Regeneration, Reconstruction & Restoration **Systematic Review**

Open Access

The Effect of Maxillary Advancement on Velopharyngeal Insufficiency in Cleft Palate Patients: A Systematic Review and Meta-Analysis

Mohammad Javad Dahaghin[1] | Hoori Mirmohammad Sadeghi[2] | Mostafa Owneq[1] | Farshid Bastami[3] | Reza Tabrizi[3]*

1. School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
2. Department of Orthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
3. Department of Oral and Maxillofacial Surgery, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Article Info

Received: 7 October, 2024

Accepted: 25 November, 2024

Published: 31 December, 2024

***Corresponding Author**

Reza Tabrizi, Department of Oral and Maxillofacial Surgery, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Email: Tabmed@gmail.com

Abstract

Background and objectives: Maxillary advancement (MA) is a common surgical procedure for correcting facial-skeletal discrepancies in patients with cleft lip and palate. Despite its prevalence, the impact of MA on velopharyngeal insufficiency (VPI) remains a subject of debate. This systematic review and meta-analysis aims to evaluate the effect of MA on VPI in cleft palate patients.

Materials and methods: Adhering to PRISMA 2020 guidelines this review included randomized controlled trials and observational studies assessing velopharyngeal function pre- and post-MA in cleft palate patients. Exclusion criteria encompassed studies on non-cleft palate patients and those lacking VPI assessments. Searches were conducted in databases like PubMed, MEDLINE, Embase, Scopus, and Cochrane Library, up to September 2023. Studies were selected and data was extracted by two independent reviewers, with disagreements resolved through consultation. The risk of bias was assessed using Cochrane's risk of bias tool. A meta-analysis was conducted using inverse variance meta-analysis with random effects for categorical data.

Results: Eleven studies involving 524 patients were included. Studies varied in design, patient demographics, and type of cleft. MA procedures primarily involved LeFort I osteotomy. Speech and VPI assessments employed various methods. Analysis revealed a shift from normal to hypernasal speech postoperatively, with a general trend towards aggravated VPI, especially in cases of MA more than 6mm. The meta-regression (coefficient of -20.35 with a standard error of 8.63, a T-value of 2.36, and a P-value of 0.046) showed a significant relationship between the extent of MA and VPI outcomes. High heterogeneity was observed across studies.

Conclusion: Maxillary advancement, especially when less than 6 mm, can negatively impact velopharyngeal insufficiency in patients with cleft palate. Successful outcomes require comprehensive preoperative assessment, precise surgical planning, collaborative care, and vigilant postoperative monitoring to minimize the risk of VPI and improve patient outcomes.

Keywords: Maxillary advancement; Velopharyngeal insufficiency; Cleft lip; Cleft palate.

Please cite this paper as:
Dahaghin MJ, Mirmohammad Sadeghi H, Owneq M, Bastami F, Tabrizi R. The Effect of Maxillary Advancement on Velopharyngeal Insufficiency in Cleft Palate Patients: A Systematic Review and Meta-Analysis. Journal of "Regeneration, Reconstruction & Restoration" (Triple R). 2024; Volume 9: e28. Doi: 10.22037/rrr.v9.44996

1. Introduction

Maxillary advancement (MA) is a prevalent surgical intervention, often utilized to rectify facial skeletal discrepancies, notably in patients with cleft lip and palate. This congenital anomaly, characterized by an incomplete fusion of the oral cavity's roof during fetal development, manifests in varying severities, ranging from minor perforations to extensive splits (1). It leads to

complications like speech and swallowing dysfunctions and dental issues. While the precise etiology of cleft palate remains elusive, it is hypothesized to stem from a blend of genetic and environmental factors (1). Symptoms encompass a gap in the upper lip or the roof of the mouth, challenges in feeding and hearing, dental malformations, and speech impediments.

Velopharyngeal insufficiency (VPI) is a condition that can emerge in both unrepaired and repaired cases of cleft lip and palate, characterized by insufficient closure of the velopharyngeal mechanism, leading to nasal emission of air during speech. Post-surgical persistence of VPI is noted in approximately 20% of cleft palate patients, predominantly due to anatomical irregularities in the velum and abnormal positioning of the levator veli palatini muscle (2). The management of VPI includes both speech therapy and surgical interventions. Speech therapy is aimed at adjusting speaking patterns to mitigate the symptoms of VPI, and it can be conducted either pre- or post-operatively. Surgical approaches are contingent on the specific structural anomalies and may comprise tonsillectomy, Furlow Z-plasty, pharyngeal flap surgery, sphincter pharyngoplasty, or posterior pharyngeal wall implantation. The choice of surgical method is determined based on individual patient assessments, including speech perception analysis, nasometry, and nasal endoscopy (3, 4). Maxillary advancement surgery is employed in cleft palate patients to address underdevelopment of the upper jaw. This procedure enhances facial aesthetics, alleviates obstructions, and improves airway functionality. However, if velopharyngeal function does not ameliorate post- operatively, further interventions may be necessary to resolve VPI and prevent speech abnormalities (5, 6). The impact of maxillary advancement surgery on VPI in cleft palate patients is a subject of ongoing debate. Further research is also needed to clarify the complex relationship between this surgical procedure and VPI. The central inquiry of this study is to ascertain the existence of a correlation between maxillary advancement surgery and velopharyngeal dysfunction in cleft palate patients. The rationale for this research stems from the need to optimize surgical outcomes and address the speech impairments associated with VPI, ultimately improving the quality of life for individuals with cleft palate.

