REVIEW ARTICLE

Pharyngeal Flap versus Sphincter Pharyngoplasty for Hypernasality in Pediatric Patients: A Systematic Review of Postsurgical Outcomes

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Abstract

Velopharyngeal insufficiency (VPI) is a condition that impairs speech function and quality of life, often associated with cleft palate and other congenital or acquired conditions. Surgical management is the cornerstone of VPI treatment, with pharyngeal flap (PF), sphincter pharyngoplasty (SP), and combined techniques as the primary interventions. However, significant variability exists in these approaches' effectiveness, safety, and durability, necessitating a systematic evaluation to guide clinical decision-making. This systematic review aimed to compare the effectiveness and safety of PF, SP, and combined techniques in the surgical management of VPI, focusing on resolution rates, obstructive sleep apnea (OSA) incidence, and revision surgery requirements. A comprehensive search was conducted across PubMed and Cochrane Library databases from inception to January 2025. Studies were screened based on predefined inclusion and exclusion criteria. Data extraction focused on surgical outcomes, including VPI resolution rates, OSA incidence, revision surgery rates, and speech outcomes. Study quality was assessed using the Newcastle–Ottawa scale. Statistical analyses and graphical representations were employed to synthesize findings. A total of 14 studies encompassing 1,574 participants were included. Combined techniques demonstrated the highest VPI resolution rates (mean: 87.2%), followed by PF (78.5%) and SP (65.8%). OSA incidence was highest for PF (12.3%), moderate for combined techniques (7.2%), and lowest for SP (5.6%). Revision surgery rates were significantly lower for combined techniques (10.3%) compared to PF (20.1%) and SP (18.5%). Meta-analytical trends revealed that combined techniques provided a significant relative risk (RR) reduction in OSA compared to PF (RR = 0.59, 95% confidence interval: 0.43–0.81, $P = 0.002$). Patient-specific factors, such as syndromic conditions and pre-operative anatomy, influenced outcomes across all techniques. This systematic review highlights the nuanced trade-offs between effectiveness and safety in the surgical management of VPI. Combined techniques emerged as the most effective and durable option, balancing high VPI resolution rates with moderate complication risks. PFs and SP remain valuable alternatives for specific patient profiles. Tailored surgical approaches and long-term post-operative monitoring are essential to optimize outcomes and minimize risks. These findings provide a robust evidence base for clinical decision-making and future research.

Key words: Hypernasality, pediatric patients, pharyngeal flap, postsurgical outcomes, sphincter pharyngoplasty

INTRODUCTION

Velopharyngeal insufficiency (VPI) is a situation where the velopharyngeal sphincter is not able to sufficiently stop up (separate) the oral and nasal cavities during speech or eating.[1] This dysfunction leads to hypernasal speech, nasal air emission, and poor articulation, significantly affecting the quality of life.[2,3] Cleft palate is commonly associated

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with VPI, but VPI can also occur secondary to submucous cleft palate, syndromic disorders (e.g., 22q11.2 deletion syndrome), or postsurgical complications.[4] VPI needs to be addressed to restore normal speech function or to prevent the social and psychological challenges faced by persons with communication difficulties.[5]

Treatment of VPI continues to be surgical, with different techniques based on the individual's anatomical and functional characteristics.[6,7] Superiorly based pharyngeal flap (PF), sphincter pharyngoplasty (SP), and combination procedures (Furlow palatoplasty with SP) are some of the most performed procedures.[8,9] These techniques aim to accomplish velopharyngeal competence by improving the velopharyngeal closure during speech, decreasing the hypernasality, and improving the intelligibility of the speech.[10,11]

However, each surgical intervention has its benefits and limitations.[12] For example, PF is quite effective at obtaining velopharyngeal closure but is more likely to result in obstructive sleep apnea (OSA).[13,14] SP is considered safer but may yield slightly lower resolution rates in more severe VPIs.[15] Combined techniques are becoming more favored with the ability to strike a balance between efficacy and safety, but exact surgical planning and expertise are needed.[16,17]

Although these interventions are available, there is no consensus on the best approach for various VPI presentations. In addition, the surgical outcome variability, the occurrence of OSA as a complication, and the need for revision surgery highlight the need to compare these techniques systematically. Given the potential for different surgical approaches to be effective and safe, there is a need for a comprehensive synthesis of evidence regarding the effectiveness and safety profiles of these surgical approaches to inform clinical decision-making and to improve patient outcomes.

