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Adverse Effects of Early Palatoplasty on Maxillary Growth in Patients with Cleft Palate: A Systematic Review

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ABSTRACT

Background: The optimal timing of palatoplasty in cleft palate repair remains a persistent clinical controversy despite advances in cleft care protocols and surgical techniques. Evidence continues to suggest that early palate closure (before 18 months of age), although beneficial for speech development, may adversely affect maxillary growth because of fibrosis, scar contracture, and tension across craniofacial growth centers. With evolving treatment philosophies and modern multidisciplinary cleft care, an updated synthesis of recent evidence is necessary to clarify the current understanding of the long-term dentofacial consequences of early palatoplasty.

Objective: To systematically evaluate and synthesize contemporary evidence published between 2020 and 2025 on the adverse effects of early palatoplasty on maxillary growth and craniofacial skeletal development compared with late or staged repair in patients with cleft palate.

Methods: This systematic review was conducted in accordance with the PRISMA 2020 guidelines. A focused search of recent literature published from January 2020 to October 2025 was performed using PubMed, Cochrane CENTRAL, and ClinicalTrials.gov to identify studies comparing maxillary growth outcomes between early (<18 months) and late (⩾ 18 months) palatoplasty. Eligible studies included randomized controlled trials and comparative observational studies involving non-syndromic cleft palate patients. Extracted outcomes included contemporary cephalometric indices (SNA, ANB, Co-A), dental arch dimensions, and occlusal classifications. Risk of bias was assessed using the Cochrane RoB 2 tool and Newcastle–Ottawa Scale.

Results: Seven eligible studies (n = 1,010) were included. Across the included studies, early palatoplasty was generally associated with reduced SNA and Co-A values, narrower maxillary arch widths, and higher GOSLON Yardstick scores, which indicate more arch constriction and maxillary retrusion. These effects were lessened but not completely eliminated by muscle-preserving and two-stage palatoplasty procedures.

Conclusion: The available evidence suggests that early palatoplasty is associated with measurable adverse effects on maxillary growth. The timing of surgery should be patient-oriented, weighing the advantages of early speech against the long-term results of craniofacial growth.

Keywords: cleft palate, palatoplasty timing, maxillary growth restriction, cephalometry, adverse effects

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INTRODUCTION

Cleft palate, with an estimated prevalence of 1 in 700 live births, whether occurring alone or in conjunction with cleft lip, is one of the most prevalent congenital craniofacial abnormalities globally[1]. Its treatment necessitates striking a careful balance between maintaining facial growth, encouraging speech development, and restoring oronasal function [2]. One of the most contentious issues in cleft treatment is the timing of palatoplasty[3, 4]. Early repair has been linked to adverse effects on maxillary growth, including midfacial retrusion and maxillary hypoplasia, which may have long-term functional and aesthetic repercussions, even though it facilitates feeding and speech development[5].

Palatal repair has traditionally aimed to close the soft palate early enough to allow for proper velopharyngeal function, ideally before the crucial stage of speech development, which occurs between 12 and 18 months of age[6]. This must be balanced, though, with the possibility of growth restriction brought on by surgical hard palate manipulation.[7] Early closure can bind the maxilla and restrict its anteroposterior and transverse growth by causing fibrosis and scar formation across the palatal mucoperiosteum.[7, 8] A Class III malocclusion, a flattened midfacial profile, and, in extreme circumstances, the eventual necessity for orthognathic surgery throughout puberty are the clinical manifestations of this condition.[9, 10] On the other hand, delayed surgery may maintain the potential for facial growth but increases the risk of velopharyngeal insufficiency and may worsen speech intelligibility.[4]

For more than 50 years, the concept of maxillary growth restriction as a negative consequence of early palatoplasty has been established; nevertheless, the evidence is still conflicting because of differences in surgery timing, technique, and follow-up time. [11] Using conventional one-stage methods like the von Langenbeck or Veau-Wardill-Kilner technique for early palate closure typically results in more extensive scar tissue and poor maxillary projection[12.] On the other hand, contemporary muscle-preserving methods like Furlow double-opposing Z-plasty and Sommerlad intravelar veloplasty seek to limit strain at the repair site and maintain muscle continuity in order to potentially mitigate unfavorable skeletal outcomes.[13, 14] To balance speech function with craniofacial growth, two-stage palatoplasty protocols have also been proposed, in which the hard palate is delayed until 18–24 months while the soft palate is closed early for speech.[15]

