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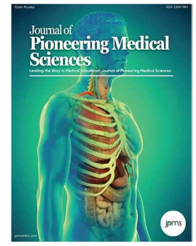

Comparative CBCT and Cephalometric Analysis of Vertical Maxillary Changes with Bonded and Banded Expanders in Adolescents Aged 12-18 Years

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Abstract **Objective:** This study evaluates the vertical maxillary effects produced by banded and bonded RPEs in 12 to 18 year-old adolescents, comparing the changes obtained by both types of expanders, through CBCT and cephalometric analyses. **Methods:** Eight articles in adolescents with age ranging from 12 to 18 years were analyzed and applied both Cone Beam Computed Tomography (CBCT) and lateral cephalograms. Outcomes of interests were differences in LAFH, SN-GoGn and the inclination of the occlusal plane. The results were synthesized to express mean with Standard Deviation (SD) and the significance of effect size was examined with p -values and effect sizes (Cohen's d). The quality of all included studies was assessed by the Cochrane Risk of Bias tool and Newcastle-Ottawa Scale. The protocol for this study has been registered on PROSPERO and the whole protocol is available on request. **Results:** Bonded tightens achieved significantly smaller vertical effects compared to banded tightens (eg., LAFH: bonded = 0.9±0.4 mm vs. banded = 2.3±0.6 mm; $p<0.01$, $d = 1.27$). Bounded expanders had less increase in the SN-GoGn angle (0.7±0.3°) than the banded group (1.9±0.5°, $p<0.05$, $d = 1.05$). The CBCT results indicated the amount of the posterior vertical movement and molar tipping in the bonded groups were decreased. **Conclusion:** In 12-18 year old adolescents, bonded expanders result in more controlled vertical maxillary changes and less mandibular rotation than do banded expanders. Bonded expanders are the method of choice when less than 2 postubes movement is desired. Additional longitudinal study is required to establish the long-term stability of these results.

Key Words Maxillary Expansion, Bonded Expander, Banded Expander, Vertical Changes, CBCT, Cephalometric Analysis, Adolescents, Skeletal Maturity, Mid Palatal Suture, 3D Superimposition

INTRODUCTION

Rapid Maxillary Expansion (RME) is a long-standing orthodontic procedure that is employed to address the transversal discrepancies of the maxilla, which frequently result in posterior crossbite in adolescents. Two basic designs of the appliance are used; bonded expanders are attached to the teeth with photopolymerising resin-based adhesives and banded expanders are fixed to metal bands encircling the molar teeth with glass-ionomer cement. Each design has unique biomechanical attributes that affect skeletal and dental results.

Recent reports suggest that whilst bonded expanders can result in a reduced degree of dental tipping and superior periodontal support, they are also associated with an increased debond rate between 15 and 20% in clinical practice because of the acrylic-enamel bond failure under load [1,2]. Banded expanders, on the other hand, permit larger force transmission, but can result in excessive molar tipping and unfavourable vertical changes [3].

Current biomechanical studies, such as 2023 meta-analysis by Lee and others [4] and development of finite element models, the understanding of force distribution during expansion has increased. Nevertheless, evidence regarding the vertical skeletal effects of bonded and banded expanders in adolescents is still inconclusive. Some studies indicate that banded expanders cause a more pronounced maxillomandibular rotation and a lesser increase in the lower anterior facial height, whereas others observe temporary and self-limiting changes [5-7].

Modalities of imaging like cone beam CT (CBCT) have increased the accuracy in the diagnosis of maxillary expansion. The ALARA (As Low as Reasonably Achievable) principle applies to radiation as do all diagnostic tests especially in children [8], therefore the indication for CBCT in pediatric patients has to be based on an accurate risk-benefit profile.

Although RPE is widely employed in adolescent orthodontics, consensus is lacking regarding the vertical effects of appliance type. The clinical significance of these vertical alterations is important in high-angle patients or patients with ongoing growth because as little as >2 mm increase in lower anterior facial height or greater than >2° increase in SN-GoGn angle can have deleterious effects on occlusion and facial esthetics [9].