2. Materials and methods

This systematic review adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) checklist (7).

Our primary research question was: "What is the effect of maxillary advancement on velopharyngeal insufficiency in cleft palate patients?" We structured our review using the following PICO format:

1) Population: Patients with cleft palate
2) Intervention: Maxillary advancement surgery
3) Comparison: Pre- and post-operative velopharyngeal function
4) Outcome: Changes in velopharyngeal insufficiency (VPI)

In this study, we included randomized controlled trials (RCTs) and prospective and retrospective observational studies that evaluated velopharyngeal function both before and after maxillary advancement surgery in patients with cleft palate (CP). Excluded from consideration were studies involving syndromic patients, animal experiments, non-cleft palate patients, and those lacking assessments of velopharyngeal function.

Our comprehensive literature search was conducted in multiple databases, including PubMed, MEDLINE, Embase, Scopus, and Cochrane Library for English-language articles. The search encompassed articles published up to September 2023.

Our search strategy was meticulously developed using a combination of Medical Subject Headings (MeSH) terms and relevant keywords related to cleft palate, maxillary advancement, and velopharyngeal dysfunction. To ensure the integrity of our study selection, two independent researchers performed an initial screening. Duplicates were systematically removed using reference manager programs. The initial screening entailed a thorough review of article titles and abstracts. Subsequently, potentially relevant articles identified in the initial screening underwent a full-text evaluation. In cases of disagreement, any discrepancies were resolved through discussions with the corresponding author.

Data extraction was independently conducted by two reviewers, who utilized a standardized data extraction form. Any inconsistencies were resolved through mutual agreement or consultation with the corresponding author. The data extraction form encompassed the following details:

1) Study Characteristics: Title, authors, publication year and study design.
2) Participant Characteristics: Demographics and cleft palate type.
3) Intervention: Maxillary advancement measurement based on lateral cephalometric images in millimeters.
4) Outcomes: Velopharyngeal competence was assessed using parameters such as velopharyngeal area, resonance, ease of speaking, nasoendoscopy and hypernasality (expressed as a percentage).
5) Risk of Bias Assessment: Quality assessment of the included studies.

To gauge the risk of bias in individual studies, we employed NIH quality assessment tool, with two independent reviewers involved in the assessment. Discrepancies were resolved through discussion or by seeking the input of the corresponding author.

For the meta-analysis of categorical data, we extracted absolute frequencies of pre- and post-operative

velopharyngeal competence from each study. We calculated individual and combined relative risks through inverse variance meta-analysis with random effects.

To determine the eligibility of studies for each synthesis, we followed a systematic process. We tabulated the intervention characteristics of each study and compared them against the predefined inclusion criteria. The selection of eligible studies for synthesis was conducted independently by two reviewers (Author A and Author B), with discrepancies resolved through discussion or consultation with a third reviewer (Author C).

Data preparation included addressing missing summary statistics and performing data conversions as needed. In cases where summary statistics were absent in the original studies, we made efforts to contact the study authors to obtain the necessary data. In cases where data were unattainable, statistical imputation techniques were applied to estimate missing information. Data conversions were carried out to ensure consistency across studies and enable meaningful comparisons.

We utilized forest plots to visually display the results of individual studies and syntheses, offering a clear overview of the study outcomes.

Heterogeneity between studies was assessed using the I2 test, and the choice of employing a random effect model or a fixed effect model was based on the presence or absence of heterogeneity. Subgroup analyses were conducted to explore potential sources of heterogeneity based on relevant study characteristics, such as cleft palate type, patient demographics and surgical techniques. Meta-regression was employed to investigate the influence of continuous variables on the outcomes.

Publication bias was assessed using funnel plots along with Egger's and Begg's tests. Sensitivity analyses were carried out to evaluate the potential impact of methodological quality and risk of bias on the results. For the meta-analysis, we performed relevant statistical commands, including metabias, metaprop, metan, meta, metap, metaregression and metainf.

3. Results

The search strategies initially yielded 1214 studies from the primary databases used in this systematic review. Following this, the reference management software removed 188 duplicate entries, leaving 1026 studies for title and abstract screening to identify those suitable for full-text review. Fifteen studies were then assessed for eligibility based on the inclusion criteria. Among these, four studies were excluded because of assessing other surgical techniques like DO, not mentioning the rate of maxillary advancement or evaluating non-cleft and syndromic patients. Ultimately, 11 studies were selected for data extraction, as outlined in the study flowchart (Figure 1).