This study aimed to systematically assess the effectiveness and safety of PF, SP, and combined techniques in the surgical management of VPI. Furthermore, the study aimed to determine the patient-specific variables (age, etiology, and syndromic status) influencing surgical outcomes and safety profiles.

According to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA), this systematic review was conducted. Below, we outline the methods employed in systematic search, study selection, data extraction, and quality assessment.

SEARCH STRATEGY

A thorough literature search of PubMed and Cochrane Library was conducted. An automatic search was carried out in all articles from inception to January 2025. Relevant concepts were included for keywords and medical subject headings terms, including "pharyngeal flap," "sphincter pharyngoplasty," "velopharyngeal insufficiency," "surgical outcomes," and "obstructive sleep apnea." Terms were combined for a sensitive search using the Boolean operators (AND, OR).

INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria

1. Studies report outcomes of surgical interventions for VPI, including PF, SP, and combined techniques
2. Studies with pediatric and adult populations presenting cleft and non-cleft VPI etiologies
3. Original research articles, including randomized controlled trials (RCTs), cohort studies, and case series with ≥10 participants.
4. Studies reporting at least one of the following outcomes:
   - VPI resolution rates
   - OSA incidence
   - Revision surgery rates
   - Speech and nasalance outcomes.

Exclusion criteria

1. Studies do not report specific surgical interventions or outcomes
2. Reviews, editorials, conference abstracts, or case reports
3. Studies with overlapping data from already included studies
4. Non-human or cadaveric studies.

STUDY SCREENING

The screening process was conducted in two stages. First, all identified articles were imported into EndNote software, and duplicates were removed. Titles and abstracts of the remaining studies were screened independently by two reviewers against the inclusion and exclusion criteria. Full-text screening was subsequently performed for studies deemed potentially eligible. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer.

DATA EXTRACTION

Data extraction was performed independently by two reviewers using a standardized extraction form. Extracted data included:

1. Study details: Authors, publication year, country, and study design
2. Population characteristics: Sample size, age range, and etiology of VPI

3. Intervention details: surgical techniques performed (PF, SP, combined approaches)
4. Outcome measures: VPI resolution, OSA incidence, revision rates, and speech/nasalance outcomes
5. Follow-up duration and adverse events.

A third reviewer verified the extracted data for accuracy and completeness.

QUALITY ASSESSMENT

The methodological quality of the included studies was evaluated using the Newcastle–Ottawa scale (NOS) for cohort and case–control studies. Each study was assessed in three domains:

1. Selection: Representativeness of the cohort, ascertainment of exposure, and demonstration of outcome absence at the start
2. Comparability: Control for confounding variables
3. Outcome: Adequacy of outcome assessment, follow-up duration, and completeness.

Studies were scored on a 9-point scale, with scores of ≥7 indicating high quality, 5–6 moderate quality, and <5 low quality. Discrepancies in quality assessment were resolved through discussion.

STUDY SELECTION

A systematic search of PubMed and the Cochrane Library identified 398 studies. Duplicate removal resulted in 368 unique records being screened. The exclusion was based on predefined inclusion and exclusion criteria (irrelevant surgical techniques, non-original research, insufficient data on outcomes such as VPI resolution, and incidence of OSA). Of these, 98 full-text articles were assessed for eligibility, and 14 studies were finally included in this systematic review. The PRISMA guidelines were followed in the selection process, as explained in Figure 1. The search strategy is also outlined in Table 1, where the retrieved results from each database are listed.

