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Comparison of Dentoskeletal Effects of Rapid Maxillary Expansion Using Different Expanders in Unilateral Cleft Lip and Palate: A Systematic Review

Dr. Jahnavi Gudigunta, Post graduate, Dr. Tejashri Pradhan, Professor

Department of Orthodontics and Dentofacial orthopaedics, KAHER's KLE VK Institute of Dental Sciences, Belagavi, - 590010

Corresponding author-

Dr. Tejashri Pradhan, Professor, Department of Orthodontics and Dentofacial orthopaedics, KAHER's KLE VK Institute of Dental Sciences, Belagavi, - 590010

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KEYWORDS:

Unilateral cleft lip and palate; Rapid maxillary expansion; Dentoskeletal effects..

ABSTRACT:

Objective: To systematically evaluate and compare the dentoskeletal effects of rapid maxillary expansion (RME) using different expander designs in patients with unilateral cleft lip and palate (UCLP).

Design: Systematic review and meta-analysis registered with PROSPERO (CRD420251015273).

Setting: Electronic databases (PubMed, Scopus, Google Scholar, Cochrane) were searched for studies published in English up to July 2024.

Patients, Participants: Seven studies (n = 208 UCLP patients; age 8–15 years) met the inclusion criteria. Participants presented with transverse maxillary deficiency and had undergone primary cleft repair.

Interventions: Different RME appliances (fan-type, inverted mini-Hyrax, modified Haas, and variants) were compared with conventional Hyrax expanders.

Main Outcome Measure(s): Anterior and posterior maxillary width changes, skeletal parameters (SNA, FH-ANS), dental crown and apical widths, nasal and airway changes, dehiscence, and buccal bone thickness.

Results: All appliances produced significant transverse expansion, predominantly dentoalveolar in nature. Meta-analysis of three studies showed no statistically significant difference between intervention and Hyrax groups for anterior maxillary width (MD −0.23; 95% CI −0.92 to 0.46; $p = 0.51$) or posterior maxillary width (MD −0.92; 95% CI −4.78 to 2.94; $p = 0.64$). Airway and nasal septum changes were minimal. Risk of bias was generally low to moderate.

Conclusions: RME effectively increases transverse maxillary width in UCLP patients. Differences among tooth-borne expanders appear minimal in the short term, with expansion largely dentoalveolar. High-quality long-term trials are required to clarify skeletal effects and stability.

INTRODUCTION

Cleft lip and palate are among the most common congenital craniofacial deformities, with an estimated global prevalence of 1 in 700 live births, varying by ethnicity and geography. Unilateral cleft lip and palate (UCLP) constitute the majority of cleft cases and results from the incomplete fusion of the medial nasal and maxillary processes during embryonic development. The cleft extends through the alveolus and hard palate on one side, producing significant morphological asymmetry and impairment in maxillary growth. Early surgical repair is essential for restoring function and aesthetics but often results in scar tissue formation that restricts subsequent maxillary growth, especially in the transverse dimension.[1,2]

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One of the major orthodontic challenges in UCLP management is transverse maxillary deficiency, manifesting as unilateral or bilateral posterior crossbites, collapsed dental arches, and insufficient arch perimeter for proper alignment. These deficiencies are often more pronounced on the cleft side due to altered bone continuity and asymmetric muscular forces. The correction of this deficiency is critical, as adequate transverse maxillary width not only improves dental occlusion and facial balance but also facilitates secondary alveolar bone grafting (SABG) and nasal symmetry restoration. Therefore, orthopedic maxillary expansion is a key preparatory phase in the multidisciplinary management of UCLP patients.[3,4]

Rapid maxillary expansion (RME) is an established orthodontic procedure used to correct transverse discrepancies by separating the midpalatal suture through heavy intermittent forces applied over a short duration. In non-cleft individuals, RME typically induces both skeletal expansion at the midpalatal suture and dental expansion through buccal tipping of the anchor teeth. However, in UCLP patients, the midpalatal suture is partially or completely absent on the cleft side, and scar tissue from surgical closure offers irregular resistance, altering the biomechanical response to expansion. These anatomical differences produce asymmetric expansion patterns, with the non-cleft side often demonstrating greater displacement compared to the cleft side.[5]

The timing of RME in UCLP patients is strategically aligned with alveolar bone grafting procedures. Pre-grafting expansion helps align the maxillary segments, widen the alveolar cleft, and create sufficient space for bone graft placement. If performed too early or too aggressively, however, it can risk alveolar bone dehiscence, excessive dental tipping, and instability post-grafting. Hence, understanding the dentoskeletal response to different expander types is crucial for achieving predictable and stable outcomes.[6]

Several expander designs have been adapted for use in cleft patients, each with unique biomechanical implications. Tooth-borne expanders (e.g., Hyrax or Haas) transmit expansion forces primarily through the teeth and alveolar processes, leading to a combination of skeletal expansion and buccal tipping.[7] In contrast, tooth-tissue-borne appliances (e.g., Haas-type with palatal acrylic) distribute forces partially to the palatal mucosa, offering more skeletal movement but still causing dental side effects. More recently, bone-borne or miniscrew-assisted expanders (MARPE) have been introduced to provide direct force application to the maxillary bone, thereby minimizing dental tipping and improving skeletal outcomes.[8]

In cleft patients, the asymmetrical resistance due to scar tissue and alveolar discontinuity may influence the magnitude and pattern of expansion achieved with each appliance type. Studies using cone-beam computed tomography (CBCT) have demonstrated that RME in UCLP often produces greater expansion in the posterior maxilla than the anterior region and that skeletal displacement is smaller on the cleft side. A CBCT study comparing modified Hyrax and inverted mini-Hyrax expanders found that both appliances effectively increased transverse width, but neither achieved symmetric skeletal expansion, and dental tipping was more pronounced on the cleft side. Similarly, finite element analyses comparing bone-borne and conventional expanders indicate that bone-borne appliances yield more uniform skeletal expansion and less dental tipping, particularly in the cleft-affected region.[9,10]

Despite several clinical and experimental studies on RME in cleft patients, the literature remains inconsistent regarding which expander type offers the most favourable balance between skeletal and dental effects. Some investigations suggest that bone-borne expanders provide superior skeletal outcomes and reduced relapse potential, whereas others report no significant difference compared to conventional Hyrax appliances when expansion is performed before SABG. Furthermore, many studies differ in their patient age range, stage of dentition, and surgical history, making direct comparison difficult.[11]

A review by Figueiredo et al. (2016) comparing two different expanders in UCLP patients concluded that both appliances produced clinically significant

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transverse gain without significant skeletal asymmetry but noted limited sample sizes and short follow-up periods. A systematic review and meta-analysis by Luyten et al. (2022) compared rapid and slow maxillary expansion (RME vs SME) in cleft lip and palate patients and found both to significantly increase intercanine and intermolar widths, though dental tipping and relapse potential remained under-reported. More recently, Meng et al. (2022) demonstrated through 3-D finite element analysis that bone-borne expanders achieved greater skeletal displacement with less dental stress in late adolescent UCLP patients. However, these findings require validation through clinical trials with long-term follow-up and standardized imaging methods.[12-15]

Given this variability, there remains a clear need to systematically compare dentoskeletal effects**,** skeletal expansion, dental tipping, alveolar segment movement, and overall symmetry achieved by different expanders in UCLP patients. Understanding these distinctions is critical for evidence-based appliance selection and timing of expansion relative to surgical interventions.