This systematic review and meta-analysis involved 524 patients from eleven studies, covering a range of both retrospective and prospective observational cohort studies. The studies focused on patients with various types of clefts including unilateral and bilateral cleft lip and palate, as well as isolated cleft palate. The primary intervention in the studies was maxillary advancement (MA), primarily through LeFort I osteotomy. The average age of patients at the time of intervention ranged from 17.9 to 23.3 years. Speech assessment methods varied across studies, including the use of nasometry, the Pittsburgh Weighted Speech Scale (PWSS) and other methodologies. Velopharyngeal insufficiency (VPI) assessment was conducted using various methods across the studies, including resonance, audible nasal air emission, video fluoroscopy, and lateral cephalometric radiography.

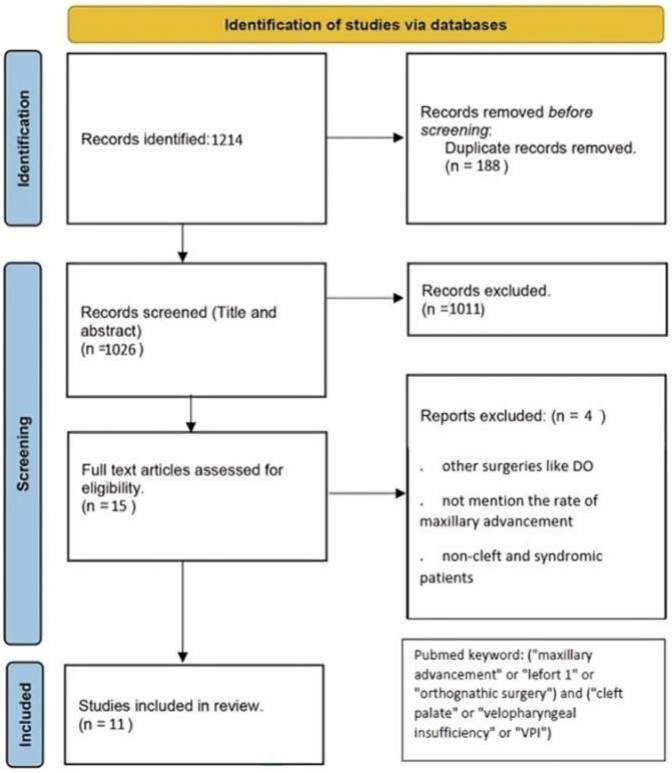

Figure 1. PRISMA flow-diagram of the study.

3.1. Maxillary advancement less than 6 mm

Figure 2 demonstrates the forest plot of the meta-analysis. In this group with maxillary advancement of less than 6 mm, all included studies reported relatively similar outcomes regarding the impact of MA on VPI. Haapanen et al. (8) conducted an observational study reporting an average MA of 4.4 mm. Their findings indicated a worsening of VPI in 26% of cases postoperatively.

Similarly, Yao et al. (9) observed mild hypernasality postoperatively with an average MA of 5.8 mm, with VPI worsening in 30% of cases. Harjunpaa et al. (10), with an average MA of just under 4 mm, reported a decrease in

velopharyngeal competence from 88.2% preoperatively to 75.3% postoperatively, indicating a significant impact on VPI. Kinter et al. (11), with an average advancement of 5.5 mm, similarly observed worsening VPI in 30% of cases, highlighting the prevalence of hypernasality post-surgery. Saleh et al.'s study (12), although not included in the meta-analysis, with an average MA of 5.2 mm, did not provide specific data on VPI changes but noted the presence of hypernasality (Table 1).

3.2. Maxillary advancement more than 6 mm

Except for the Tekin et al.'s study (13), which was not included in the analysis, 5 studies were included in this group. Chua et al.'s study (14) was a clinical trial, while the others were retrospective or prospective observational cohort studies. The types of clefts in the patients studied varied, but most involved unilateral and bilateral cleft lip and palate. Sample sizes ranged from 2 participants in Nohara et al.'s study (15) to 65 in McComb et al.'s study (16). Interventions in these studies, except for Tekin et al.'s, (13) were of the LeFort I osteotomy type. Speech assessment methods varied, including tools like nasometry and endoscopy. The average maxillary advancements in these studies were all more than 6mm. For instance, Schultz et al. (17) reported an average advancement of 9.8 mm, while Impieri et al. (18) and Nohara et al. (15) reported advancements of 6.7 mm and 8.5 mm, respectively. These advancements, compared to the previous group, indicate a more aggressive surgical approach. The outcomes related to VPI and postoperative speech changes varied. In Chua et al.'s study (14), VPI improved in 10% of cases postoperatively, showing a positive outcome. Conversely, McComb et al. found that VPI worsened in 35% of cases. Schultz et al. (17) Reported that VPI improved in 10% of cases postoperatively, showing a positive outcome. Conversely, McComb et al. found that VPI worsened in 35% of cases. Schultz et al. (17) reported no significant changes, while Impieri et al. noted an overall worsening of VPI. Nohara et al.'s small-scale study also observed no changes in VPI postoperatively. These varied results indicate that the impact of maxillary advancement on VPI is not uniform and may depend on multiple factors, including surgical technique and individual patient characteristics (Table 2).