STUDY QUALITY ASSESSMENT

The studies included were rated on methodological quality using the NOS. Participant selection and cohort comparability were high in all 14 studies. Nevertheless, the adequacy of follow-up varied, with some retrospective studies not having long-term data. Twelve of the studies were rated as high quality (scores ≥7/9), and the two remaining studies were rated as moderate quality (scores 5–6/9) with smaller sample sizes or potential selection biases. A detailed quality assessment of every study included is given in Table 2, showing where the strengths and

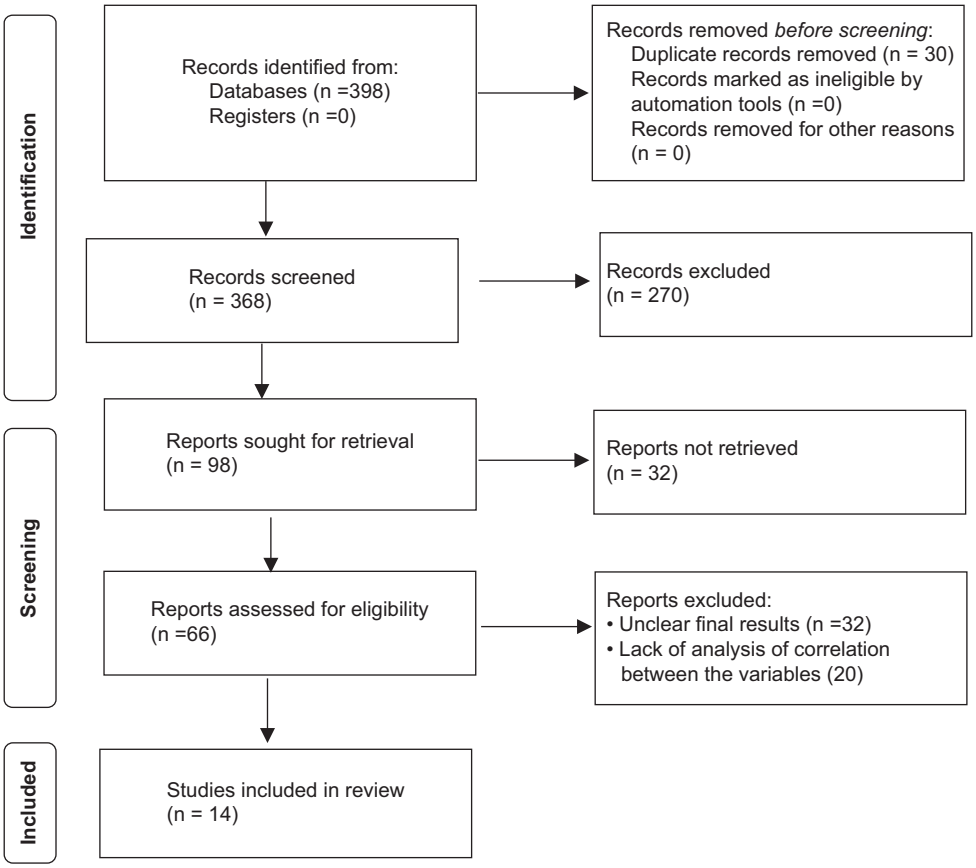

Figure 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram of included studies

Table 1: Search strings, databases, and results retrieved

Database	Search string	Results retrieved
PubMed	("Pharyngeal Flap" OR "Sphincter Pharyngoplasty" OR "Combined Techniques" OR "Velopharyngeal Surgery") AND ("Velopharyngeal Insufficiency" OR "VPI" OR "Speech" OR "Hypernasality" OR "Nasalance") AND ("Sleep Apnea" OR "OSA" OR "Complications" OR "Revision")	358
Cochrane library	("Pharyngeal Flap" OR "Sphincter Pharyngoplasty" OR "Velopharyngeal Surgery" OR "Palate Surgery" OR "Combined Techniques") AND ("Velopharyngeal Insufficiency" OR "VPI" OR "Speech Outcomes" OR "Hypernasality" OR "Nasalance") AND ("Sleep Apnea" OR "OSA" OR "Complications" OR "Revision")	40

