	Comparability	Outcome
Laudemann *et al.* [40]	34	***	*	***
Nada *et al.* [41]	45	***	*	***
Barone *et al.* [43]	24	***	*	**

Studies were categorized based on the Newcastle–Ottawa Scale as follows: a study was considered to be of good quality if it received three or four stars in the selection domain, one or two stars in the comparability domain, and two or three stars in the outcome/exposure domain. A study was rated as fair quality when it earned two stars in selection, one or two stars in comparability, and two or three stars in outcome/exposure. Conversely, a study was deemed poor quality if it scored zero or one star in the selection domain, 0 stars in comparability, or 0 or 1 star in the outcome/exposure domain.

Results of individual studies

Landes *et al.* [32] investigated both skeletal and dental expansion in the first and second premolars and molars after SARPE performed with either bone-borne (BB) or tooth-borne (TB) appliances. Measurements were carried out pre- and post-expansion using cone-beam computed tomography (CBCT). The study also evaluated buccal and lingual alveolar bone loss in the premolar and molar regions. The BB group included twenty four participants, while the TB group had 26. Results indicated that BB appliances produced greater skeletal widening in the first premolar region, whereas TB appliances were associated with increased buccal bone resorption in the same area [32].

Three studies [39, 40, 43] employed digital 3D cast models to quantify dental expansion in the canine, first premolar, and first molar regions. Koudstaal *et al.* [39] reported that BB appliances resulted in significantly more skeletal expansion in the first molar region. In contrast, Barone *et al.* [43] found that TB expanders led to greater dental widening in the same area. All three investigations found no statistically meaningful differences in dental expansion at the canine region between BB and TB groups.

Kayalar *et al.* [42] examined 20 participants, equally split between BB and TB groups, using CBCT scans. The study assessed skeletal and dental expansion, periodontal outcomes in premolars and molars, changes in premolar root length, and intermolar and inter-premolar angulations. Measurements were collected at baseline, immediately after expansion, and six months following the retention phase. Results demonstrated that TB expanders generated more anterior dental expansion, greater premolar root length changes, and differences in buccal and lingual alveolar thickness. Posterior dental expansion in the first molar region did not differ significantly between BB and TB groups [42].

Zandi *et al.* [28] and Nada *et al.* [41] evaluated skeletal and dental widening in the first premolar and first molar regions among patients receiving SARPE with BB or TB devices. Nada *et al.* [41] additionally assessed expansion in the canine region, identifying a significant difference between the two expander types,

whereas expansion in other regions showed similar outcomes for both BB and TB appliances [28, 41].

Meta-analysis

Five studies [28, 32, 39, 41, 42] were included in a quantitative meta-analysis to compare skeletal expansion in the first premolar and first molar regions between BB and TB SARPE. Due to considerable heterogeneity in the premolar region, a random-effects model was employed, revealing no significant difference (mean difference: 0.25; 95 percent CI: −0.27, 0.76) **(Figure 3)**. In the first molar region, a fixed-effects model was applied, also showing no statistically significant difference between the BB and TB groups (mean difference: 0.16; 95 percent CI: −0.34, 0.67) **(Figure 4)** [28, 32, 39, 41, 42].

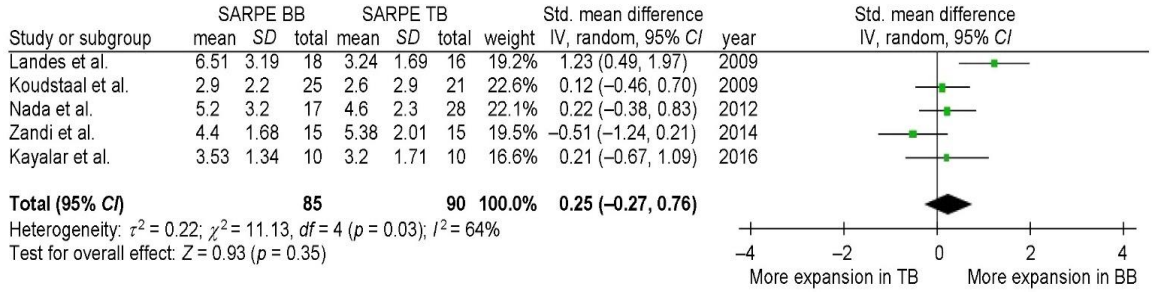

Figure 3. Forest plot showing the mean difference in skeletal widening of the first premolar region between bone-borne (BB) and tooth-borne (TB) expanders following surgically assisted rapid palatal expansion (SARPE)