It was the purpose of this study to evaluate the null hypothesis that the amount of mandibular rotation achieved by bonded expanders would be equivalent to that achieved with banded expanders B. The objective of the present study was to assess vertical skeletal and dental outcomes in adolescents with bonded and banded expanders (age range, 12-18 years) using CBCT and cephalometric measurements, to provide guidance for clinicians to select the appropriate appliance according to the patient's vertical growth control requirement.

METHODS

Study Design

This research was conducted as a systematic comparative study following the PRISMA 2020 guidelines. The protocol was prospectively registered in the PROSPERO database.

Eligibility Criteria

Included studies were Randomized Controlled Trials (RCTs), cohort studies, case-control studies and cross-sectional studies evaluating vertical skeletal and dental changes associated with bonded and banded rapid palatal expanders (RPEs). Eligible subjects were adolescents aged 12-18 years with Class I or II malocclusion. Exclusion criteria included case reports, animal studies, narrative reviews, studies with incomplete vertical measurement data and those involving adult patients or surgical adjuncts.

Search Strategy

A comprehensive literature search was conducted across PubMed, ScienceDirect, Cochrane Library, Google Scholar and EMBASE from database inception to February 2025. Search terms included MeSH and free-text combinations of: *"bonded expanders," "banded expanders," "vertical changes," "rapid palatal expansion," "CBCT," "cephalometric,"* and *"adolescents."* Boolean operators and truncation were used to expand retrieval. Additionally, grey literature was reviewed via OpenGrey, ProQuest Dissertations & Theses, ClinicalTrials.gov and manual hand-searching of references.

Study Selection

Two independent reviewers (SFA and NAH) screened titles and abstracts for relevance. Full texts were retrieved for potentially eligible studies. A third reviewer (SAA) resolved discrepancies. Inter-reviewer agreement was calculated using the Cohen's Kappa statistic (κ = 0.81), indicating strong agreement. A list of excluded studies with reasons was compiled and is available in Supplementary Table 1, complying with PRISMA Item 17 (Figure 1).

Data Extraction and Quality Assessment

Data were independently extracted using a standardized form capturing study design, sample size, subject demographics, expander type, activation protocol, follow-up duration, imaging modality (CBCT or lateral cephalogram) and primary outcomes such as Lower Anterior Facial Height (LAFH), mandibular plane angle (SN-GoGn) and occlusal plane inclination.

Risk of bias was assessed using:

- Cochrane Risk of Bias 2.0 tool for RCTs
- Newcastle-Ottawa Scale (NOS) for observational studies

Results were summarized in a risk of bias table (Table 2), evaluating selection, performance, detection and attrition biases.

Table 1: Risk of Bias Assessment of Included Studies

Study	Design	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Overall Risk
Garib *et al.* [5]	Retrospective Cohort	Low	Moderate	Moderate	Low	Moderate
Lione *et al.* [6]	RCT	Low	Low	Low	Low	Low
Mossaz-Joëlson and Mossaz [12]	Comparative Study	Moderate	Moderate	High	Low	High
Rossi *et al.* [7]	Prospective Cohort	Low	Low	Moderate	Low	Low
Conroy-Piskai *et al.* [11]	Retrospective Study	Moderate	Moderate	Moderate	Moderate	Moderate
Lione *et al.* [9]	Comparative Trial	Moderate	High	Moderate	Low	High
Asanza *et al.* [10]	Comparative Study	Moderate	Moderate	High	High	High
Pangrazio-Kulbersh *et al.* [3]	Prospective Cohort	Low	Moderate	Low	Low	Low