There is still no consensus on the best time for palatoplasty among clinicians and academics, and the long-term effects of early repair on craniofacial growth are still a topic of discussion.[16, 17] When comparing patients who had early palatoplasty to those who had it done later, a number of observational studies have shown quantifiable decreases in cephalometric parameters like SNA, ANB, and Co-A length. However, other studies have suggested that technique and surgeon skill may have a greater impact than timing alone. Heterogeneous results in the literature have also been caused by variations in study design, sample size, and growth assessment techniques.[18]

Understanding maxillary growth restriction as a foreseeable adverse effect of early palatoplasty is essential for evidence-based decision-making in cleft care because of its practical and aesthetic implications. The timing decision has long-term effects on dental occlusion, face harmony, speech results, and the possibility of secondary procedures.[19]

This systematic review aims to critically assess the adverse effects of early palatoplasty on maxillary growth in cleft palate patients. It specifically aims to: (1) compare cephalometric and occlusal outcomes across surgery timings; (2) determine the degree of growth restriction following early versus late palatoplasty; and (3) evaluate the impact of surgical method and follow-up time on long-term facial development.

METHODS

Study Design and Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) standards with a focused search of recent literature published from January 2020 to October 2025. The objective was to identify and synthesize existing evidence on the adverse effects of early palatoplasty (<18 months) on maxillary growth and facial skeletal development in patients with cleft palate. The review was structured around the PICO framework.

Search Strategy & Eligibility Criteria

A systematic search was conducted to evaluate studies that evaluated children with cleft palate (P), and compared early palatoplasty (I), with late palatoplasty (C), and assessed its adverse effect on maxillary growth and adverse facial development outcomes (O).

The search was conducted in the following databases: PubMed (MEDLINE), Cochrane CENTRAL, and ClinicalTrials.gov, for studies within the last 5 years (year 2020 to 2025) and without language restrictions. Search terms combined controlled vocabulary and free-text words related to cleft palate, palatoplasty, surgical timing, and maxillary growth.

The PubMed search string used was:

("Cleft Palate"[Mesh] OR "Cleft Lip"[Mesh] OR cleft palate OR cleft lip OR cleft lip and palate OR palatal cleft) AND (palatoplasty OR "palatal repair" OR "palate repair" OR palatoplasty[tiab] OR "palatal repair"[tiab]) AND (early OR late OR timing OR delayed OR "age at surgery" OR "age at repair" OR "timing of palate closure") AND (maxilla* OR "maxillary growth" OR cephalom* OR "maxillary retrusion" OR "maxillary hypoplasia" OR "arch width" OR "arch length" OR SNA OR ANB OR "dental arch")

Filters were applied for humans, articles published within the last 5 years, and children (0–18 years). Additional records were identified from Cochrane CENTRAL, and grey literature (ClinicalTrials.gov).

The search of Cochrane CENTRAL did not identify any additional eligible records. This finding likely reflects the narrow focus of the review on studies published between 2020 and 2025 evaluating maxillary growth outcomes following early versus late palatoplasty, rather than the absence of evidence on the topic. Relevant controlled studies identified during the review period were retrieved through PubMed and supplementary searches, and no unique eligible studies were found within Cochrane CENTRAL.

Eligible studies included randomized controlled trials (RCTs), prospective or retrospective cohort studies, case–control studies, and comparative cross-sectional studies that examined maxillary growth outcomes after early versus late palatoplasty.

1. **Population:** Non-syndromic children with cleft palate (with or without cleft lip).
2. **Intervention:** Early palatoplasty performed before 18 months of age.
3. **Comparator:** Late palatoplasty ($\geqslant$ 18 months) or staged repair.
4. **Outcomes:** Objective measures of maxillary and facial skeletal growth, including cephalometric parameters (SNA, ANB, Co–A), dental arch width and length, and occlusal relationship indices such as the GOSLON Yardstick.