SD – standard deviation; CI – confidence interval; df – degrees of freedom

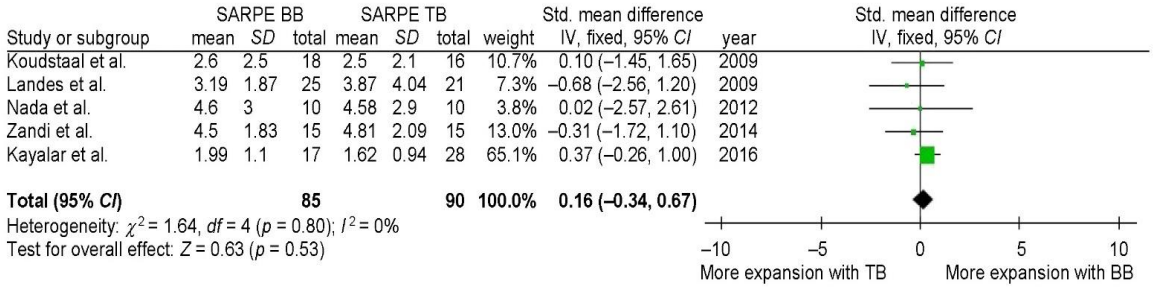

Figure 4. Forest plot illustrating the mean difference in skeletal widening of the first molar region between bone-borne (BB) and tooth-borne (TB) expanders following SARPE

The meta-analysis included seven studies aiming to evaluate dental expansion in the first premolar and first molar regions for both BB and TB groups. Due to notable heterogeneity among the studies, a random-effects model was applied for the first premolar region, which showed no statistically significant difference between the groups (mean difference: −0.67; 95 percent CI: −1.45, 0.11) **(Figure 5)**. For the first molar region, a fixed-effects model was used, and similarly, no significant difference was found between BB and TB expanders (mean difference: −0.29; 95 percent CI: −0.77, 0.19) **(Figure 6)**.

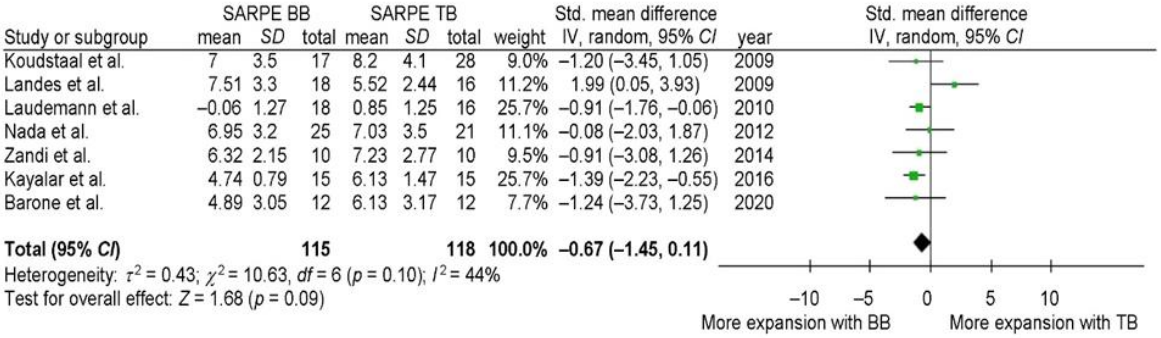

Figure 5. Forest plot showing the mean difference in dental expansion of the first premolar region between bone-borne (BB) and tooth-borne (TB) expanders following SARPE