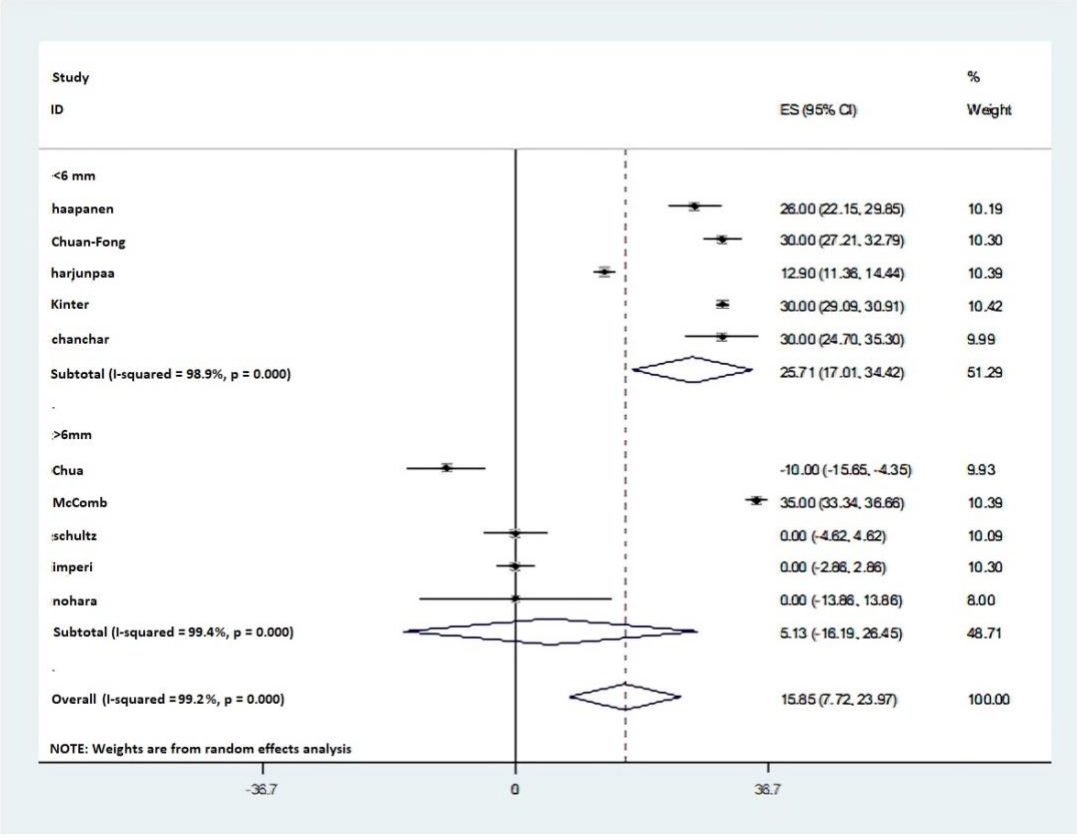

Figure 2. The forest plot for the estimation of the effect of maxillary advancement on the velopharyngeal insufficiency.

Table 1. Characteristics of the included studies with maxillary advancement less than 6 mm.

Study	Type	No. Of patients	Gender	Mean age (year)	Average MA (mm)	MA amplitude (mm)	Intervention	Reported changes in speech	VPI pre-op	VPI post-op	Reported changes in VPI
Kinter et al. 2022	Retro - Cohort	199	M: 121 F: 78	17.9	5.5	4 - 10	Lefort 1	Hypernasality	Ompetent in 85%	Competent in 55%	Worsened in 30%
Chuan-fong Yao et al. 2020	Retro - Ob	25	M: 19 F: 6	19.53	5.8	2 - 11	OGS	Mild hypernasality	Competemt in 90%	-	Worsened in 32%
Saleh et al. 2020	Retro - Cohort	44	M: 24 F: 20	20.3	5.2	NR	Lefort 1	Hypernasality	-	-	-
Harjunpaa et al. 2019	Retro - Cohort	93	M: 51 F: 42	17.9	4	2.8 – 11.3	Lefort 1	-	Competent in 88.2%	Competent in 75.3%	Got better in 12.9%
Chanchareonsook et al. 2007	Clinical trial	10	M: 6 F: 4	19.8	4.28	0.78 – 7.78	Lefort 1	Hypernasality	Competent in 100%	Competent in 70%	Worsened in 30%
Haapanen et al. 1997	Ob	15	NR	23.3	4.4	0-8	Lefort 1	Hypernasality Nasal Emisions	Competent in 93%	Competent in 67%	Worsened in 27%

Retro: retrospective, ob: observational, M: male, F: female, MA: maxillary advancement, VPI: velopharyngeal insuffieciency.