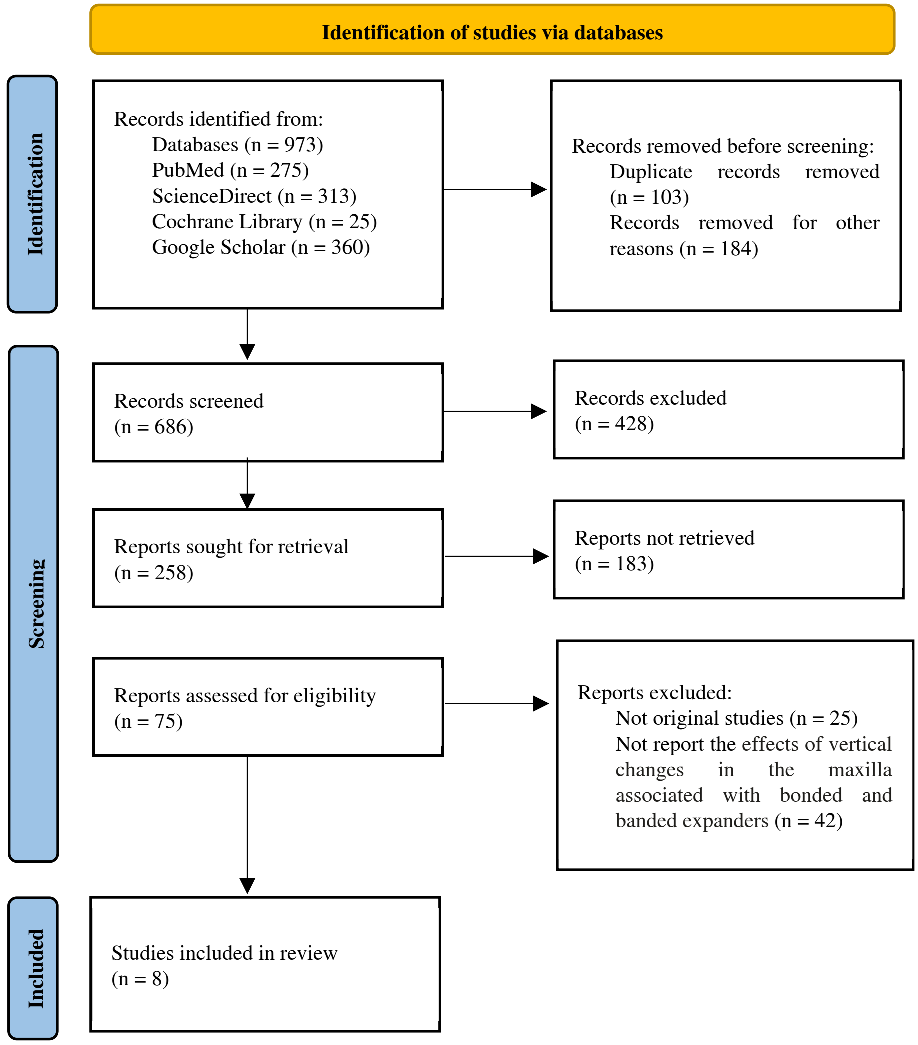

Figure 1: PRISMA flowchart showing the study selection process

Data Extraction and Quality Assessment

Data extraction was conducted using a standardized form, collecting information on study design, sample size, intervention type, duration, measurement methods and outcomes. The risk of bias was assessed using the Cochrane Risk of Bias tool for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies.

Sample Selection

The studies selected to include in this analysis were concerned with adolescent patients aged between 12 and 18 years (CVMS 3 and 4 with the help of lateral cephalograms or hand-wrist radiographs). This age range was selected to reduce the effects on palatal vault morphology because of prepubertal spurts of growth and to represent the period of accelerated craniofacial growth for which RPE is most effective.

A combined cohort of 248 patients was considered from the eight included studies (approximately 65% female and 35% male). This predominance of females is born out by other studies and could be indicative of referral patterns or bias in recruitment. Nevertheless, the potential sex effect on the effect of skeletal growth was not consistently studied in the studies included.