The present systematic review aims to systematically assess and compare the skeletal and dental effects induced by different RME appliances in the UCLP population, to identify the most effective expansion strategy with optimal orthopedic and orthodontic outcomes.

FOCUSED QUESTION

What are the skeletal and dental outcomes of rapid maxillary expansion using different expanders in unilateral cleft lip and palate patients?

METHODOLOGY

Protocol and registration

This systematic review has been officially registered with PROSPERO, International Prospective Register of Systematic Reviews. PROSPERO is an open-access database dedicated to the registration of systematic reviews on health-related topics. It is maintained by the National Institutes of Health and supported by, the Centre for Reviews and Dissemination (CRD) at the University of York. This platform ensures transparency and prevents duplication by providing access to detailed review protocols. The registration number for this systematic review is CRD420251015273.

Eligibility criteria

The "eligibility criteria" were based on PICOS (population, intervention, comparators and outcomes and study design) as follows:
Population: Patients diagnosed with unilateral cleft lip and palate with transverse deficiency and patients of any age or gender undergoing orthodontic treatment

Intervention: Rapid maxillary expansion, Rapid palatal expansion with HYRAX expander.

Comparator: Patients who were treated with other palatal expanders apart from HYRAX

Outcome: Expansion achieved in the poster region (Intermolar distance in mm), Expansion achieved in the anterior segment, Upper airway assessment, Dehiscence and buccal bone thickness

Study design: comparative studies, cohort studies, randomized and non-randomized controlled trials

Inclusion criteria

1. Patients diagnosed with unilateral cleft lip and palate with transverse deficiency and patients of any age or gender undergoing orthodontic treatment.
2. Patients who had undergone Rapid palatal expansion with the use of different rapid palatal expanders.
3. Articles published in English language
4. Studies published till July 2024.

Exclusion criteria

1. Patients with craniofacial syndromes or developmental disorders affecting craniofacial structures other than cleft lip and palate.
2. Studies lacking sufficient detail on the methodology or outcomes.
3. Articles published in languages other than English
4. Reviews, Conference proceedings, Letters to editor, short communications

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Information sources

A systematic search strategy was developed to include all available articles comparing dentoskeletal effects after Rapid maxillary expansion in Unilateral cleft lip and palate patients using different expanders. The words present in the titles and abstracts of the relevant articles, and the index terms used to describe the articles were used to develop a full search strategy. The search strategy, including all identified keywords and index terms, was adapted for each included information source.

All the studies in English language published from till July 2024, globally were screened for inclusion criteria. The search was conducted on Scopus, Cochrane, PubMed and Google Scholar. A thorough search of reference lists from all the studies that meet our inclusion criteria was conducted. The subject matter experts were contacted for identification of grey literature. Cross references for pertinent papers were verified. When the whole texts of the pertinent research were not accessible through an electronic database, a manual search in the institutional library was performed.

Search

A comprehensive data search was performed in Scopus, Cochrane, PubMed and Google Scholar. While carrying out the search through PubMed the following filters were put:

1. Article type - Randomized and non-randomized clinical trials, prospective and retrospective studies, case control studies
2. Publication date – till July 2024
3. Species - Humans
4. Best match option

Studies were only excluded due to language. Filters for full text articles were set. The keywords for search were as follows:

Primary keywords	**Secondary keywords**
Patients with unilateral cleft lip and palate with transverse deficiency (P)	• Maxillary transverse discrepancy in conjunction with UCLP • Unilateral cleft with maxillary hypoplasia
Rapid Maxillary Expansion (I)	• iMini, modified Hyrax expander
Other types of expanders (C)	• Hyrax appliance
Expansion achieved in the poster region (Intermolar distance in mm). (O)	• Dentoskeletal effects of RME • Upper airway assessment, • Dehiscence and buccal bone thickness

The search strategy used in databases for searching articles was as follows:

Search strategy

To find pertinent studies on the clinical outcomes of our review, a thorough search was undertaken in the Google scholar, PubMed, Scopus and Science direct database. Controlled vocabulary (MeSH terms in PubMed) and free-text terms in the titles and/or abstracts were used to define the search strategy in the database. The search strategies developed using Boolean operators was as follows:

Search strategy:

(("Cleft Lip"[MeSH] OR "Cleft Palate"[MeSH] OR "Cleft Lip and Palate"[tiab] OR "unilateral cleft lip and palate"[tiab] OR UCLP[tiab])) AND ("Rapid Maxillary Expansion"[MeSH] OR "Maxillary Expansion"[MeSH OR "Palatal Expansion Technique"[MeSH] OR "rapid maxillary expansion"[tiab] OR RME [tiab] OR "maxillary expansion"[tiab]) AND ("Orthodontics, Corrective"[MeSH] OR "Tooth Movement Techniques"[MeSH] OR "Orthodontic Appliances"[MeSH] OR "Orthodontic Appliances, Fixed"[MeSH] OR "Orthodontic Appliance Design"[MeSH]) AND ("Hyrax"[tiab] OR "Hyrax expander"[tiab] OR "Fan type expander"[tiab] OR "Fan-type expander"[tiab] OR "Quad Helix"[tiab] OR "Skeletal expander"[tiab] OR "Bone-borne