In addition to studies with external comparison groups, prospective longitudinal studies employing repeated objective measurements before and after palatoplasty within the same patient cohort were considered eligible when they provided quantitative data on maxillary growth outcomes. Such studies were included as supportive evidence regarding postoperative growth changes but were interpreted separately from studies directly comparing surgical timing protocols.

Although the preferred comparator was late palatoplasty ($\geqslant$ 18 months) or staged palatal repair, studies comparing patients who underwent early palatoplasty with age-matched healthy non-cleft controls were also considered eligible when they provided objective measurements of maxillary growth and craniofacial development. These studies were included because contemporary comparative evidence directly evaluating different timings of palatoplasty remains limited, and healthy controls provide a normative reference for assessing the magnitude and direction of growth restriction associated with surgical intervention. Findings from these studies were interpreted as supportive evidence regarding growth restriction rather than direct evidence of the effect of surgical timing.

Purely descriptive case series without longitudinal or comparative assessment, studies focusing exclusively on syndromic clefts, animal studies, and narrative reviews were excluded. When mixed populations were included, only non-syndromic subsets were analyzed.

Study Selection and Data Extraction

Two independent reviewers loaded all retrieved studies into Covidence and conducted title/abstract screening followed by full-text assessment for eligibility.

Discrepancies were resolved through discussion and consensus. Relevant data were extracted after eligible studies had been thoroughly assessed. Extracted characteristics included author, publication year, study setting, sample size, cleft type, age at surgery, surgical technique, outcome measurements (occlusal and cephalometric indices), and duration of follow-up. Data were collated and descriptively summarized to identify patterns and trends related to maxillary growth restriction.

Quality and Risk of Bias Assessment

Each study's risk of bias was evaluated using validated instruments. Randomized trials were subjected to the Cochrane Risk of Bias 2.0 (RoB 2) tool, which assessed the randomization procedure, allocation concealment, blinding, and data completeness. The Newcastle–Ottawa Scale (NOS), which evaluates selection, comparability, and outcome dimensions, was used to evaluate non-randomized trials. Every study was categorized as having a low, moderate, or high risk of bias.

Data Synthesis

A narrative synthesis methodology was employed due to the heterogeneity of study designs, time definitions, and measuring methods. Individual study quantitative results (means and standard deviations) were descriptively presented rather than statistically pooled. To identify recurring patterns of unfavorable outcomes linked to early palatoplasty, findings from the included studies were examined. To understand the clinical consequences of maxillary growth restriction, directional trends in cephalometric and occlusal characteristics were highlighted.

Level of Evidence

The overall certainty of the evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) framework. Each primary outcome, cephalometric indicators (SNA, ANB, Co–A), dental arch dimensions, and occlusal relationships (GOSLON Yardstick), was evaluated across five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias.

RESULTS

Study Selection and Characteristics

A total of 24 records were retrieved from PubMed, none from Cochrane CENTRAL, and six from ClinicalTrials.gov. After screening and removal of duplicates, 12 full-text articles were assessed for eligibility. Following exclusions for non-comparative design, syndromic populations, and incomplete outcome reporting, seven studies comprising 1,010 participants (848 patients with cleft and 162 controls) met the inclusion criteria and were included in the review (Figure 1).

Cephalometric and Dental Arch Outcomes

Patients who had early palatoplasty showed a consistent pattern of maxillary retrusion. According to Shetty et al.[20] the early group's mean SNA and ANB angles were 75.6° ± 2.1° and 1.4° ± 0.6°, respectively, while the later repair group's angles were 78.9° ± 2.4° and 3.1° ± 0.7°. Similarly, Otsuki et al.[15] found that early two-stage closures had a shorter maxillary length (Co–A) (80.5 ± 3.2 mm) than one-stage delayed closures (82.9 ± 3.0 mm), Table 1.

While Singhania et al.21 reported an anterior arch depth reduction of 1.8 mm, Li et al.[14] found that three-dimensional intraoral imaging revealed an average 2.6 mm reduction in anterior arch width following early Sommerlad palatoplasty. These results show quantifiable transverse constriction after early intervention.

Several studies evaluated dental arch connections using the GOSLON Yardstick. According to Ozawa et al.[22] individuals who underwent early surgery (9–12 months) had a mean GOSLON score of 3.7 ± 1.2, whereas those who underwent repair between 15 and 18 months had a score of 2.9 ± 0.8. Additionally, Alforaidi et al.[23] found that the early group had higher mean GOSLON scores (3.39 ± 0.9), which indicate less desirable occlusal outcomes, Table 1.