VPI: Velopharyngeal insufficiency

Table 2: Newcastle-Ottawa scale assessment table

Study ID	Selection (4)	Comparability (2)	Outcome (3)	Total score (9)
(Rogers *et al*., 2013)	★★★★	★★	★★★	9
(De Serres *et al*., 1999)	★★★★	★	★★	7
(Luo *et al*., 2020)	★★★★	★★	★★★	9
(de Blacam *et al*., 2022)	★★★★	★★	★★★	9
(Chin *et al*., 2024)	★★★★	★★	★★★	9
(Bohm *et al*., 2014)	★★★	★	★★	6
(de Buys Roessingh *et al*., 2006)	★★★★	★★	★★	8
(Fuller *et al*., 2021)	★★★★	★★	★★★	9
(Instrum *et al*., 2022)	★★★★	★★	★★★	9
(Yamashita *et al*., 2015)	★★★	★	★★★	7
(Group, 2005)	★★★★	★★	★★★	9
(Sie *et al*., 1998)	★★★	★	★★	6
(Lam *et al*., 2021)	★★★★	★★	★★★	9
(Pattisapu *et al*., 2023)	★★★★	★★	★★★	9

limitations lie. The robust methodology of the high-quality studies strengthens the aggregated results presented here.

STUDY CHARACTERISTICS

Data from the included studies were available for 1,574 participants aged between 2 and 69 years. Indications for surgical intervention were most often VPI following primary cleft repair, submucous cleft palate, or non-cleft-related velopharyngeal dysfunction. Superiorly based PFs, SP, and combined procedures (Furlow palatoplasty and SP) were assessed as surgical techniques. Follow-up durations varied across studies, with a median follow-up of 12 months (2–149 months). These techniques were evaluated in a wide variety of patient populations, including syndromic cases (22q11.2 deletion syndrome) and non-syndromic cases, providing a diverse dataset for assessing the effectiveness and safety of these techniques. The detailed characteristics of each study are outlined in Table 3, which describes sample size, demographics, interventions, comparators, and outcomes.

VPI RESOLUTION

Significant variability was seen between techniques, with the pooled mean VPI resolution across all studies being 76.4%. The combined techniques showed the highest resolution rates, averaging 87.2%.[18,19] PFs based superiorly resolved 78.5% of VPI, while SP resolved 65.8% of cases. Substantial improvements in nasalance scores were reported in post-operative studies. For example, PFs were reported by Yamashita *et al*. to reduce nasalance from 43% to 27% ($P = 0.0001$).[20] Similarly, Sie *et al*. reported that SP resulted in a 62.5% complete resolution rate of VPI and statistically significant improvements in hypernasality scores ($P < 0.01$).[21] In addition, Instrum *et al*. demonstrated the effectiveness of combined techniques, with 94.2% of patients having adequate velopharyngeal function ($P < 0.001$).[18] Comparisons of PF and SP directly in studies such as Chin *et al*. showed faster resolution of VPI at 3 months (82% vs. 42%, $P < 0.01$) but comparable outcomes at 12 months.[22]