Table 2. Characteristics of the included studies with maxillary advancement more than 6 mm.

Study	Type	No. Of patients	Gender	Mean age (year)	Average MA (mm)	MA amplitude (mm)	Intervention	Reported changes in speech	VPI pre-op	VPI post-op	Reported changes in VPI
Schultz et al. 2019	Prosp - cohort	18	M: 9 F: 9	19.2	9.8	2.8 - 12	Lefort 1	Normal	Competent	Competent	Indifferent
Impieri et al. 2018	Retro - Ob	47	M: 19 F: 28	20.7	6.7	0 – 13.7	Lefort 1	Hypernasality	Competent	Competent	-
McComb et al. 2011	Retro - Ob	65	M: 35 F: 30	18	7.7	2 - 16	Lefort 1	Hypernasality	Competent in 95%	Competent in 60%	Worsened in 35%
Chua et al. 2010	Clinical trial	11	M: 6 F: 5	18.5	7	4 - 10	Lefort 1	Normal	Competent in 90%	Competent in 100%	Got better in 10%
Nohara et al. 2006	Ob	2	NR	18	8.5	5 - 12	Lefort 1	Hypernasality	Competent in 100%	Competent in 100%	Indifferent

Prosp: prospective, retro: retrospective, ob: observational, M: male, F: female, MA: maxillary advancement, VPI: velopharyngeal insuffieciency.

3.3. Comparison of the two groups

Comparing these two groups, it is evident that the extent of maxillary advancement plays a significant role in the outcomes related to VPI. In the group with MA more than 6mm, a consistent trend of worsening VPI postoperatively was observed across multiple studies and the majority of studies report a worsening of VPI and speech. On the other hand, in the group with MA less than 6mm, results seem to favor worsening to a lesser extent than advancements more than 6mm. This suggests that lesser advancement may be more effective in correcting structural defects associated with cleft palate, consequently improving velopharyngeal function. A meta- regression was conducted, showing a coefficient of -20.35 with a standard error of 8.63, a T-value of 2.36 and a P-value of 0.046. The meta-regression revealed that the extent of maxillary advancement (below or above 6 mm) might have a considerable impact on velopharyngeal insufficiency outcomes in cleft palate patients. Additionally, the negative coefficient in the meta-regression indicates a potential differential effect based on grouping, although the precise nature of this effect is unclear.

3.4. Heterogeneity of results

Analysis was divided into two subgroups based on the extent of maxillary advancement: less than 6 mm and more than 6 mm. A Funnel plot (Figure 3) was used to assess publication bias, with a 95% confidence interval. High heterogeneity indicates significant variability in the study outcomes. Both subgroups showed high levels of heterogeneity (I-squared values of 98.9% for < 6 mm and 99.4% for > 6 mm), indicating considerable variability in study outcomes within each subgroup. The overall I-squared value was 99.2%, indicating high heterogeneity across all studies. Therefore, a random-effects approach was used due to this heterogeneity. Risk of bias for the included studies is summarized in Tables 3 and 4, differentiated by study type.

4. Discussion

Our systematic review and meta-analysis, encompassing 11 studies with 524 patients, revealed a significant impact of maxillary advancement (MA) on velopharyngeal insufficiency (VPI) in cleft palate patients. The primary finding indicates that MA, particularly when more than 6 mm, can negatively affect VPI. This effect appears to be more pronounced in cases where MA exceeds 6 mm, suggesting a potential threshold effect.

Our findings align with several previous studies in the field. For instance, Sales et al. (19) reported that the impact of maxillary advancement surgery on speech and VP function is debated. In their study, four studies argued that no adverse effects occur, and six others suggested that speech can worsen post-surgery. Variability in findings may stem from differences in cleft types, surgical techniques and patient history. Schutz et al. (17) suggest