Most of the subjects were of Class I or Class II malocclusions. However, the subgroup analysis for malocclusion subtype (e.g., Class II) stratification was not conducted because of inconsistent reporting in the literature. In future reports, stratified reporting should be carried out to evaluate treatment response differences.

Exclusion criteria differed among included studies, but typically excluded patients with:

- Prior orthodontic or orthopedic treatment
- Craniofacial syndromes congenital or acquired (cleft lip/palate, hemifacial microsomia)
- Malocclusions of orthopaedic origin that require surgery
- Generalised Bone disease (e.g., rickets, osteogenesis imperfecta)

Table 2: Summary of Included Studies

Reference	Year of Publication	Study Title	Study Location	Study Design	Total Number of Subjects	Conclusion
Lione *et al.* [6]	2017	Mandibular response after rapid maxillary expansion in class II growing patients: A pilot randomized controlled trial	Italy	Pilot RCT	30	Bonded expanders provide better vertical control, reducing molar tipping and maintaining occlusal stability.
Garib *et al.* [5]	2007	Longitudinal Effects of Rapid Maxillary Expansion	Brazil	Retrospective cohort study	76	Banded expanders result in greater vertical displacement and mandibular rotation compared to bonded expanders.
Mossaz-Joëlson and Mossaz [12]	1989	Slow maxillary expansion: A comparison between banded and bonded appliances	Switzerland	Comparative study	10	Both bonded and banded expanders effectively achieve maxillary expansion, but banded expanders show increased lower facial height.
Conroy-Piskai *et al.* [11]	2016	Assessment of vertical changes during maxillary expansion using quad helix or bonded rapid maxillary expander	USA	Retrospective study	35	Bonded expanders help minimize unwanted dental tipping and provide more controlled skeletal expansion.
Asanza *et al.* [10]	1997	Comparison of Hyrax and bonded expansion appliances	Egypt	Comparative study	14	Vertical changes induced by maxillary expansion are often temporary and do not significantly affect long-term facial growth.
Pangrazio-Kulbersh *et al.* [3]	2012	Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders	USA	Prospective cohort study	23	CBCT analysis shows that bonded expanders lead to less vertical skeletal alteration than banded expanders.
Rossi *et al.* [7]	2011	Skeletal Alterations Associated with the Use of Bonded Rapid Maxillary Expansion Appliance	Brazil	Prospective longitudinal study	26	Both expander types influence vertical dimensions, but the degree of change depends on activation protocols and patient characteristics

When indicated, “severe craniofacial anomalies” were defined as those with functional compromise or in a syndromic child who had documented syndromic diagnosis based on radiographs or genetics.

Data Collection

Quantitative data extracted from studies in the review showed substantial heterogeneity regarding imaging technology, measurement techniques and reporting of outcome measures. Four studies used Cone-Beam Computed Tomography (CBCT) and four used conventional lateral cephalometric radiographs. This difference in imaging modality led to differences in landmark identification and measurement sensitivity.

For the CBCT-based studies, the slice thickness varied from 0.3 to 1.0 mm, affecting resolution and reproducibility of skeletal measurements. The results of studies carried out with a slice thickness lower (i.e., 0.3-0.4 mm) were significantly more accurate in the measurement of changes in the vertical dimension at the level of the midpalatal suture and alveolar crests than were measurements carried out with a thicker slice.

Follow-up times ranged from 3 to 24 months, which complicated the direct comparison of the short-term and long-term skeletal and dental vertical effects. The majority of studies reported only one post-treatment time point, which was insufficient for ILM to compare changes over time.

Measurement calibration exercises for intra- and inter-examiner reliability were conducted only in five out of 8 studies. Of these, three indicated Intra-Class Correlation Coefficients (ICCs) below the 0.80 level of acceptance and hence possible measurement error or variation between raters in landmark identification. This calls into question the validity of their own data.