Qualitative Synthesis

Narrative synthesis revealed consistent directional trends across all studies. Midfacial retrusion, anterior arch constriction, and unfavorable occlusal relationships have all been linked to early hard-palate closure. Following early correction, studies like Shetty et al. [20] and Otsuki et al. [15] found reduced forward maxillary projection and flatter

Table 1: Study Characteristics and Maxillary Growth Outcomes

Study	Year	Country	Population (n)	Early Palatoplasty (<18 mo)	Late Palatoplasty (⩾18 mo)	Primary Outcomes	Key Findings (Adverse Effects)	Design	Risk of Bias
Ozawa et al.	2020	Brazil	448 UCLP	9–12 mo	15–18 mo	GOSLON Yardstick	Higher mean GOSLON in early group (3.7 ± 1.2 vs 2.9 ± 0.8)	RCT	Moderate
Shetty et al.	2021	India	80 UCLP	9–11 mo	18–20 mo	SNA, ANB, Co–A	SNA ↓3.3°, ANB ↓ 1.7°, Co–A ↓2.4 mm	Retrospective cohort	High
Otsuki et al.	2022	Japan	86 UCLP	1.0 & 1.5 yrs (two-stage)	15 mo (one-stage)	Cephalometric & GOSLON	Improved GOSLON in delayed group	Retrospective	Moderate
Li et al.	2024	China	60 cleft, 95 controls	<18 mo	Non-cleft	3D arch width/length	Anterior arch width ↓2.6 mm	Cross-sectional	Moderate
Harada et al.	2021	Japan	92 cleft vs 67 controls	9–18 mo	None	Velar & nasopharyngeal morphology	Reduced velar length and nasopharyngeal depth	Case–control	Moderate
Singhania & Bhojraj	2021	India	8 UCLP	18–24 mo	None	Arch depth & width	Anterior arch depth ↓1.8 mm	Prospective pilot	High
Alforaidi et al.	2023	Saudi Arabia	74 UCLP	Mixed (<18 mo)	Mixed (⩾18 mo)	GOSLON Yardstick	Poorer arch relationships in early repairs	Retrospective	Moderate

facial profiles. On the other hand, skeletal alignment and arch shape were better with staged or delayed protocols, which involved early soft-palate closure but delayed hard-palate closure.

Early closure resulted in smaller nasopharyngeal and soft-tissue dimensions in Li et al. [14] and Harada et al. 24, indicating that surgical scarring during early growth periods influences both bony and soft-tissue morphology. The observation of anterior constriction shortly after surgery was confirmed by the pilot data from Singhania et al.21, underscoring the temporal correlation between early correction and limited maxillary development.

Risk of Bias Assessment

The randomized clinical trial by Ozawa et al.[22] was assessed using the RoB 2 tool. The study demonstrated a generally robust design with an adequate randomization process and a large sample size. However, allocation concealment was not clearly described, raising some concerns regarding potential selection bias. Although outcome assessment using the GOSLON Yardstick is considered reliable and standardized, the study reported a significant surgeon-dependent effect, suggesting possible deviations from intended interventions and performance bias. Missing outcome data did not appear to meaningfully influence the results, and outcome reporting was consistent with prespecified objectives.

Overall, this trial was judged to have a moderate risk of bias, primarily due to unclear allocation concealment and the influence of operator variability.

All six non-randomized studies were assessed using the Newcastle–Ottawa Scale, focusing on selection, comparability, and outcome domains.

The retrospective cohort study by Alforaidi et al.[23] included participants from multiple centers, enhancing representativeness. However, the absence of a control group and lack of adjustment for confounding variables, such as surgical protocol differences and surgeon expertise, limited internal validity. Despite the use of a validated outcome measure (GOSLON Yardstick) with high inter- and intra-examiner reliability, the study was judged to have a moderate risk of bias.