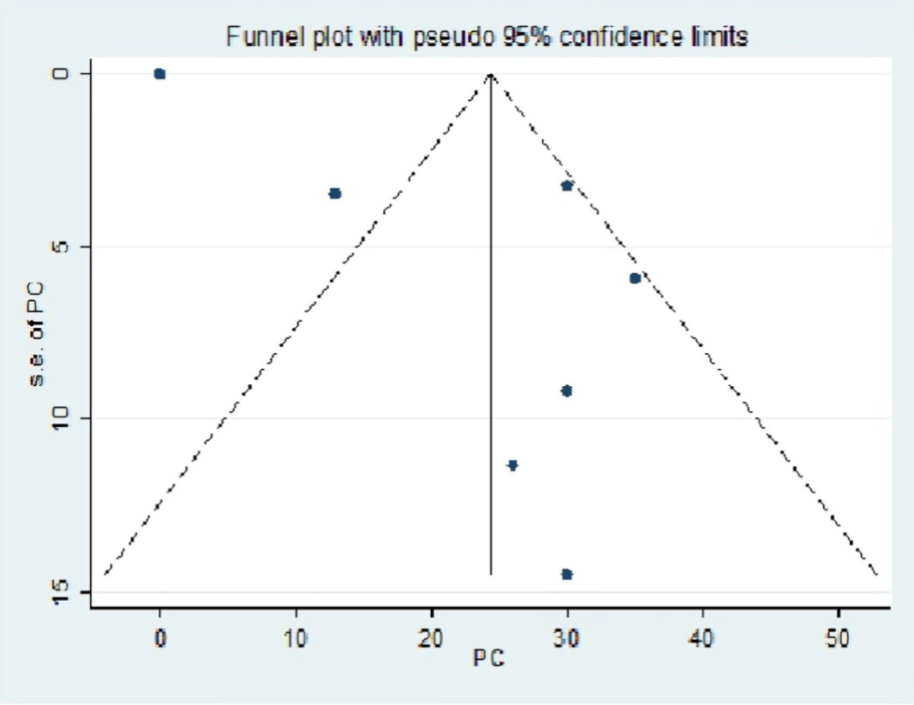

Figure 3. Funnel plot of the included studies for exploration of the potential publication bias.

Table 3. Quality assessment of the included observational studies.

Study	1	2	3	4	5	6	7	8	9	10	11	12	Over-all
Kinter et al. 2022	+	+	+	+	?	+	+	+	+	+	?	?	Low
Chuan-fong Yao et al. 2020	+	+	+	+	?	+	+	?	+	+	?	?	Fair
Saleh et al. 2020	+	+	+	+	?	+	+	?	+	+	?	?	Fair
Harjunpaa et al. 2019	+	+	+	+	?	+	+	?	+	+	?	?	Fair
Schultz et al. 2019	+	+	+	+	?	+	+	?	+	+	?	?	Fair
Impieri et al. 2018	+	+	+	+	?	+	+	?	+	+	?	?	Fair
McComb et al. 2011	+	+	+	+	?	+	+	?	+	+	?	?	Fair
Nobara et al. 2006	+	-	+	+	?	+	+	?	+	+	?	?	High
Haapanen et al. 1997	+	-	+	+	?	+	+	?	+	+	?	?	High

1: Objective clear, 2: Eligibility specified, 3: Participants representative, 4: All eligible enrolled, 5: Sample size, 6: Intervention, 7: Outcome measures, 8: Blinded assessors, 9: Follow up rate, 10: Statistical analysis, 11: Multiple outcome measures, 12: Individual level data to determine group effect.

Table 4. Quality assessment of the included clinical trial studies.

Study	1	2	3	4	5	6	7	Over-all
Chanchareonsook et al. 2007	Moderate	Low	Moderate	High	Low	Low	Low	High
Chua et al. 2010	Moderate	Low	Low	High	Low	Low	Low	Moderate

1: Random sequence generation, 2: Allocation concealment, 3: Blinding of participant and personnel, 4: Blinding of outcome assessment, 5: Incomplete outcome data, 6: Selective reporting, 7: other sources of bias.

that patients with CLP may be predisposed to VP deterioration post-maxillary advancement due to factors such as scarring from previous surgeries or increased pharyngeal depth. However, the study's data did not show statistically significant correlations between the amount of maxillary advancement or preoperative conditions (such as hypernasality, VPI, oronasal fistula, etc.) and postoperative VPI. In another study, Pereira et al. (20) described the risk factors. All four participants who developed velopharyngeal insufficiency (VPI) post-surgery were asymptomatic preoperatively. This suggests that even those judged to have normal velopharyngeal function can face setbacks post- surgery, aligning with Witzel et al.'s (21) notion that borderline preoperative status is a risk factor for surgery-related VPI.

However, not all studies in the literature concur with our findings. Harjunpää et al. (10) reported in their study that The amount of maxillary advancement (averaging 4.0 mm, with variations from 2.8 to 11.3 mm) did not significantly influence velopharyngeal function. While 10 patients showed improved speech post-surgery, 18 had no change and 12 exhibited worsened intelligibility. The group with worsened speech had a higher average advancement (12.2 mm). The strength of this study lies in the large cohort (nearly 100 patients) operated on by experienced surgeons. However, subjectivity in cephalometric measurements and speech assessment poses limitations. While the study used reliable perceptual evaluations and nasometer tests, combining visual assessment methods like videofluoroscopy could enhance the accuracy of speech evaluations.

The outcome variability across studies underscores the complex relationship between MA and VPI. Factors such as pre-existing velopharyngeal function, cleft type, and individual anatomical variations likely play crucial roles in determining post-operative outcomes.