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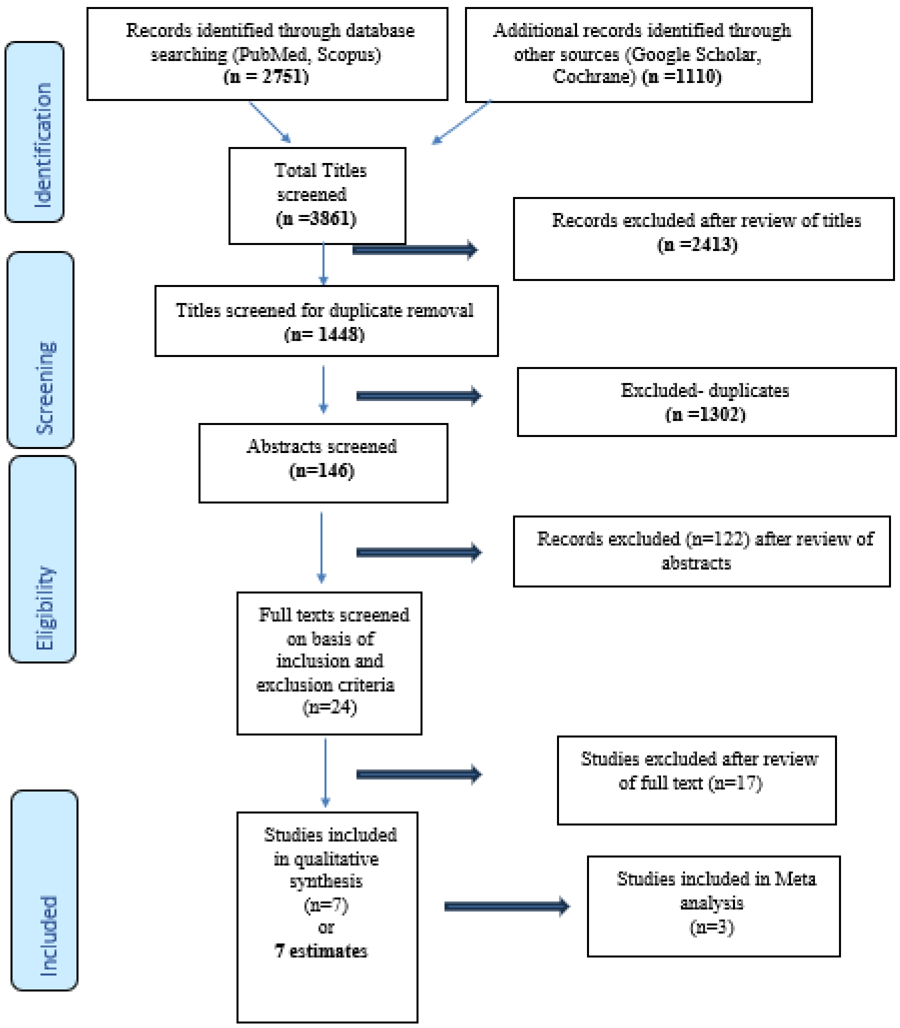
expander"[tiab] OR "Tooth-borne expander"[tiab]) AND ("Dentofacial Abnormalities"[MeSH] OR "Jaw Abnormalities"[MeSH] OR "Facial Bones"[MeSH] OR "dentoskeletal effects"[tiab] OR "skeletal effects"[tiab] OR "dental effects"[tiab] OR "dento-skeletal"[tiab] OR dentofacial[tiab])

Study selection

In this process, one reviewer initially assessed the titles and abstracts identified through the search strategy, considering whether they met the inclusion criteria. Subsequently, the full texts of all the studies meeting these criteria were acquired. The full-text articles were then thoroughly reviewed, and then decided if they met the inclusion criteria. In cases of uncertainty regarding a study's eligibility, the problem was resolved through consultation/discussion with a second author. In case of discrepancies in data extraction, both reviewers developed consensus before making a decision. Rayyan QCRI software was used to remove duplicates and MS Excel 2013 was used to store the data. Ultimately, the systematic review included five studies identified through the search process. The screening process of studies is presented in the form of PRISMA flow-chart (Figure1).

Figure 1: PRISMA Flow chart presenting the screening process



Data collection process

A standardized data extraction form was prepared in Microsoft Excel with the help of an expert. Initially 2-3 entries were made in the Excel and it was reviewed by an expert. Any disagreement between the authors was resolved by discussion.

Data items

Data items included for extracting the data were:

1. Study Id - Number given to each included study
2. Author's name - Name of the author
3. Year of publication - Year in which the study was published
4. Study design - Whether the study was randomized, or non-randomized study, prospective or retrospective study
5. Clinical parameter – Rapid maxillary expansion
6. Intervention - Different types of RME's
7. Follow-up duration - The duration for which the patients were followed-up.
8. Sample size - Number of patients included in the study
9. Outcome - Dental and skeletal effects of expansion amongst different devices
10. Inference - The conclusion of the study and remarks by the author

Risk of bias

The risk of bias was assessed by Risk-of-bias VISualization tool (ROBVIS) tool. The risk of bias of the included studies is presented as a "Traffic Light" Plot of individual studies and a summary diagram. For non-randomized studies; ROBINS-I tool was used; whereas for case series, JBI's critical appraisal too was used.

Results

The present systematic review was conducted to systematically assess and compare the skeletal and dental effects induced by different RME appliances in the UCLP population, to identify the most effective expansion strategy with optimal orthopedic and orthodontic outcomes. The screening process was undertaken in three steps that included screening of titles followed by screening of abstracts and finally screening of full text for inclusion in the review. The characteristics of the studies included in the systematic review are presented in the below tables.

Table no.1- Details of the studies included in the systematic review

Sr. no	Author	Year	Location	Study design	Sample size
1	Facanha AJ et al[16]	2012	Sao Paulo	Comparative analytical study	n=48
2	Figueiredo DS et al[17]	2014	Brazil	Prospective comparative study	n=30
3	Figueiredo DS et al[12]	2016	Brazil	Prospective comparative study	n=20
4	Mordente CM et al[18]	2016	Ohio	Prospective analytical study	n=40
5	Cardinal L et al[19]	2017	Brazil	prospective cohort study	n=30

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6	Veloso NC et al[20]	2020	Brazil	Case series (retrospective)	n=40
7	Cardinal L et al[21]	2022	Brazil	Prospective cohort study	n=30

The table 1 represents seven studies included in the systematic review as per the pre-defined eligibility criteria. All studies evaluated and compared the skeletal and dental effects induced by different RME appliances in the UCLP population. With respect to publication year, the studies were published from 2012 to 2022. Regarding study design, all of the studies were prospective comparative clinical studies and only 1 study was case series in which retrospective data collection was done. The sample size across the included studies ranged from as low as 20 patients to a maximum of 48 patients. Majority of the studies were conducted in Brazil.

Table 2- Details of the study participants, intervention, and comparator of the studies included in the systematic review

Sr. no	**Author**	**Population**	**Interventions/treatments used (Test group)**	**Exposure/Comparator (Control group)**	**Follow-up period**	**Primary outcomes**	**Secondary outcome, Any additional outcomes**	**Results**	**Conclusion**
1	Facanha AJ et al	Patients had unilateral complete cleft lip and palate, had undergone primary surgeries at an early	Modified Haas appliance	Hyrax appliance	Casts were taken during pre-expansion and 6 months after removal of the appliance at the end of the retention period.	Results of the measurement reliability and transverse distances measured on the models.	NR	The mean expansion obtained between cusp tips and cervical-palatal points for inter-canine width was 4.80 mm and 4.35 mm with the Haas appliance and 5.91 mm and 5.91 mm with the Hyrax appliance	Rapid maxillary expansion significantly increased the transverse dimensions of the upper dental arch in patients with cleft palate, with no significant differences between the Hass and Hyrax expanders.

		age and were in the mixed dentition phase, exhibiting maxillary atresia							
2	Figueiredo DS et al	Patients aged 10-13 years with unilateral cleft lip and palate with transverse maxillary deficiency were divided into 3 groups, according to the type of	Fan-type, and inverted mini-hyrax expander	Hyrax expander	Cone-beam computed tomography images were taken before and 3 months after expansion	Skeletal - SNA, FH-ANS and Dental changes - Dental crown width (DCW), Maxillary basal width (MBW), Dental apices width (DAW) etc in the maxillae of patients	Anterior maxillary dental changes	The cleft and the noncleft sides expanded symmetrically with all appliances, and there was no difference in dental tipping between these sides (P .0.05)	The hyrax expander showed better results for cleft patients requiring anterior and posterior maxillary expansion. The inverted mini-hyrax most effectively restricted posterior expansion, optimizing anterior expansion without causing as much buccal tipping of the supporting teeth as did the fan-type