Similarly, the case–control study by Harada et al.[24] demonstrated strengths in objective cephalometric measurements and longitudinal assessment across multiple time points. Nevertheless, its retrospective design

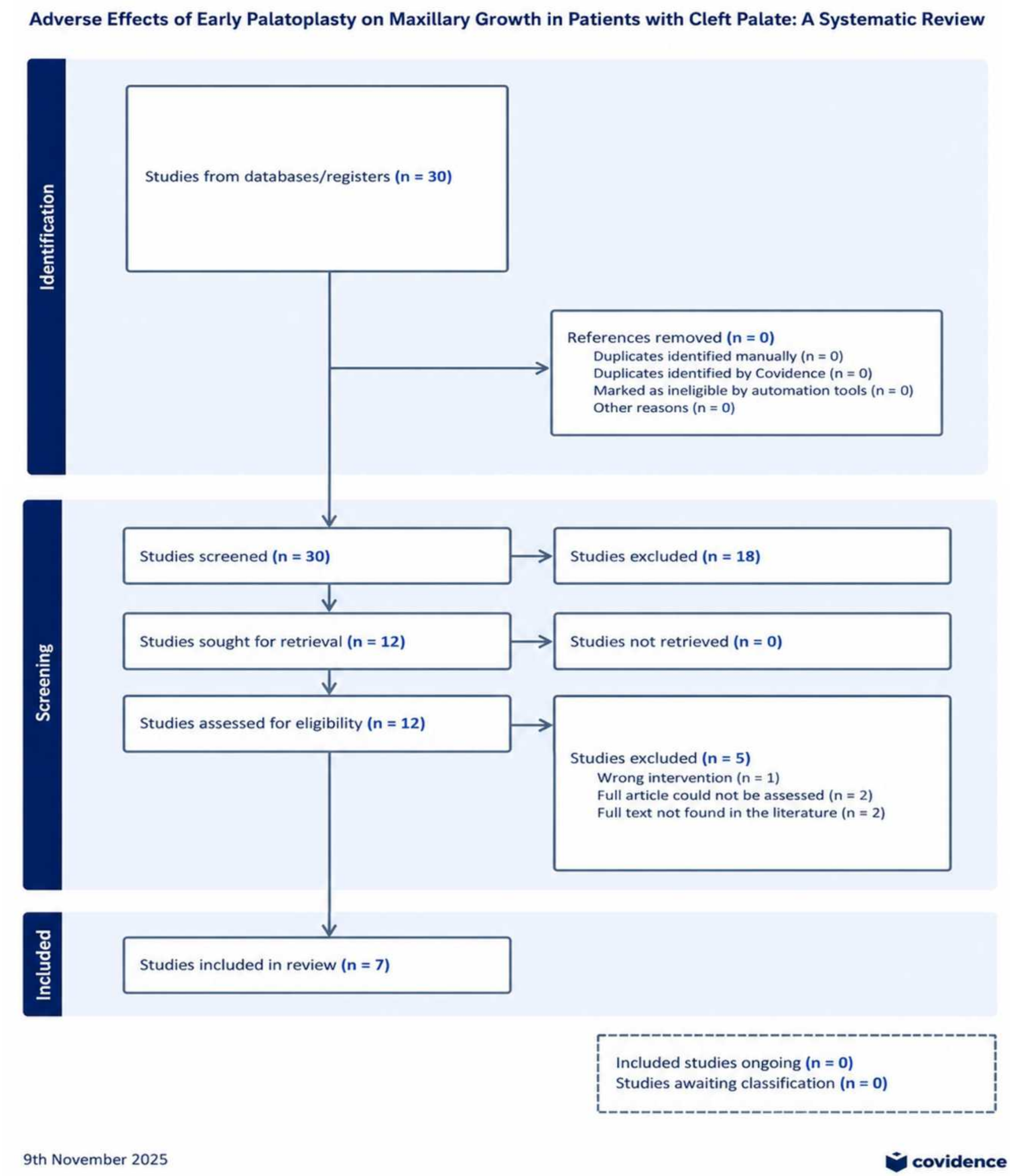

Figure 1: PRISMA Flow Chart showing number of studies screened at each stage of the review

and limited control for confounders reduced its methodological rigor. This study was also classified as having a moderate risk of bias.

The observational comparative study by Li et al.[14] benefited from a relatively large sample size, inclusion of a healthy control group, and the use of objective three-dimensional intraoral scanning techniques. However, the lack of comprehensive adjustment for confounding variables and the inherent limitations of non-randomized designs resulted in a moderate risk of bias.