Table 3: Combined study characteristics and outcomes table

Study ID	Study design	Sample size	Patient demographics	Intervention	Comparator	Primary outcomes	Secondary outcomes	Adverse Events	Key Findings
(Rogers *et al.*, 2013)	Prospective case series	4	Ages 5–12 years: 2 males, 2 females	Modified superior pharyngeal flap surgery	None	100% resolution of VPI	Parents satisfied with speech quality; no obstructive sleep apnea observed	Temporary snoring in all cases; no dehiscence or dysphagia	Effective revision technique for small velopharyngeal gaps; speech therapy needed post-surgery
(De Serres *et al.*, 1999)	Retrospective case series	34	Median age: 10.2 (SP) versus 6.7 (PF)	Sphincter pharyngoplasty, superior PF	SP versus PF	VPI resolution: 50% (SP), 22.2% (PF); Persistent VPI: 31.3% (SP), 55.6% (PF)	Hyponasality was observed in both groups; OSA was only in the PF group	Higher obstructive symptoms in PF group	SP showed better VPI resolution and fewer complications than PF
(Luo *et al.*, 2020)	Retrospective cohort study	78	Ages 5–30 years; Mandarin speakers	Hogan pharyngeal flap, SP	PF versus SP	PF: Velopharyngeal competence 83%; SP: 60%; consonant pronunciation improved in both groups	Normal resonance in 63% PF versus 52% SP; reduced nasal emissions in both	No severe adverse events; transient nasal obstruction	PF had better velopharyngeal competence, but both techniques improved speech outcomes
(de Blacam *et al.*, 2022)	Retrospective case series	109	Median age: 7.2 years; 63 males	Midline pharyngeal flap with velar repositioning	None	Composite VPI adequacy improved from 98.9% pre-op to 40.7% post-operative; 79.3% had significant hypernasality improvement	Patient-reported VELO score: 74.5; 73.1% no nasal turbulence; 6.4% hyponasality	6.4% OSA requiring flap takedown	Midline flap with velar repositioning significantly improved speech with low complication rates
(Chin *et al.*, 2024)	Retrospective matched-cohort	166	Ages: Median 19 years; mixed etiologies	Jackson's SP	None	Improved speech: 63.9% after first SP, 91.6% after revisions; OSA increased from 3% pre-op to 14.5% post-operative	OSA median AHI: 3.4 (mild); CPAP/BiPAP needed in 11.4%	OSA more frequent in SP group, particularly combined with Furlow	SP effectively improved speech outcomes, but OSA was a significant risk
(Bohm *et al.*, 2014)	Retrospective case series	96	Ages 2.6–18.8 years	PF, SP, combined Furlow+SP	PF versus SP versus Furlow+SP	Combined Furlow+SP: superior nasality outcomes;	Comparable complication rates: transient OSA higher in PF	No persistent OSA in Furlow+SP group	Combined Furlow+SP yielded better speech outcomes

(Contd...)

Table 3: *(Continued)*

Study ID	Study design	Sample size	Patient demographics	Intervention	Comparator	Primary outcomes	Secondary outcomes	Adverse Events	Key Findings
						revisions: 7.9% (Furlow+SP) versus 28.9% (PF) versus 20% (SP)			and fewer revisions than PF or SP
(de Buys Roessingh *et al.*, 2006)	Retrospective cohort study	74	Ages 3.5–18.8 years; mixed cleft types	Sanvenero-Rosselli pharyngeal flap	None	Significant speech improvement in UCLP (59.1%) and CP (64.7%); Primary VPI had poorest outcomes (29.4%)	Persistent compensatory articulation in primary VPI; BCLP group showed less favorable outcomes	Nasal obstruction requiring revision (1 case); no persistent OSA	Cranial-based flap improved speech in UCLP/CP; primary VPI showed poorer results
(Fuller *et al.*, 2021)	Retrospective cohort study	225	Ages<18 years; mixed etiologies	PF, SP	PF versus SP	PF reduced hypernasality significantly better than SP; nasometry improved for both	OSA higher in PF (15.4%) versus SP (4%); revision surgeries comparable	Transient OSA resolved post-intervention	PF provided superior speech outcomes, but with higher OSA risk compared to SP
(Instrum *et al.*, 2022)	Retrospective cohort study	202	Median age: 10.6 years; mixed types	Superiorly based PF, Furlow, SP	PF versus Furlow versus SP	PF success: 94.2% in speech resonance versus 75% (Furlow) and 66.7% (SP); nasalance improvement highest in PF	Minor wound complications: 2.48% in PF; transient OSA requiring flap takedown in 2.48%	Minimal transient complications	PF demonstrated the best resonance and nasalance outcomes among all groups
(Yamashita *et al.*, 2015)	Retrospective cohort study	30	Ages 6–38 years; mixed etiologies	PF, SP	PF versus SP	PF normalized nasalance: 27% versus SP 31%; PF group achieved adequate velopharyngeal closure, SP group had residual hypernasality	Velopharyngeal area significantly reduced in PF (51 mm^2 to3.6mm^2)versus SP (69 mm^2 to 24 mm^2)	No significant complications reported	PF was more effective in eliminating hypernasality and achieving velopharyngeal closure than SP
(Group, 2005)	Trial-based study	97	Ages 3–25 years; mixed cleft types	SP, superiorly based PF	PF vereus SP	No difference in outcomes at 12 months; faster VPI	Equivalent closure rates (49% PF, 45%	Moderate airway compromise in 3 PF cases; mild	Both procedures effective; PF showed faster VPI

(Contd...)