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		expander that they used							
3	Figueiredo DS et al	Presence of UCLP, need for maxillary expansion treatment and age between 8 and 15 years.	Inverted Mini-Hyrax.	Modified Hyrax	Pretreatment cone-beam computed tomographic image (T0) was taken as part of the initial orthodontic records and three months after RME, for bone graft planning (T1)	Skeletal - SNA, FH-ANS and Dental changes - Dental crown width (DCW), Maxillary basal width (MBW), Dental apices width (DAW) etc in the maxillae of patients	Anterior maxillary dental changes	Both showed a significant transverse maxillary expansion ($p < 0.05$) and no significant forward and/or downward movement of the maxilla ($p > 0.05$).	The appliances tested are effective in the transverse expansion of the maxilla. However, these appliances should be better indicated to cleft cases also presenting posterior transverse discrepancy, since there was greater expansion in the posterior maxillary region than in the anterior one.
4	Mordente CM et al	Patients with transverse maxillary deficiency who were submitted for rapid	Fan-Type, inverted mini-hyrax supported on the first permanent molars (iMini-M),	Hyrax expander	Cone-beam computed tomography images were taken before and 3 months after expansion.	The anterior and posterior maxillary width, the nasal passage volume, the oropharyngeal minimum axial	NR	The intergroup comparison demonstrated differences among all groups except between Hyrax and iMini-M, which showed the greatest posterior expansions. intergroup comparison	Only the Hyrax and inverted mini-hyrax on the molar expanders effectively increased the nasal passage volume, and none of the expanders evaluated in this study modified the

		maxillary expansion were divided in four groups	or invertedmini-hyrax supports on the first premolars (iMini-B).			area, and volume changes		revealed a significant difference only between Fan-Type and inverted mini-hyrax on the molars. None of the expanders caused significant changes in the oropharyngeal measurements.	oropharyngeal airway.
5	Cardinal L et al	Presence of maxillary atresia, age between and15, erupted first permanent molars, no previous orthodontic treatment	iMini and Fan type	Hyrax expander	A cone beam CT scan was performed before (T1) and 3 months after stabilization of the appliance (T2).	Measurements of root lengths of the first permanent maxillary molars were taken to evaluate root development and external apical root resorption (EARR).	NR	There were no differences among groups, or correlation between cleft side and gender was found vis-à-vis to changes in the root length ($p > .05$).	Orthopaedic forces of RME were neither able to interrupt the root development process nor to cause EARR in cleft subjects.
6	Veloso NC et al	Consecutive patients with	Hyrax expander	NA	Scans were acquired prior to RME (T0)	Three-dimensional changes of the nasal	NR	No changes in the NS deviation were observed following RME.	Following RME, no changes were observed in the NS and maxillary

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		UCLP (mean age 11.16 2.2 years).			and after removal of the expander (T1) before graft surgery.	septum (NS), alveolar width, alveolar cleft volume, and maxillary basal bone following rapid maxillary expansion (RME)		Significant increases of the alveolar transverse dimension were found in the anterior and posterior regions as well as in the volume of the alveolar cleft	basal bones of patients with UCLP despite the significant gain in the anterior and posterior alveolar width and the increase of the alveolar cleft defect. Clinicians should be aware that maxillary changes following RME in patients with UCLP are restricted to the dentoalveolar region
7	Cardinal L et al	20 males and 10 females, with unilateral CLP; transversal maxillary atresia; age between 8 and 15	G2, fan-type; G3, inverted mini-hyrax.	G1, hyrax;	Cone-beam computed tomography scans were performed immediately before treatment and after 90 days of retention	Dehiscence and buccal bone thickness	NR	There was no significant difference between the cleft and noncleft side for all variables (P .0.05), as there was no significant difference between groups (P .0.05).	The findings in this study allow the conclusion that the orthopedic forces of rapid maxillary expansion led to a decrease in the posterior buccal bone volume in unilateral cleft lip and palate patients.

		years ;							

NA- Not Available, NR – Not Reported

The table 2 represents study characteristics with respect to sample, population, intervention and comparator, results and conclusion. In the included studies, the patients eligible were those with unilateral complete cleft lip and palate, had under gone primary surgeries at an early age and were in the mixed dentition phase, exhibiting maxillary atresia which includes 208 patients. The age group of the patients was between 8 and 15 years; with a mean age of 11.5 years. The intervention group consisted of different types of maxillary expanders like fan-type, and inverted mini-hyrax expander, inverted mini-hyrax supported on the first permanent molars (iMini-M), or inverted mini-hyrax supported on the first premolars (iMini-B) and modified Haas appliance. The control or comparator appliance was conventional Hyrax expander. The method of assessment was Cone-beam computed tomography images were taken before and 3 months after expansion in majority of the studies. The primary outcomes of the majority of the studies were skeletal - SNA, FH-ANS and dental changes - Dental crown width (DCW), Maxillary basal width (MBW), Dental apices width (DAW) etc in the maxillae of patients; three-dimensional changes of the nasal septum (NS), alveolar width, alveolar cleft volume, and maxillary basal bone following rapid maxillary expansion (RME) etc. The results of few studies showed no changes in the nasal septum deviation following RME. Significant increases of the alveolar transverse dimension were found in the anterior and posterior regions as well as in the volume of the alveolar cleft and a few studies showed no significant difference between the cleft and non-cleft side for all variables (P .0.05), as there was no significant difference between groups (P .0.05). The studies concluded that orthopedic forces of rapid maxillary expansion led to a decrease in the posterior buccal bone volume in unilateral cleft lip and palate patients. Further, Clinicians should be aware that maxillary changes following RME in patients with UCLP are restricted to the dento-alveolar region

Risk of bias

Seven studies included in the systematic review were assessed for quality assessment. For prospective cohort comparative/clinical studies, risk of bias assessment was done by using the Cochrane's ROBINS-I tool for non-randomized comparative studies whereas for one case series included; JBI's critical appraisal tool for case series was performed.

A) Risk of Bias for Prospective Non-randomized studies

The ROBINS-I tool revealed that majority of the studies had low risk of bias across all domains; except for the domain; deviations from intended interventions; wherein no information was available in 1 of the included studies for domain; bias due to missing outcome data, moderate risk was reported for 3 of the included studies. In the summary plot, about 100% low risk of bias was noted across majority of the domains; except for deviations from the intended interventions and missing outcome data; wherein 25% each risk of bias was denoted for the studies. Thus, overall low risk of bias was noted across both included studies. (Figure 2a and Figure 2b).