The findings of this study carry several important clinical implications for the management of patients undergoing maxillary advancement (MA):

1. Patient selection: A careful pre-operative evaluation of velopharyngeal function is crucial, particularly for patients requiring an MA of more than 6 mm. This assessment can help identify individuals at greater risk for post-operative VPI and guide surgical decisions.
2. Surgical planning: Surgeons should take into account the potential impact of MA on VPI when determining the extent of advancement. When feasible, advancements lesser than 6 mm may be preferable from a VPI perspective, as they are associated with a lower risk of worsening velopharyngeal function.
3. Informed consent: It is essential that patients are thoroughly counseled about the potential risk of worsening VPI following MA, especially for larger advancements. Providing clear information allows patients to make informed decisions regarding their treatment options.
4. Post-operative monitoring: Close follow-up and ongoing speech evaluation are vital to promptly identify and address any deterioration in velopharyngeal function after surgery. Early intervention can be critical in managing any complications that may arise, ensuring that patients receive the appropriate care in a timely manner.

By considering these clinical implications, healthcare professionals can better navigate the complexities of surgical intervention in cleft patients, ultimately improving surgical outcomes and patient quality of life (22).

The mechanisms by which MA affects velopharyngeal function are complex and not fully understood. One proposed explanation is that anterior movement of the maxilla increases the depth of the velopharyngeal port, potentially compromising closure. Additionally, changes in the tension and orientation of the levator veli palatini muscle following MA may alter its function.

Compensatory mechanisms, such as increased posterior pharyngeal wall movement or adaptive changes in soft palate function, may explain why some patients maintain adequate velopharyngeal function despite significant MA. Further research into these physiological adaptations could inform surgical techniques and post- operative management strategies.

This study is bolstered by several key strengths. First, it employs a comprehensive search strategy that covers multiple databases, ensuring a thorough and robust collection of relevant literature. Second, the rigorous methodology adheres to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which promote transparency and reproducibility in systematic reviews. Lastly, the inclusion of a diverse range of studies enhances the generalizability of the findings, allowing for broader application of the results across different populations and clinical settings. Together, these strengths contribute to the reliability and validity of the study's conclusions.

Despite the strengths of this study, there are several notable limitations that should be considered. First, there is a high degree of heterogeneity among the included studies, which could potentially affect the reliability of the pooled estimates and make it challenging to draw definitive conclusions. Second, the potential for publication bias has been indicated by the funnel plot analysis, suggesting that existing studies may not fully represent the entire body of research on this topic. Lastly, the variability in methods for assessing velopharyngeal insufficiency (VPI) across different studies complicates direct comparisons and may influence the interpretation of the findings. Together, these limitations highlight the need for caution in generalizing the results and underscore the importance of standardizing assessment techniques in future research.

For future research, several important directions should be considered to enhance our understanding of the

relationship between maxillary advancement (MA) and velopharyngeal insufficiency (VPI). First, there is a pressing need for large-scale, prospective studies that utilize standardized VPI assessment protocols. These studies are essential to definitively establish the relationship between the magnitude of MA and VPI outcomes, providing clearer insights into how surgical decisions impact patient function.

Additionally, investigating patient-specific factors, such as pre-operative velopharyngeal closure patterns, cleft type, and age, could be invaluable in predicting the risk of post-MA VPI. This knowledge would allow for more individualized treatment planning, tailored to the unique characteristics of each patient.

Furthermore, there is an opportunity for research into modified MA techniques or complementary surgical procedures that may help mitigate the risk of post-operative VPI. Innovations in surgical approaches could significantly improve outcomes and enhance patient quality of life.

Finally, studies that examine the long-term trajectory of velopharyngeal function following MA are crucial. Understanding how velopharyngeal function evolves over time can provide insights into adaptive processes and help guide effective post-operative management strategies. By pursuing these avenues of research, we can significantly improve the surgical care and outcomes for patients undergoing maxillary advancement.

5. Limitations

We did an extensive literature search across multiple databases, however our inclusion criteria limited us to research published in English. This may have led to the exclusion of important studies published in other languages. In studies with missing data, we employed statistical imputation techniques to fill in the gaps. It is vital to understand that imputation might introduce a degree of uncertainty, which can affect the accuracy of outcomes.

6. Conclusion

This systematic review and meta-analysis provide compelling evidence for a relationship between maxillary advancement and velopharyngeal insufficiency in cleft palate patients, with bigger advancements (> 6 mm) potentially carrying a higher risk of VPI deterioration. These findings underscore the importance of careful pre-operative assessment, individualized surgical planning.

Acknowledgements

None.

Ethics

The study protocol obtained ethical approval from the Shahid Beheshti University of Medical Sciences (IR.SBMU.DRC.REC.1402.021).

Author contributions

Mohammad Javad Dahaghin: Investigation, Data curation, Writing – Original draft

Hoori MirMohammad Sadeghi: Conceptualization, Methodology, Supervision

Mostafa Owneq: Formal analysis, Visualization, Writing – Review & editing

Farshid Bastami: Methodology, Validation, Supervision, Project administration

Reza Tabrizi: Conceptualization, Methodology, Supervision, Project administration, Funding acquisition

Conflict of interest

The authors declare no conflict of interest.

Funding

None.