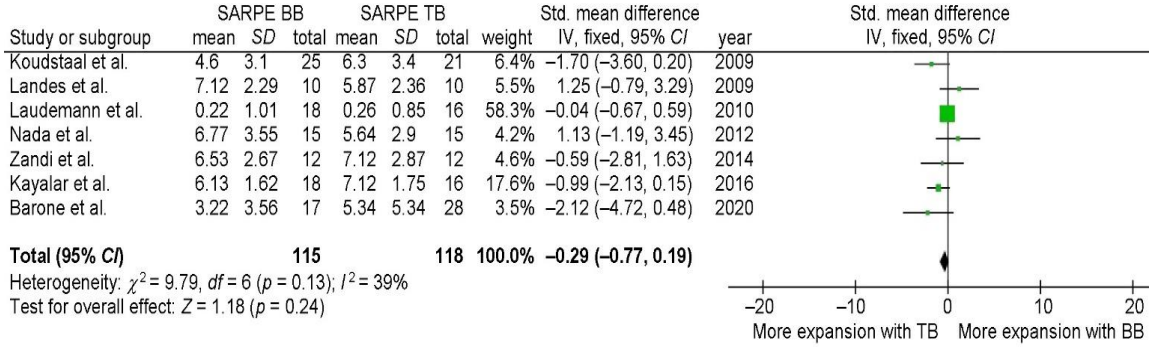

Figure 6. Forest plot illustrating the mean difference in dental expansion of the first molar region between bone-borne (BB) and tooth-borne (TB) expanders following SARPE

A total of four studies [32, 39, 41, 43] were incorporated into the meta-analysis to evaluate dental expansion in the canine region for the BB and TB groups. Given the notable heterogeneity among the studies, a random-effects model was applied for data synthesis. The results indicated no statistically significant difference between the two groups (mean difference: 0.05; 95 percent CI: −0.50, 0.60) **(Figure 7)**.

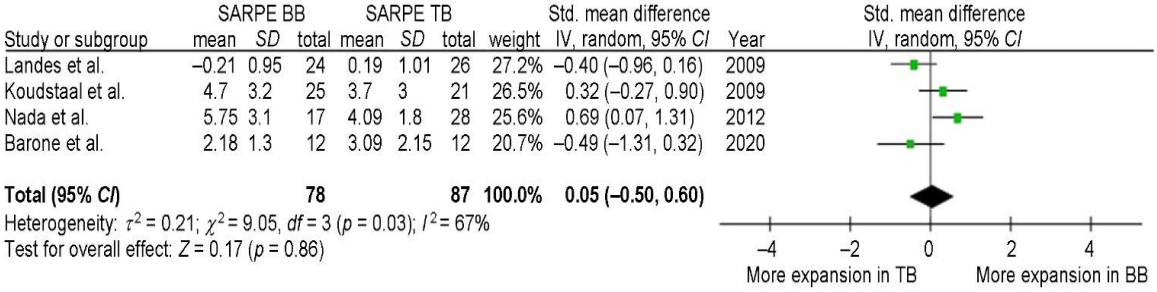

Figure 7. Forest plot illustrating the mean difference in canine region dental expansion between bone-borne (BB) and tooth-borne (TB) expanders following SARPE

Assessment of the certainty of the evidence

The certainty of the evidence from the included studies was evaluated using the GRADE tool. The analysis indicated no significant differences in maxillary expansion between the two techniques. Assessment of the evidence quality showed that clinical trials were rated as high-quality, whereas cohort studies were of low quality. Consequently, the interpretation of the review's findings should be approached with caution **(Table 1)**.

Discussion

This systematic review and meta-analysis examined skeletal and dental outcomes following bone-borne (BB) and tooth-borne (TB) surgically assisted rapid palatal expansion (SARPE) in individuals with maxillary transverse deficiency (MTD). The results revealed that both skeletal and dental parameters in the transverse dimension were largely comparable between the two treatment approaches. The reliability of these findings is strengthened by the inclusion of only studies that utilized cone-beam computed tomography (CBCT). Clinical relevance is further supported by the GRADE assessment, which rated all clinical trials as providing high-quality evidence, while cohort studies contributed low-quality evidence. To generate robust conclusions regarding skeletal expansion in the premolar and molar regions, data from five clinical trials were quantitatively synthesized through meta-analysis [28, 32, 39, 41, 42]. The Newcastle–Ottawa scale indicated that the non-randomized and cohort studies included in this review and meta-analysis were of good quality.