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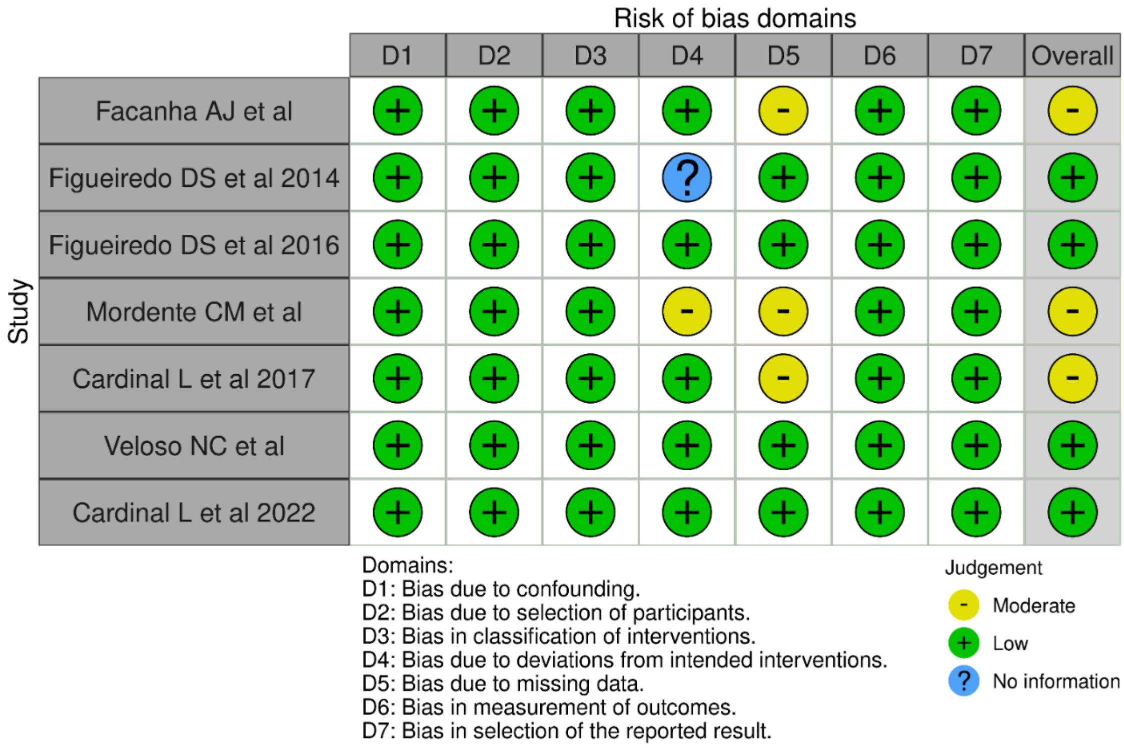

Figure 2a: Risk of bias traffic light plot using ROBINS- I tool

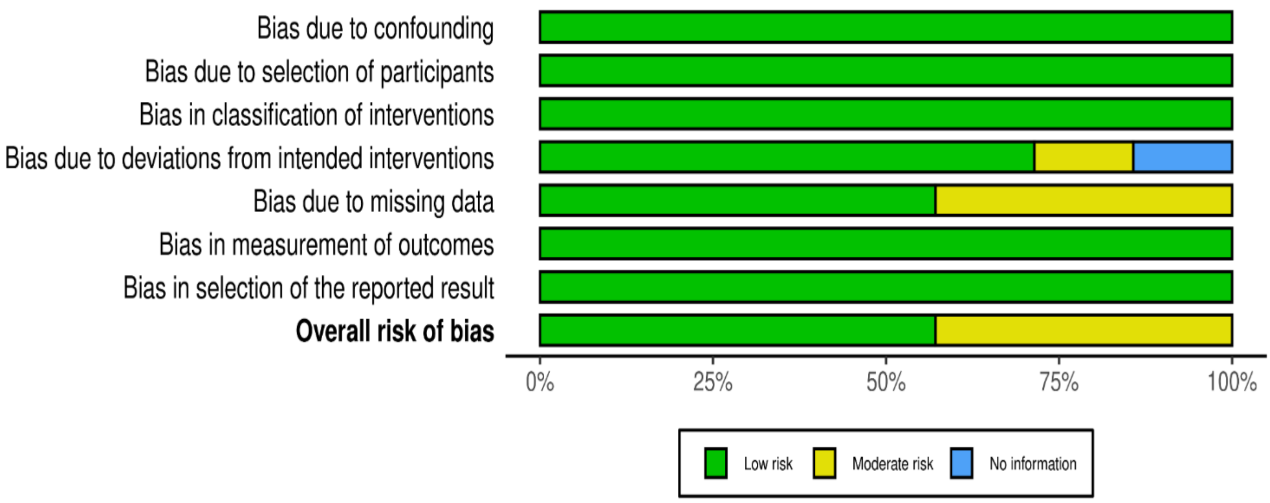

Figure 2b: ROBINS-I "Summary Plot" distribution of risk of bias among the studies

B) Risk of bias assessment of Case series study

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Table 3 – Critical appraisal of Case series (JBI appraisal tool)

Study ID	Author	Were there clear criteria for inclusion in the case series?	Was the condition measured in a standard, reliable way for all participants included in the case series?	Were valid methods used for identification of the condition for all participants included in the case series?	Did the case series have consecutive inclusion of participants?	Did the case series have complete inclusion of participants?	Was there clear reporting of the demographics of the participants in the study?	Was there clear reporting of clinical information of the participants?	Were the outcomes or follow-up results of cases clearly reported?	Was there clear reporting of the presenting sites'/clinics' demographic information?	Was statistical analysis appropriate?
1	Veloso NC et al	Yes	Yes	Yes	Yes	Yes	yes	yes	Yes	yes	yes

QUANTITATIVE DATA SYNTHESIS

The quantitative synthesis via meta-analysis was performed for the study outcome; Anterior maxillary width and Posterior maxillary width depicting the dental changes. This particular outcome was reported across 3 studies included in the systematic review. In the remaining studies, wither there was no comparison group; or the intervention group differed as compared to other studies. So, the meta-analysis was performed for Anterior maxillary width and Posterior maxillary width depicting the dental changes. Table 4 represents the outcome; in the form of mean and SD as presented for each study for change in the Anterior maxillary width; whereas Table 5 represents the outcome; in the form of mean and SD as presented for each study for change in the Posterior Maxillary width.

Table 4 – Quantitative data depicting Mean and SD values of change in the Anterior maxillary width in intervention group (different expander appliances) and control group (Hyrax expander) amongst included studies

Sr. no	Included studies	Intervention group						Control group (Conventional hyrax expander)		
		iMini type expander (Inverted mini hyrax)			Fan type expander					
		Mean	SD	Total	Mean	SD	Total	Mean	SD	Total
1	Figueiredo et al 2014	3.93	1.44	10	6.11	3.26	10	4.69	1.26	10

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2	Mordente CM et al 2016	4.68	1.6	10	5.7	2.89	10	4.67	0.87	10
3	Figueiredo et al 2016	4.76	1.6	10	-	-	-	4.69	1.26	10

Table 5 – Quantitative data depicting Mean and SD values of change in the Posterior maxillary width in intervention group (different expander appliances) and control group (Hyrax expander) amongst included studies

Sr. no	**Included studies**	**Intervention group**						**Control group (Conventional hyrax expander)**		
		iMini type expander (Inverted mini hyrax)			**Fan type expander**					
		Mean	**SD**	**Total**	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**
1	Figueiredo et al 2014	0.36	0.6	10	3.16	1.35	10	4.73	1.09	10
2	Mordente CM et al 2016	5.18	1.78	10	2.1	1.25	10	4.68	1.05	10
3	Figueiredo et al 2016	5.93	1.86	10	-	-	-	4.73	1.09	10

Forest plots

Figure 3a and Figure 3b represent the forest plot depicting the left side favouring intervention/experimental group (iMini hyrax expander) and the right-side favouring comparator/control (conventional hyrax expander). For included studies for outcome; change in Anterior Maxillary Width (Figure 3a); the heterogeneity across the studies was low, 0%, so a fixed effects model was used for analysis. The mean difference between the groups was -0.23 (95% confidence interval: -0.92 to 0.46). The pooled estimate did not show statistically significant differences (p value = 0.51) for AMW between the intervention and control group and the overall effect across studies showed almost equal results for intervention and control group. Thus, it can be concluded that statistically, there was no significant difference between intervention and control group.