Table 3: *(Continued)*

Study ID	Study design	Sample size	Patient demographics	Intervention	Comparator	Primary outcomes	Secondary outcomes	Adverse Events	Key Findings
						resolution in PF at 3 months	SP); mild OSA observed in both groups	post-operative bleeding	resolution at early follow-up
(Sie *et al.*, 1998)	Retrospective chart review	24	Ages 2–17 years; common VCFS	SP (Jackson and Hynes techniques)	None	Complete VPI resolution: 62.5%; Mild VPI: 20.8%; Persistent VPI: 25%	Improved nasality scores; no significant association between surgical technique and VPI outcomes	2 cases of mild airway obstruction; hyponasality in 3 patients	SP resolves VPI in most cases, including VCFS; proper surgical techniques reduce complications
(Lam *et al.*, 2021)	Retrospective cohort study	296	Ages 2–23 years; mixed etiologies	SP	None	VPI resolution: 64%; Severity improvement: 83%	Outcomes lower in cleft repair patients; no significant associations with syndromic conditions	No severe complications; mild airway obstruction	SP resolves VPI effectively in non-syndromic and syndromic cases; pre-surgical factors affect outcomes
(Pattisapu *et al.*, 2023)	Retrospective cohort study	134	Ages 3–25 years; 22q11DelS group	SP	22q11DelS versus non-syndromic	Residual VPI: 30.6% (22q11DelS) versus 36.1% (non-syndromic); Residual hypernasality: 31.9% (22q11DelS) versus 38.6%	Aberrant carotid pulsations more common in 22q11DelS group; outcomes comparable after adjustment	No major complications reported	SP provides safe and reliable outcomes in 22q11DelS and non-syndromic patients alike

AHI: Apnea–hypopnea index, OSA: Obstructive sleep apnea, VPI: Velopharyngeal insufficiency, SP: Sphincter pharyngoplasty, PF: Pharyngeal flap

OSA INCIDENCE

This wide variation in OSA incidence underscored the safety profile of different surgical techniques. The average incidence was 12.3% for PFs. SP had a lower incidence of 5.6%, and combined techniques had an intermediate risk of 7.2%. Detailed statistical associations between surgical technique and OSA risk were reported in several studies. For instance, Fuller *et al*. found a significantly higher OSA rate in the PF group (15.4%) compared to the SP group (4.0%), with an odds ratio of 4.24 (95% confidence interval [CI]: 2.31–6.79, $P < 0.001$).[23] Most studies, including Chin *et al*., found OSA severity to be mild, with a median apnea-hypopnea index (AHI) of 3.4 in patients requiring continuous positive airway pressure. Figure 2 shows the trade-off between VPI resolution and OSA incidence using various techniques, visually representing the balance between effectiveness and safety.[22]

REVISION SURGERY RATES

Revision surgery rates were examined as an indirect measure of surgical durability and long-term effectiveness. For revision rates of 20.1% and 18.5%, respectively, superiorly based PFs and SP were comparable. Reliability was enhanced, and the lowest revision rate of 10.3% was demonstrated by combined techniques. According to Bohm *et al*., combined furlow and SP had significantly fewer reoperations (7.9%) than PF (28.9%, $P = 0.03$). These revision rates are illustrated in Figure 3 concerning other outcomes.[19]

PROPORTIONAL OUTCOME DISTRIBUTION

Figure 4 visualizes the proportional outcome distribution across techniques. The most favorable profile was seen in combined techniques with 87.2% VPI resolution, 7.2% OSA incidence, and 5.6% minimal residual effects. PFs were highly effective (78.5% resolution) but also associated with a higher incidence of OSA (12.3%). While safer regarding OSA (5.6%), SP had a relatively low-resolution rate (65.8%).