In adolescents, maxillary expansion can be achieved using TB appliances through either slow or rapid protocols, as sutures are not fully fused and the zygomaticomaxillary complex is still developing [44]. In adults, however, the intermaxillary and circummaxillary sutures are fully ossified, making tooth-borne expansion largely limited to dentoalveolar effects rather than true orthopedic changes. In such cases, stable maxillary expansion typically requires surgical interventions, such as maxillary osteotomy or

SARPE. Both procedures involve a horizontal osteotomy of the lateral maxillary wall, separation of the lateral nasal wall, disarticulation of the nasal septum, and a palatal osteotomy. However, in multiple-piece maxillary osteotomies, the maxilla is downfractured, whereas SARPE does not include this downward repositioning. SARPE represents a less invasive and more physiological approach, allowing greater expansion potential through tissue regeneration [45]. Although surgery is performed by maxillofacial surgeons, the expansion extent is guided by orthodontists using surgical guides. Advances in guide accuracy have been achieved using novel methods, including 3D-printed resins such as BioMed Amber [46].

For robust evidence regarding skeletal expansion in the premolar and molar regions, meta-analysis was conducted on five clinical trials [28, 32, 39, 41, 42]. Among these studies, only Landes *et al.* reported that BB expanders produced greater skeletal expansion in the interpremolar region compared to TB Hyrax devices [32]. In this study, the surgical approach was likely a major factor influencing the observed skeletal changes, with osteotomies performed either as a bipartite median approach between the central incisors and bilaterally along the nasal septum, or as a tripartite paramedian approach between lateral incisors and canines [32]. The other four clinical trials, which did not find significant skeletal improvements in interpremolar width, utilized three-piece Le Fort I SARPE with midsagittal suture osteotomy. In all studies, TB expansion was performed using the Hyrax expander.

It is well-established that arch constriction is influenced not only by the midpalatal suture but also by multiple maxillary sutures [6, 7, 25]. Notably, Nada *et al.* reported significant skeletal intermolar expansion, finding that transpalatal distractors produced greater skeletal widening than the Hyrax appliance [41]. Dental expansion following SARPE was evaluated in terms of molar and premolar tipping across all included studies. Each of the seven studies in this systematic review assessed dental changes in the first premolar and first molar regions. Kayalar *et al.* found that the TB Hyrax expander induced more pronounced premolar tipping compared to hybrid maxillary expanders [40]. Similarly, Barone *et al.* observed increased molar tipping after SARPE [43]. These outcomes are likely attributable to the use of tooth-anchored appliances, as the buccal resistance of surrounding structures opposes suture opening, necessitating high forces. Consequently, appliances anchored to teeth tend to cause buccal tipping of molars prior to actual skeletal suture separation.

Limitations

Among the reviewed studies, Nada *et al.* examined long-term effects, analyzing outcomes six months post-expander removal [42], whereas Landes *et al.* focused on short-term postoperative changes following TB and BB appliance use [32]. Variations in follow-up duration may have influenced the results; however, meta-analytic methods were applied to control for these confounding factors. Much of the existing literature comparing BB and TB expansion post-SARPE consists of cross-sectional studies or narrative reviews. Our systematic search identified five clinical trials and two cohort studies that assessed these outcomes longitudinally. A key limitation of these studies is their small sample sizes. A major strength of this review is its strict inclusion of studies employing CBCT for assessment, which is considered the gold standard.

To determine whether differences truly exist between BB and TB SARPE, future randomized clinical trials with larger cohorts and extended follow-up periods are warranted.

Conclusions

Within the constraints of the currently available evidence, this systematic review and meta-analysis found no significant differences in skeletal or dental expansion between BB and TB SARPE. Given the limited data, further research is needed to clarify the potential clinical advantages of one approach over the other.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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