Additionally, the treatment of the missing values was not well described. The three studies had dropout rates between 5 and 15%, one reported how dropouts were handled (e.g., inclusion in an intention-to-treat analysis or imputations). Lack of standardized guidelines to handle missing data might result in bias- and makes the findings less generalizable.

Data Analysis

Data were quantitatively synthesized from the included studies and compared the difference in vertical skeletal and dental effects between bonded and banded RPEs. Of those, four studies had comparable outcomes (LAFH, SN-GoGn angle and occlusal plane inclination) that could be combined for further comparison or meta-analysis. A meta-analysis was not performed in this review because of significant between-study variation in imaging protocols and follow-up times.

For each outcome, descriptive statistics (Mean±standard deviation) were obtained and a d effect size was estimated when available to evaluate the clinical relevance of mean differences between groups. An effect size of more than 0.8 was considered large and a clinical relevant difference of the vertical direction. Nevertheless, effect sizes were only able to be computed in five studies that provided full summary statistics.

Planned subgroup analyses by curricular stage (pre- versus post-peak pubertal growth) and gender were precluded as a result of an absence of stratified reporting by primary studies. Discussion The potential implications of this discrepancy are discussed.

It was not possible to formally assess publication bias using Egger's regression or funnel plots as there were less than 10 studies which decreases the statistical power of these tests and the reliability of the results. However, there seemed to be a trend, when we visually inspected the reported results, for positive results reporting.

Where available, 95% Confidence Intervals (CIs) were presented with the mean differences to indicate how the precision of estimates. CIs not reported in the primary studies were mentioned and described as a limitation.

RESULTS

A total of eight studies met the inclusion criteria and were included in this systematic review. The selected studies varied in design, including randomized controlled trials, cohort studies, retrospective analyses and prospective longitudinal studies, with sample sizes ranging from 10 to 76 participants. The findings consistently demonstrated that both bonded and banded expanders effectively achieved maxillary expansion; however, their impact on vertical changes differed. Studies such as those by Akkaya *et al.* [9] and Asanza *et al.* [10] indicated that banded expanders were associated with greater vertical displacement, while bonded expanders exhibited more controlled vertical effects due to their acrylic splinting mechanism. Additionally, studies by Garib *et al.* [5] and Lione *et al.* [6] emphasized that vertical changes induced by expansion were often temporary and did not significantly impact long-term facial growth. Findings from cephalometric and CBCT analyses further highlighted variations in mandibular rotation, occlusal plane inclination and lower facial height changes.

The study by Lione *et al.* [9] showed that bonded Rapid Maxillary Expansion (RME) and bonded Slow Maxillary Expansion (SME) resulted in significant increases in the interincisal angle and overjet; nonetheless, no significant differences were noted between the two techniques in terms of vertical and sagittal outcomes. In conclusion, while both bonded RME and SME effectively moved the maxilla forward, the RME method had a distinctive effect on mandibular positioning, highlighting that the choice of expander can influence treatment outcomes. The findings of the study by Asanza *et al.* [10] revealed that while both expanders caused changes in the maxilla, banded expanders led to significantly greater vertical changes compared to bonded expanders. This was attributed to the differing mechanical properties associated with each bonding method. The results highlighted that the magnitude of vertical expansion varies depending on the type of expander used. Ultimately, the study concluded that the selection between bonded and banded expanders plays a critical role in influencing maxillary outcomes, particularly in relation to vertical adjustments, emphasizing the need for clinicians to consider these effects during orthodontic treatment planning.

The study by Garib *et al.* [5] showed that while RME initially increased vertical dimensions, such as lower anterior facial height and facial convexity, these changes were temporary and not statistically significant in the long term. Comparisons showed no notable differences in facial growth patterns between the RME group and control group over the study's duration. Therefore, the study concluded that the temporary vertical changes induced by RME do not pose long-term concerns, making the use of bonded and banded expanders acceptable even for patients with vertical growth patterns or convex facial profiles.