References

1. Kosowski TR, Weathers WM, Wolfswinkel EM, Ridgway EB, editors. Cleft palate. Seminars in plastic surgery; 2012: Thieme Medical Publishers.

2. Sweeney WM, Lanier ST, Purnell CA, Gosain AK. Genetics of cleft palate and velopharyngeal insufficiency. Journal of pediatric genetics. 2015;4(01):009-16.

3. Nam SM. Surgical treatment of velopharyngeal insufficiency. Archives of Craniofacial Surgery. 2018;19(3):163.

4. Young A, Spinner A. Velopharyngeal Insufficiency. 2020.

5. Poole MD, Robinson PP, Nunn ME. Maxillary advancement in cleft palate patients: A modification of the Le Fort I osteotomy and preliminary results. Journal of maxillofacial surgery. 1986;14:123-7.

6. Ganoo T, Sjöström M. Outcomes of maxillary orthognathic surgery in patients with cleft lip and palate: a literature review. Journal of Maxillofacial and Oral Surgery. 2019;18:500-8.

7. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. J Clin Epidemiol. 2021;134:178-89.

8. Haapanen M-L, Kalland M, Heliövaara A, Hukki J, Ranta R. Velopharyngeal function in cleft patients undergoing maxillary advancement. Folia phoniatrica et logopaedica. 1997;49(1):42-7.

9. Yao C-F, Bhandari K, Lee M-C, Chen PK-T, Lu T-C. Videofluoroscopic findings as predictors of velopharyngeal insufficiency after orthognathic surgery in

patients with cleft lip and palate. Annals of plastic surgery. 2021;86(2S):S46-S51.
10. Harjunpää R, Alaluusua S, Leikola J, Heliövaara A. Le Fort I osteotomy in cleft patients: Maxillary advancement and velopharyngeal function. Journal of Cranio-Maxillofacial Surgery. 2019;47(12):1868-74.
11. Kinter S, Susarla S, Delaney JC, Chapman K, Kapadia H, Weiss N. Does Distraction Lower Risk of VPI Compared to Conventional Maxillary Advancement? A Retrospective Cohort Study of Adolescents with Cleft Palate. The Cleft Palate Craniofacial Journal. 2022:10556656221138895.
12. Saleh E, Saleh J, Beauchemin G, El-Jalbout R, Borsuk DE. Velopharyngeal space assessment in patients undergoing le fort 1 maxillary advancement. Plastic and Reconstructive Surgery Global Open. 2020;8(11).
13. Tekin U, Akdeniz BS, Keller EE. Pharyngeal airway space changes and stability following an extended LeFort-I osteotomy advancement in cleft lip and palate and non-cleft lip and palate patients: A long term comparison study. Journal of Stomatology, Oral and Maxillofacial Surgery. 2022;123(2):121-7.
14. Chua H, Whitehill T, Samman N, Cheung L. Maxillary distraction versus orthognathic surgery in cleft lip and palate patients: effects on speech and velopharyngeal function. International journal of oral and maxillofacial surgery. 2010;39(7):633-40.
15. Nohara K, Tachimura T, Wada T. Prediction of deterioration of velopharyngeal function associated with maxillary advancement using electromyography of levator veli palatini muscle. The Cleft palate-craniofacial journal. 2006;43(2):174-8.
16. McComb RW, Marrinan EM, Nuss RC, LaBrie RA, Mulliken JB, Padwa BL. Predictors of velopharyngeal insufficiency after Le Fort I maxillary advancement in patients with cleft palate. Journal of oral and maxillofacial surgery. 2011;69(8):2226-32.
17. Schultz KP, Braun TL, Hernandez C, Wilson KD, Moore EE, Wirthlin JO, et al. Speech outcomes after LeFort I advancement among cleft lip and palate patients. Annals of Plastic Surgery. 2019;82(2):174-9.
18. Impieri D, Tønseth KA, Hide Ø, Brinck EL, Høgevold HE, Filip C. Impact of orthognathic surgery on velopharyngeal function by evaluating speech and cephalometric radiographs. J Plast Reconstr Aesthet Surg. 2018;71(12):1786-95.
19. Sales PHH, Costa FWG, Cetira Filho EL, Silva PGB, Albuquerque AFM, Leão JC. Effect of maxillary advancement on speech and velopharyngeal function of patients with cleft palate: Systematic Review and Meta-Analysis. Int J Oral Maxillofac Surg. 2021;50(1):64-74.
20. Pereira VJ, Sell D, Tuomainen J. Effect of maxillary osteotomy on speech in cleft lip and palate: perceptual outcomes of velopharyngeal function. Int J Lang Commun Disord. 2013;48(6):640-50.
21. MA W. commentary. cleft palate journal. 1989;26(3):199-200.
22. Opriş D, Băciuţ G, Bran S, Dinu C, Armencea G, Opriş H, et al. The quality of life after cleft lip and palate surgery. Med Pharm Rep. 2022;95(4):461-6.