Otsuki et al. [15] conducted a retrospective comparative analysis of two surgical protocols. While outcome assessment was robust and included blinded repeated measurements, the study was affected by temporal (historical) bias, as the comparison groups were treated in different time periods. This introduces potential confounding due to evolving surgical practices. Consequently, this study was judged to have a moderate risk of bias.

In contrast, the study by Shetty et al. [20] exhibited more substantial methodological limitations. The retrospective single-center design, heterogeneity of surgical techniques within groups, and absence of adjustment for confounding factors significantly increased the likelihood of bias. Therefore, this study was classified as having a high risk of bias.

The pilot study by Singhania and Bhojraj[21] was also judged to have a high risk of bias. Its very small sample size (n = 8), absence of a control group, and limited statistical power substantially restrict the reliability and generalizability of its findings, despite the use of repeated measurements.

`Across the body of evidence, several recurring methodological concerns were identified. Most studies employed retrospective observational designs, which are inherently prone to selection bias and confounding. A key limitation across studies was inadequate control for confounding variables, particularly surgeon skill, surgical technique variations, and timing of intervention. Additionally, although outcome assessment methods were generally robust and standardized (e.g., GOSLON Yardstick, cephalometric analysis, 3D scanning), blinding of outcome assessors was inconsistently reported.

Level of Evidence

The majority of the evidence was derived from observational comparative studies, which are classified as low-certainty evidence under GRADE. In comparison to later or staged repairs, early palatoplasty (less than 18 months) was linked to lower SNA and Co-A values, narrower arch width, and worse occlusal classifications. These findings were consistent across several independent studies from various populations. An increase in certainty to moderate was justified by this consistency and the biological plausibility of growth restriction brought on by early scarring.

However, there were slight reductions in the likelihood of bias and imprecision due to randomization restrictions, sample size variance, and heterogeneity in timing definitions. There was no evidence of significant publishing bias or indirectness. As a result, the GRADE criteria classified the overall certainty of evidence regarding the detrimental impact of early palatoplasty on maxillary growth as moderate.

DISCUSSION

This contemporary systematic review synthesized evidence from seven studies involving 1,010 participants published between 2020 and 2025 regarding the adverse effects of early palatoplasty (<18 months) on maxillary growth in patients with cleft palate. The review suggests that early palatal closure during infancy may adversely influence the normal growth trajectory of the maxilla.[15, 20] Early surgery may result in fibrosis and scar formation within the palatal tissues, which have been proposed as mechanisms contributing to restricted bone growth and reduced forward maxillary displacement.[24] Clinically, this manifests as Class III malocclusion, reduced facial convexity, and arch constriction, features that frequently require surgical or orthodontic treatment during adolescence.[22, 23]

However, the reviewed studies also report that tissue handling and surgical skill, rather than only timing, have an impact on the degree of growth inhibition.[14, 21] Growth limitation seemed to be lessened but not completely prevented by muscle-preserving and tension-free closure techniques such as Furlow double-opposing Z-plasty and

Sommerlad intravelar veloplasty.[14] Similarly, compared to single-stage early repairs, two-stage palatoplasty protocols that involved early soft-palate repair followed by delayed hard-palate closure showed better maxillary and occlusal outcomes15. These results provide credence to the idea that although growth-related adverse effects remain a recognized concern following early repair, their severity may be lessened by judicious procedure selection and staging[20.]