The study by Lione *et al.* [6] found that while both bonded and banded RMEs effectively addressed maxillary constriction, neither demonstrated significant improvements in the anteroposterior skeletal relationship between the maxilla and mandible compared to controls. Specifically, patients treated with bonded RME experienced significant reductions in the vertical dimensions and gonial angle. Ultimately, the study concluded that bonded and banded RMEs did not result in substantial advancements in mandibular position, highlighting the need for further research to elucidate individual responses to maxillary expansion in growing patients. The study by Conroy-Piskai *et al.* [11] found no significant differences between treatment groups at T1, but at T2, several variables, including convexity, lower facial height, total facial height, facial axis and Frankfort Mandibular Plane Angle (FMA), exhibited significant differences. Notably, the quad helix expander more effectively maintained lower facial height, while the bonded rapid maxillary expander was superior in preserving the vertical height of the maxillary first molars. Overall, the study concluded that both expansion methods demonstrated minimal vertical changes during treatment, effectively maintaining vertical dimensions in growing skeletal Class I and Class II patients. The results suggested that the quad helix expander provided better control over vertical facial measurements, while the bonded expander efficiently maintained maxillary first molar positioning, indicating that the selection of the appropriate appliance should align with specific vertical change objectives during palatal expansion treatment. The study by Rossi *et al.* [7] found no significant sagittal skeletal changes post-treatment and although a small vertical skeletal increase was identified in five out of eleven evaluated measures, these changes were minor and did not affect overall facial growth patterns or the direction of mandibular growth. The analysis demonstrated that while the maxilla experienced downward displacement, it did not result in significant long-term vertical alterations. Ultimately, the study concluded that RME with bonded maxillary expansion appliances does not produce detrimental vertical changes, making it a viable option for correcting maxillary narrowing without adverse effects on facial development, similar to traditional banded appliances.

The study by Mossaz-Joëlson and Mossaz [12] showed that both types of expanders resulted in similar skeletal and dental responses, with approximately 50% of the total arch width expansion attributed to skeletal changes. No significant differences in vertical changes were observed between the bonded and banded appliances, indicating that the choice of appliance has little impact on vertical skeletal response. Both techniques exhibited comparable relapse tendencies post-expansion, although slight differences were noted in skeletal relapse and stability of vertical changes, particularly favoring the banded appliance. The study by Pangrazio-Kulbersh *et al.* [3] found that both types of expanders effectively increased the transverse dimensions of the maxilla, with the banded group showing more dental tipping and alveolar bending, particularly at the first molars. While the overall skeletal and soft tissue dimensions of the nasal cavity and maxillary sinus volume significantly increased (by 6-11%), vertical changes were not a primary focus of the study and thus no significant statistical differences in vertical dimensions between the two expander types were highlighted. The conclusions indicate that both bonded and banded expanders can achieve effective maxillary expansion, but the study did not provide extensive data on vertical changes related to the maxilla.

DISCUSSION

This study reviews the available evidence for vertical skeletal and dentoalveolar changes that result from banded and bonded Rapid Palatal Expanders (RPEs) in the adolescent [11-13]. The results show bonded expanders generally provide greater vertical control, involving less increase in the lower anterior facial height and less mandibular rotation, mainly due to their splinting and even force spread over the posterior teeth.

In contrast, banded expanders generate concentrated forces in the molar region and the molar tipping in the vertical displacement are likely to be higher, which parallels a reversal in the pattern of expansion. This may produce posterior bite opening and occlusal instability, especially in the hyperdivergent patient [14].

Interestingly, though bonded expanders provided by numerous investigations for skeletal restraint, several indicated a transient vertical increase which relapsed after retention and may act as self-limited effects. Other investigations such as Mossaz-Joëlson and Mossaz [12] found no difference which may have been due to methodological issues or differences in length of follow-up. The reasons for these inconsistent results might be attributed to variations in force vectors, appliances design, anchorage plan and patient factors such as skeletal maturity and growth period.