For included studies for outcome; change in Posterior Maxillary Width (Figure 3b); the heterogeneity across the studies was high, 97%, so a random effects model was used for analysis. The mean difference between the groups was -0.92 (95% confidence interval: -4.78 to 2.94). The pooled estimate did not show statistically significant differences (p value = 0.64) for PMW between the intervention and control group and the overall effect across studies showed almost equal results for intervention and control group. Thus, it can be concluded that statistically, there was no significant difference between intervention and control group.

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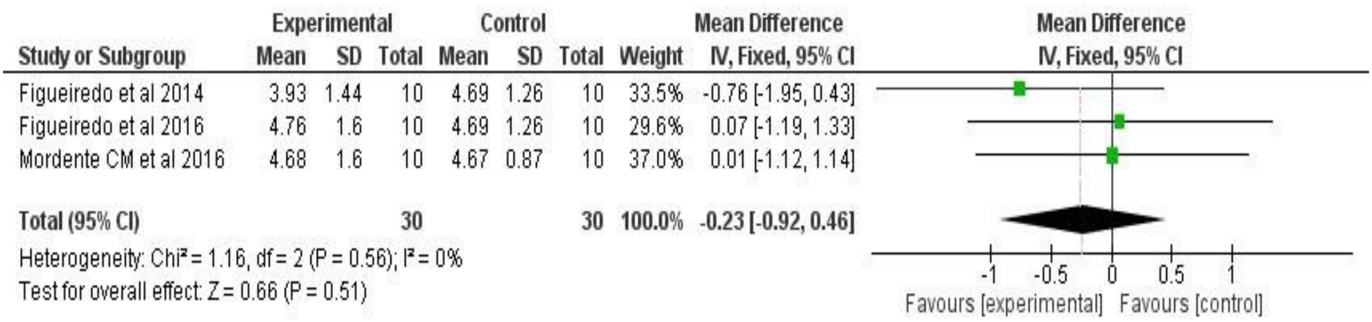

Figure 3a: Forest Plot Distribution for Outcome: Change in Anterior Maxillary Width (AMW) in intervention group and control group

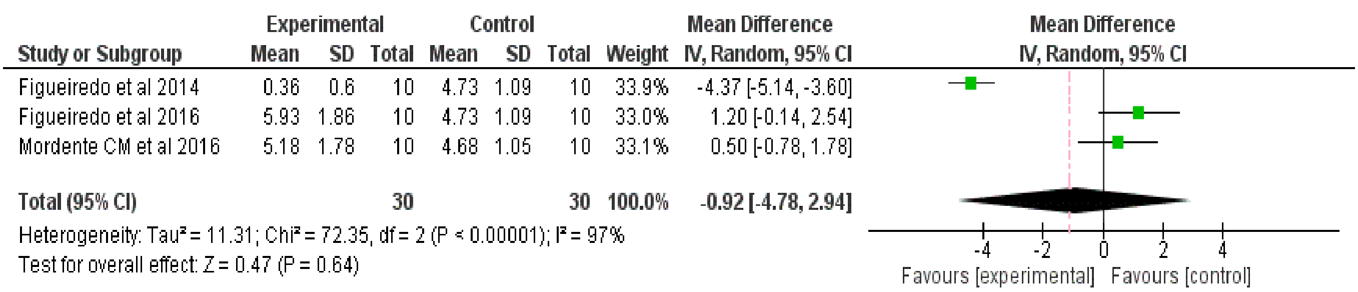

Figure 3b: Forest Plot Distribution for Outcome: Change in Posterior Maxillary Width (PMW) in intervention group and control group

Publication bias

In the current systematic review and meta-analysis, the publication bias across the studies was assessed using a Funnel plot. It is a statistical tool that helps in the identification of bias in meta-analysis. The y-axis represents the measure of study precision i.e. the standard error (SE) while the x-axis estimates the effect sizes of different studies included in the meta-analysis. In the funnel plot of the current meta-analysis (Figure 4a), it has been observed that all of the studies lie within the diagonal lines (95% CI); representing the absence of bias of AMW outcome. For Figure 4b, 2 studies lie within the 95% CI and only 1 study lies at the edge of the 95% CI. Thus, overall, it can be interpreted from the funnel plot that the studies show absence of publication bias for PMW outcome.

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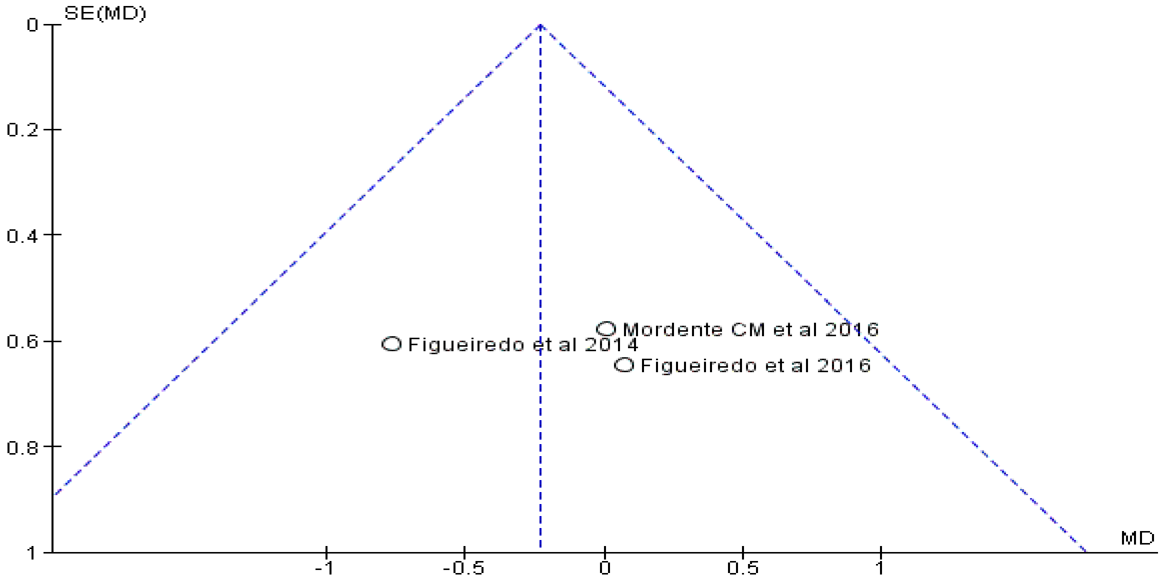