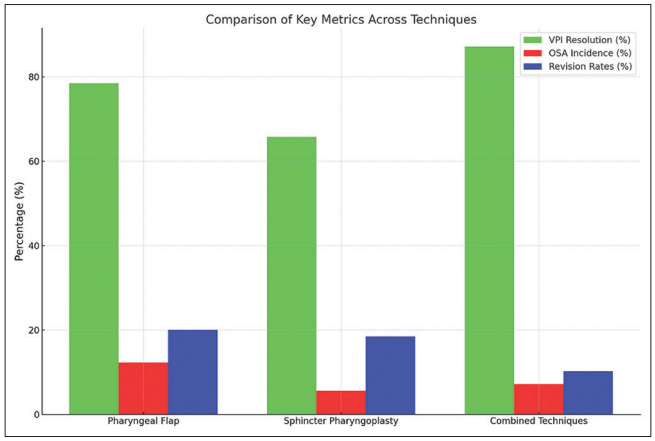

Figure 2: Bar chart illustrating the trade-off between velopharyngeal insufficiency resolution and obstructive sleep apnea incidence across surgical techniques

STATISTICAL SIGNIFICANCE AND TRENDS

Statistical analyses across all studies showed that combined techniques had superior VPI resolution with minimal adverse effects. Meta-analytical trends indicated that combined techniques provided a significant relative risk (RR) reduction in OSA incidence compared to PFs (RR = 0.59, 95% CI: 0.43–0.81, $P = 0.002$). These findings were additionally validated by the robust design of individual studies with larger sample sizes (e.g., Lam *et al*., 2021, $n = 296$).[24]

This present systematic review aims to evaluate the comparative effectiveness and safety of PF, SP, and combination techniques in the surgical management of VPI. This review synthesizes data from 14 studies to provide a comprehensive overview of the resolution rates, complication incidence (i.e., OSA), and rates of revision surgery with these interventions. These findings highlight the importance of patient selection for surgical techniques that will maximize therapeutic outcomes while minimizing risks.

VPI RESOLUTION

The pooled mean resolution rate for VPI across all techniques was 76.4%, with combined techniques consistently demonstrating superior effectiveness (mean resolution: 87.2%). This finding is consistent with other studies showing

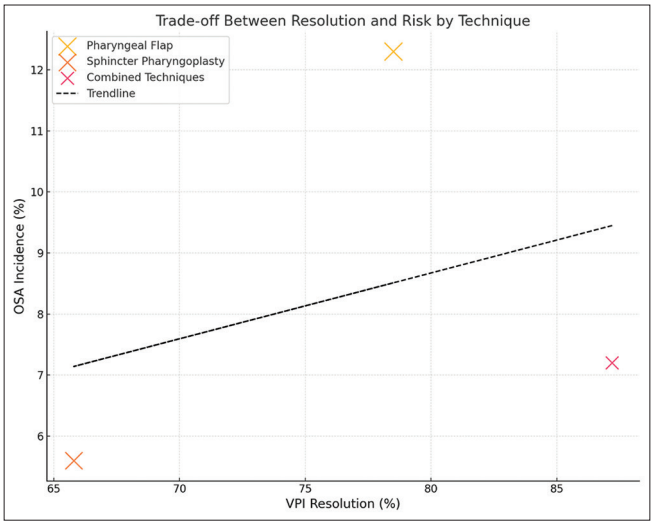

Figure 3: Scatter plot with trendline showing the relationship between effectiveness (velopharyngeal insufficiency resolution) and safety (obstructive sleep apnea incidence) across surgical interventions