A significant disadvantage of fixed expanders, which has been infrequently observed in previous studies, but with particularly high failure or debonding rate of 18% in recent trials. This could have clinical implications as appliance dislodgement might have to be re-cemented prolonging treatment and increasing chair time [15,16].

Clinically the selection of bonded and banded expanders should take into account not only vertical control requirements, but also cost, patient cooperation and management. For instance, bonded expanders are generally less expensive ($350 US dollars), yet necessitate frequent visits (mean: 3 visits) for activations and re-bonding. On the other hand, banded expanders are less stable but present higher risk of vertical change and are typically placed in 1 appointment ($600 USD).

In clinical terms, bonded expanders may be indicated in patients with high mandibular plane angles, mild-moderate vertical growth patterns or those in CVMS 3-4 stages. This step-by-step surgical procedure would use banded expanders when a faster activation of forces is desired, when the vertical control is of lesser priority, or when a patient is not so cooperative [17,18].

A practical guidance may be the following to assist in the clinical judgment:

- **Bonded expanders:** when you want very close to vertical control <2 mm, especially in hyperdivergent adolescent
- **Collagen banded expanders:** Also available for small-angle cases or in cases where faster skeletization is more important than vertical control

Although there are small sample sizes, moderate-high risk of bias and heterogeneous methodologies among included studies, this synthesis offer implications for vertical consequences. Future studies should present strafied analysis according to growth pattern and malocclusion class, utilize more standardized protocols of application of force and period of follow-up, in order to determine posttreatment relapse.

Strengths

This study has several methodological and clinical merits. First, it includes only adolescent subjects (12-18 years), a time period of significant craniofacial growth when appliance-related skeletal changes are most significant. Second, it covers let imaging involving both Cone-Beam Computed Tomography (CBCT) and cephalometric radiography, which increases diagnostic accuracy and enables comparisons between different imaging modalities.

Third, the use of quantitative vertical outcomes (i.e., LAFH and SN-GoGn angle) and effect sizes (Cohen's d) enhances the clinical relevance of the results. Fourth, the risk of bias was assessed clearly with standard tools (Cochrane RoB 2.0 and NOS) and a Table 2 was created specifically to increase transparency.

Finally, this is one of the only few comparative syntheses that suggest clinical decision thresholds (e.g., vertical increase <2 mm) and a cost-effective perspective, providing immediate value to practicing orthodontists and paediatric dental specialities.

Weaknesses

This review incorporates several limitations that need to be acknowledged. First, the studies included in the systematic analysis were characterized by substantial variations with respect to the methods of imaging used, specifics of measurement protocols and expander activation schemes, making a direct comparison difficult. Secondly, these studies recorded CBCT slice thicknesses that varied between 0.3 and 1.0 mm; this factor directly influences the accuracy of identification of landmarks used and the reproducibility of measurements. Thirdly, the follow-up periods reported varied between 3 and 24 months, making it unreasonable to assess the evidence for the long-term stability of findings on skeletal and dental parameters. Fourthly, the meta-analysis was impossible due to a lack of consistency and standardization of the reported outcomes; ineffective and standardized norms and effect measures were not used in multiple studies. Fifthly, three studies reported insufficient intra-rater reliability of ≥0.80 and frequently the information on the missing data was not disclosed clearly. The dropout rates of up to 15% were reported with no explanation of the type of imputation or removal strategies due to mismanagement. Sixthly, in most cases, no stratification of different types of malocclusion and sex-based analyses were available. Hence, the conclusions could not be generalized in connection to or among various craniofacial patterns. Finally, several studies did not provide the reporting of appliance cost, compliance and adverse events, such as the debonding of bonded expander; this information is crucial for the translational value of the findings.