Figure 4a – Funnel plot showing absence of publication bias in majority of the studies for AMW in Intervention and control group

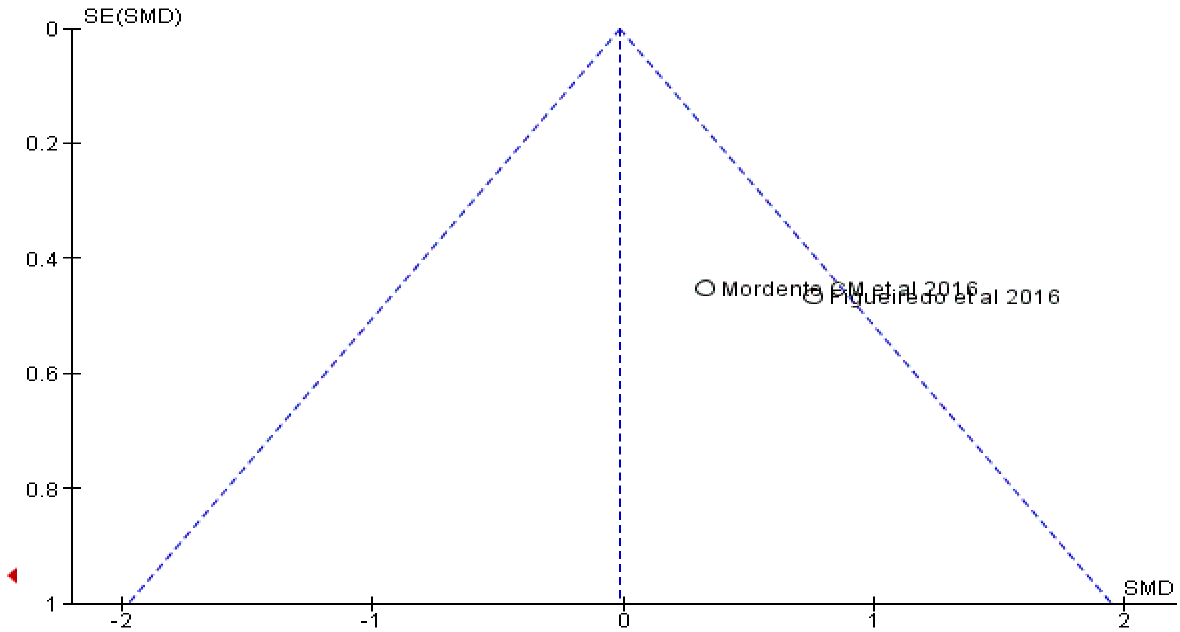

Figure 4b – Funnel plot showing absence of publication bias in majority of the studies for PMW in Intervention and control group

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DISCUSSION

The literature on maxillary expansion in patients with Unilateral Cleft Lip and Palate (UCLP) shows that transverse maxillary expansion can be achieved using different expander designs without major differences in many of the dento-skeletal outcomes. For example, in a clinical trial of 20 UCLP patients comparing a modified Hyrax vs an inverted Mini-Hyrax expander, both appliances produced significant transverse expansion and there were no significant differences in maxillary movement (antero-posterior or vertical) between groups.

Similarly, a broader systematic review comparing slow vs rapid maxillary expansion (SME vs RME) in cleft lip and/or palate (CL/P) patients found that both techniques produced meaningful arch width and perimeter increases; posterior expansion was roughly equal between methods, while SME showed somewhat greater anterior: posterior expansion ratio.[16] Moreover, in a study comparing UCLP patients with non-cleft patients, the dentoalveolar changes after RME were broadly similar (except for arch-length decrease and palatal depth in UCLP) suggesting that UCLP patients can achieve comparable expansion effects to non-cleft populations. Finally, a finite-element modelling (FEA) study compared conventional tooth-borne vs bone-borne expanders in a late adolescent UCLP model and found that bone-borne expanders generated greater skeletal expansion and less dental tipping than conventional designs. Thus, the available evidence suggests that (a) expansion is feasible and effective in UCLP patients, (b) choice of expander design (within the tested tooth-borne designs) often does not yield markedly different transverse outcomes in the short term, and (c) newer designs (e.g., bone-borne) may offer biomechanical advantages though clinical data remain sparse.[17,18]

In UCLP patients, the transverse deficiency of the maxilla is a common challenge, often due to scar tissue and altered growth from early lip/palate repair. Expansion aims to correct the transverse arch deficiency, relieve crossbite, and facilitate subsequent surgical alveolar grafting or orthodontic alignment. In the trial comparing Hyrax vs inverted Mini-Hyrax in UCLP, it was observed that the transverse expansion was mostly at the level of the dental crowns rather than apices, indicating a predominance of dental tipping rather than pure skeletal movement. Specifically, there was greater dental crown than apical expansion ($p < 0.05$) in both groups.
Similarly, in the non-cleft versus UCLP comparison, although all transverse widths, arch perimeter, palatal volume, and palatal depth increased in the UCLP group, the arch length actually decreased and buccal tipping of canines and posterior teeth was observed. These findings indicate that while expansion is achieved, a substantial component may be dental displacement/tipping rather than true skeletal separation. This may be particularly relevant in cleft patients given the altered skeletal architecture and presence of the alveolar cleft defect.[19,20] The FEA study provides a biomechanical rationale: the bone-borne expander generated greater skeletal movement (transverse movement of the nasomaxillary complex) and reduced dental tipping compared to conventional tooth-borne expander in UCLP. When evaluating dento-skeletal effects, it is important to distinguish between skeletal widening (i.e., sutural or alveolar bone movement) and dental tipping/arch adjustment, and to recognise that many conventional expanders may deliver more of the latter, especially in the cleft context.[21]

In the context of UCLP, various expander types and activation protocols have been studied. The Hyrax and inverted Mini-Hyrax designs in the UCLP trial and Slow expansion (SME) using Quad Helix (QH) appliance vs RME using Hyrax in the CL/P systematic review. Tooth-borne vs bone-borne (miniscrew assisted) expanders in finite element modelling context. The systematic review comparing SME vs RME found no significant difference in posterior expansion, but SME (QH) demonstrated a greater anterior: posterior expansion ratio (i.e., more anterior expansion relative to posterior). In the UCLP clinical trial, despite the two different expanders, no significant difference was observed between groups in transverse outcome ($p > 0.05$) and no significant antero-posterior or vertical maxillary movement.[22,23]

These findings suggest that in UCLP patients at least in the early/mid mixed dentition context studied different tooth-borne expanders may yield similar transverse improvement. However, newer bone-borne designs (though less studied clinically in cleft patients) hold promises for more skeletal effect and less dental side-effect (less tipping).