An important contemporary consideration when interpreting the present findings is the landmark Timing of Primary Surgery (TOPS) randomized controlled trial by Gamble et al.[4], which provides the highest level of evidence currently available regarding the timing of cleft palate repair. In this multicenter international trial involving 558 infants with isolated cleft palate, primary palatoplasty performed at 6 months of age resulted in significantly lower rates of velopharyngeal insufficiency at 5 years compared with repair at 12 months (8.9% vs. 15.0%), supporting the long-held premise that earlier restoration of palatal anatomy facilitates more favorable speech development and velopharyngeal function. Importantly, the TOPS investigators also reported greater maxillary arch constriction at 5 years among children who underwent surgery at 6 months, although no significant difference in soft-tissue ANB angle was observed between groups. These findings are particularly relevant to the present review because they illustrate the fundamental speech-versus-growth tradeoff that has shaped cleft palate management for decades. While our review identified consistent evidence that earlier palatoplasty is associated with reduced maxillary projection, narrower arch dimensions, and less favorable occlusal relationships, the TOPS trial suggests that delaying repair to potentially preserve craniofacial growth may come at the expense of speech outcomes that are critical for long-term communication and psychosocial development. Rather than supporting a universally early or universally delayed approach, the combined evidence suggests that timing decisions should be individualized and balanced against competing functional and developmental priorities. The TOPS findings further highlight the need for surgical protocols that preserve the speech advantages of early repair while minimizing scar-related growth restriction, such as muscle-preserving techniques, tension-free closure, and carefully selected staged repair strategies. Ultimately, the optimal timing of palatoplasty should be viewed not as a question of speech versus growth alone, but as an effort to maximize both outcomes within the context of multidisciplinary cleft care.

The impact of institutional protocol and surgeon expertise is another significant highlight in this review. Compared to studies from diverse clinical settings, studies conducted in specialist cleft facilities using standardized surgical techniques tended to report less severe growth restriction[22.] This emphasizes how crucial long-term multidisciplinary care, postoperative monitoring, and technical consistency are to reducing unfavorable outcomes.[24] Most of the included studies had a moderate level of evidence quality. The majority of research were observational, which made it difficult to prove causation. Any kind of quantitative synthesis was impossible due to heterogeneity caused by variations in outcome measures, patient age, and follow-up duration. A limitation of this review is that two included studies, Li et al.[14] and Harada et al.[24] used healthy non-cleft controls rather than patients undergoing late palatoplasty or staged repair. Consequently, these studies do not directly evaluate the effect of surgical timing and may overestimate differences in craniofacial growth attributable to surgery itself. Nevertheless, they provide valuable contextual information regarding deviation from normal maxillofacial development and were therefore retained as supportive evidence within the narrative synthesis. Additionally, Singhania and Bhojraj 21 employed a prospective repeated-measures design without an external comparator group. While the study provides useful evidence regarding early postoperative maxillary growth changes, its small sample size and lack of a delayed-repair control group limit causal inference regarding the effect of surgical timing.

However, the direction of findings was generally consistent across the included studies, supporting the notion that early palatoplasty has quantifiable negative effects on maxillary development, especially when complete hard-palate closure is involved.

The findings support the importance of individualized surgical planning from a clinical standpoint. For functional reasons, early closure may still be justified, particularly when delayed repair might impair velopharyngeal competence or speech21. Surgeons must, however, weigh these advantages against the long-term danger of skeletal limitation and make sure patients and caregivers are aware of this trade-off[14]. Monitoring facial growth and identifying patients who could need additional procedures need long-term surveillance into adolescence.

Standardized, multicenter prospective studies that assess long-term craniofacial growth outcomes utilizing consistent cephalometric and 3D imaging techniques should be the main emphasis of future research. Best practices will be improved through comparative evaluations of one-stage, two-stage, and muscle-preserving methods. Additionally, creating regional cleft registries could enhance data quality and enable ongoing outcome monitoring across various treatment centers, facilitating longitudinal evaluation of surgical outcomes and supporting evidence-based improvements in cleft care.

CONCLUSION

Our systematic review found that the available evidence generally supports an association between early palatoplasty (<18 months) and less favorable maxillary growth outcomes, such as transverse constriction and decreased maxillary projection. Early scarring and restricted maxillary growth during critical developmental periods have been proposed as potential mechanisms underlying these observed growth limitations[15, 20]. However, the degree of these effects varies according to surgical technique and operator skill, with two-stage and muscle-preserving methods generally demonstrating more favorable growth outcomes[14, 15]. Therefore, the timing of surgery should be patient centered and oriented, weighing the advantages of early speech against the possibility of long-term skeletal growth restriction.

Future studies aimed at determining the optimal timing and technique for palatoplasty should incorporate standardized imaging protocols and long-term longitudinal follow-up. In current clinical practice, meticulous surgical planning and coordinated interdisciplinary follow-up remain essential to minimize growth-related complications while preserving favorable functional outcomes.

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