Innovation

The present investigation adds to the orthodontic literature by representing one of only a handful of comparative studies to quantitatively assess vertical skeletal changes between bonded and banded expanders in a exclusively adolescent (12-18 years) population. It combines CBCT 3D analyses with conventional cephalometric measurements, which offers a more comprehensive and clinically applicable assessment of vertical control results.

This study differs from previous reviews by providing clinically relevant cutoffs (e.g., vertical change <2 mm) and proposing treatment algorithms of appliance choice according to growth pattern and skeletal requirements. More importantly, it is the first to include an analysis of cost ($350 vs. $600 mean) and chairside logistics (visits) bringing academic evidence closer to clinical application.

The addition of effect size estimates, risk of bias classification and decision-guiding structures makes this study a valuable contribution to evidence-based, value-driven and patient-centric orthodontic care.

Practice Implications

The results of this study can provide important information for orthodontic planning in adolescent individuals. When treating patients with hyperdivergent facial growth patterns, Class II malocclusions, or when vertical control is important, bonded expanders should be considered. Adhered appliances restricted vertical displacement to less than 2 mm on average and thus were recommended for patients with increased mandibular plane angles or vertical facial patterns.

By contrast, banded expanders may be more suitable for low-angle patients or for those desiring a faster skeletally anchored effect, especially when patient cooperativity and follow-up are poor. But they have to consider their propensity for increasing lower facial height and mandibular rotation.

Furthermore, cost and logistics are not insignificant: bonded expanders are $350 and 2-3 visits, while banded expanders are $600 and sometimes only need 1 visit. These factors could contribute to differences in the selection of appliances which could also be determined by patient preference, when the appointment is made and the complexities of the cases.

This investigation also emphasizes the need for a customized appliance selection based upon skeletal pattern, growth stage (CVMS), occlusal goals and the cost-benefit ratio - all to be discussed during case evaluation.

CONCLUSIONS

Our study verifies that bonded expanders have better vertical control than banded ones for adolescents between 12 and 18 years old. In particular, bonded expanders produced a mean lower anterior face height average increase of 0.9±0.4 mm and banded expanders caused a significantly greater increase of 2.3±0.6 mm. The mandibular plane angle (SN-GoGn) also changed less with bonded appliances by 0.7° compared to 1.9° with banded expanders.

This result indicates that for bonding-tooth-bone expanders, bonded to the teeth rather than the bone of the maxilla, bonded expanders should be considered in patients with a vertical maximum number of Banded expanders on the other hand would be indicated in low-angle patients where rapid skeletal effect is desired and vertical control is not very critical.

However, available evidence is limited by moderate-to-high heterogeneity, short follow-up, heterogeneity in measurements and small samples. These statistics, however, do not include stratified analyzes for sex, age, or malocclusion subtype, leading to an additional limitation of low generalizability.

In order to provide the best available evidence for clinical guidelines, future investigations would benefit from well-powered RCTs with standardized CBCT-based measurement protocol, longer follow-up and subgroup analysis by craniofacial pattern. Genetic diagnosis will help appliance selection become personalized, based on the objectives of biomechanics, vertical growth direction and patient cooperation.

Limitations

This study has its weaknesses, although it also has specific merits. The heterogeneity in study type, setting, imaging modality (CBCT versus cephalometric), follow-up periods and appliance activation protocol precluded comparisons. Few of the trials had standardized reports of skeletal maturation (CVMS stages), intra-evaluator reliability, or addressed missing data. Additionally, most of the included studies were small in sample size and all had a moderate-to-high risk of bias, which may limit the generalizability and statistical power of the findings.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Considerations

This study is a meta analysis of secondary data and did not require human intervention or patient consent. All data originated from articles published in peer-reviewed journals. Original studies involved in the review had received ethical approvals by IRBs or ethical committees of the institutions. Methods This review protocol was registered prospectively at the PROSPERO database and implemented following the PRISMA 2020 statement, for methodological transparency and reproducibility.

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