For protocol, note that activation rate, retention period, timing relative to alveolar bone graft, and patient age may all modify outcomes. The review points out the heterogeneity in activation protocols among included studies. In planning treatment, the clinician should consider expander design, expansion rate (rapid vs slow), anchorage type (tooth vs bone), age/maturation of the mid-palatal suture/cleft segments, and the potential for dental tipping vs skeletal effect.[24]

In UCLP patients, transverse maxillary deficiency is common because of early surgical repair on the lip and palate, scar contraction, and disrupted growth. Expansion serves several functions: correction of posterior cross-bite, aligning the dental arch, creating space for alveolar bone grafting (SABG), and improving arch symmetry and form to facilitate subsequent orthodontic/orthognathic steps. For example, the systematic review on RME in UCLP showed that the treatment produced significant increases in arch widths, arch perimeter and palatal volume, which are beneficial for arch form. Moreover, the UCLP trial found symmetrical expansion on the cleft side and non-cleft side (no significant difference between sides) for the transverse dimension, which is clinically reassuring. However, some caveats: The arch length decreased in UCLP patients after RME in one study, and palatal depth decreased, suggesting that arch form is altered, and possibly the alveolar segments respond differently.[25] Also, the timing of expansion relative to SABG is important: some authors propose expansion prior to grafting enhances surgical access and may improve graft success by widening the alveolar cleft defect and decompressing the segments. Therefore, when interpreting dento-skeletal effects in UCLP, clinicians must integrate these outcomes with the broader surgical/orthodontic pathway including SABG, alignment of maxillary segments, and eventual orthognathic correction if needed.[26]

When comparing different expanders in UCLP patients, the evidence suggests that among tooth-borne expanders (e.g., Hyrax vs Mini-Hyrax) in UCLP, the differences in outcomes are minimal in the short term (as per the cited trial). In comparing expansion protocols (SME vs RME) in CL/P, SME may offer a more favourable anterior expansion relative to posterior, but posterior expansion is similar between methods. Deviating from the standard tooth-borne design, bone-borne expanders show biomechanical superiority in modelling studies.[27,28] This suggests that in patients with more complex anatomy such as UCLP, bone anchorage may yield more skeletal change and less dental side-effect particularly important in asymmetry or late adolescents. Thus, clinician decision-making may hinge less on minor variations among standard tooth-borne expanders in younger UCLP patients, and more on identifying when a bone-borne design may be warranted (e.g., older patient, severe transverse deficiency, large alveolar cleft, asymmetry, prior surgical scarring).

Strengths of our review

- The topic addresses a clinically significant issue transverse maxillary deficiency in UCLP which directly affects facial symmetry, occlusion, and surgical outcomes (e.g., alveolar bone grafting). The comparison of different expander designs (tooth-borne vs bone-borne, rapid vs slow) provides practical guidance for clinicians managing cleft patients, where treatment decisions are often complex and multidisciplinary.
- The study is conducted as a systematic review**,** following an explicit methodology for literature search, inclusion criteria, and data extraction. This evidence-based framework enhances transparency, reproducibility, and comprehensiveness of the findings.
- The review includes various expansion modalities such as Hyrax, Mini-Hyrax, Quad Helix (slow expansion), and bone-borne expanders — allowing for a comparative evaluation of mechanical and biological responses.
- Unlike earlier cleft literature that mainly reported overall arch widening, this review explicitly distinguishes skeletal expansion (midpalatal suture opening, alveolar movement) from dental effects (tooth tipping)**.**

- The study links orthodontic findings to surgical planning (e.g., alveolar bone grafting) and functional outcomes (airway, speech)**,** emphasizing interdisciplinary treatment. This holistic integration strengthens its clinical applicability in cleft management teams (orthodontists, surgeons, speech therapists).

Limitations of our review

- Heterogeneity of protocols**:** Differences in expander designs, activation rates, anchorage types, retention durations, timing relative to grafting or other surgeries, and patient age make direct comparisons difficult. The review emphasised this heterogeneity.
- Outcome measures focussed often on dento-alveolar metrics: Many studies measure arch width, arch perimeter, tooth inclinations, etc., rather than true skeletal changes (e.g., mid-palatal suture separation, alveolar bone changes, 3D CBCT metrics). For example, studies in UCLP often find crown expansion and tipping rather than pure skeletal widening.
- Lack of long-term follow-up**:** Many reported outcomes are short term (e.g., 3-6 months post-expansion). Long-term stability of expansion, relapse, and effect on subsequent grafting/orthognathic results are less well documented. The review noted the need for stability data.
- Lack of randomized comparisons of different expander types in UCLP: For example, while tooth-borne vs bone-borne expanders show biomechanical promise in FEA modelling, clinical trials in UCLP comparing these directly are scarce or absent.
- Complex anatomy of UCLP**:** The presence of alveolar cleft, scar tissue, altered sutural anatomy, asymmetric maxillary segments, and variation in timing of surgeries all complicate the biomechanics of expansion. This may limit generalizability of non-cleft expansion data to the UCLP population.

Future research recommendations

- Conduct prospective, multi-centre randomized trials comparing expander designs (e.g., tooth-borne vs bone-borne) specifically in UCLP cohorts.
- Incorporate 3D imaging (e.g., CBCT) to quantify skeletal changes (mid-palatal suture opening, alveolar segment displacement), dental tipping, arch form changes, and volumetric changes of the nasal cavity if relevant.
- Evaluate long-term outcomes: stability (1-5 years), relapse risk, the effect of expansion on success of alveolar bone grafting and on subsequent orthognathic outcomes.
- Standardize protocols (activation rate, retention time) and report core outcome sets for comparability.

Clinical implications

- Maxillary expansion is feasible and effective in UCLP patients, and can yield meaningful transverse improvement in arch width, perimeter, and volume of the palatal region.
- Choice of expander (among the tested tooth-borne designs) may not drastically change short-term transverse outcomes, but clinicians should still consider design features such as anchorage type, screw location, activation rate, retention protocol, and individual patient anatomy (cleft vs non-cleft side, alveolar segment status, presence of scar tissue).
- Dental tipping remains a concern: crown expansion often exceeds apical expansion, indicating that a portion of the movement is dental rather than skeletal. Therefore, careful monitoring of tooth inclination and alveolar bone in expansion is important.
- For patients in later adolescence or with significant transverse deficiency, bone-borne expanders may offer advantage in achieving more skeletal expansion and less dental tipping though clinical evidence in UCLP is still emerging.
- Timing relative to alveolar bone grafting should be considered: expansion prior to grafting may facilitate surgical access and segment

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alignment; however, coordination between orthodontist and surgeon is essential.

CONCLUSION

Within the limitations of this systematic review, it can be concluded that in UCLP patients, maxillary expansion (especially transverse) can be achieved with different expander designs, with meaningful dento-alveolar outcomes. Differences between tooth-borne expander types appear modest in younger UCLP patients; however, skeletal vs dental effect must be distinguished. Bone-borne anchorage shows biomechanical advantages (more skeletal expansion, less dental tipping) though clinical trials in the UCLP context remain sparse. Protocol factors (age, activation rate, retention, alveolar graft timing) and patient-specific anatomy (cleft side vs non-cleft, scar tissue) play a major role in outcomes. Long-term stability, skeletal vs dental responses, asymmetry handling and standardisation of outcome measures require further high-quality research. For clinicians, the choice of expander in UCLP should be integrated with interdisciplinary management (orthodontics + surgery) and tailored to the patient's anatomical, functional and surgical status rather than simply defaulting to one device type.

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