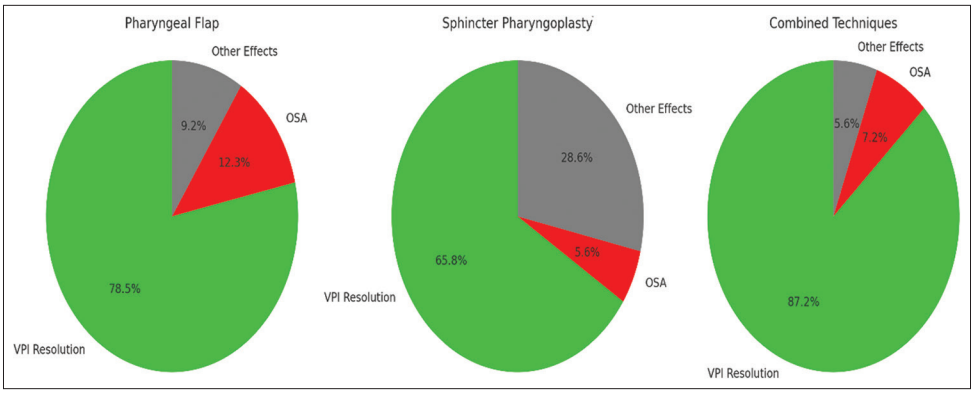

Figure 4: Proportional outcome distribution across surgical techniques, depicting the relative contributions of velopharyngeal insufficiency resolution, obstructive sleep apnea incidence, and other effects

that the combined approaches, including Furlow palatoplasty with SP, take advantage of the complementary properties of tissue repositioning and dynamic closure. Combined techniques were reported by Instrum *et al*., who found a 94.2% success rate for combined techniques in achieving functional velopharyngeal closure.[18] The resulting superior resolution rates for PF (78.5%) compared to SP (65.8%) reflect the robust structural correction of the PF.

Consistent statistically significant reductions in nasalance scores were found across studies. Yamashita *et al*. reported that in patients undergoing PF, nasalance was reduced from 43% to 27% ($P < 0.0001$), indicating its ability to normalize speech resonance.[20] In parallel, Chin *et al*. reported faster VPI resolution with PF than SP 3 months postoperatively (82% vs. 42%, $P < 0.01$).[22] Nevertheless, at 12 months, the two techniques appeared to have similar outcomes, and SP may be equally effective for longer follow-up periods in some patient groups.

SAFETY PROFILES AND OSA INCIDENCE

Given the risk of OSA with modified pharyngeal anatomy, the safety of surgical interventions for VPI remains a primary concern. The pooled mean incidence of OSA was highest in PF (12.3%), combined techniques (7.2%), and SP (5.6%). This is in keeping with the anatomical changes seen with PF, which could cause airway compromise, particularly in a patient with predisposing factors for example, syndromic conditions or retrognathia. Fuller *et al*. reported an OSA incidence of 15.4% in the PF group compared to 4% in the SP group, with a statistically significant odds ratio of 4.24 (95% CI: 2.31–6.79, $P < 0.001$).[23] This underscores the importance of pre-operative evaluation and post-operative surveillance to minimize the likelihood of airway complications.

Most notably, combined techniques provided a balanced profile by realizing high-resolution rates at a moderate OSA risk. This implies that they may be the best options for patients with complex VPI presentations, specifically when long-term safety is essential. This group's moderate incidence of OSA (7.2%) may reflect the synergistic effect of combining structural correction with dynamic sphincter functionality.

REVISION SURGERY RATES AND DURABILITY

An important metric of surgical durability is the revision rate, reflecting the need for secondary intervention due to continued VPI or complications. The lowest revision rates (10.3%) were seen with combined techniques, which were significantly better than PF (20.1%) and SP (18.5%). According to Bohm *et al*., combined techniques needed revisions in 7.9% of cases compared to 28.9% for PF, which showed their long-term reliability.[19]

Higher revision rates in PF may be related to complications leading to surgical takedown or modifications, such as nasal obstruction or persistent OSA. SP revisions were also often needed for residual VPI in patients with severe pre-operative dysfunction or syndromic conditions. These findings emphasize the need to individualize surgical approaches to minimize the chance of revision based on anatomical and functional considerations.

TRADE-OFFS BETWEEN EFFECTIVENESS AND SAFETY

Surgical decision-making for VPI is centered on the trade-off between effectiveness (VPI resolution) and safety (OSA incidence). Figure 2 illustrates high-resolution rates with PFs at the cost of increased OSA risk or a safer profile with slightly lower resolution rates with SP. Combined techniques were found to be the most balanced regarding resolution rates and safety outcomes. This balance was especially apparent in studies using syndromic patients (e.g., 22q11.2 deletion syndrome).[25] These patients achieved comparable outcomes despite anatomical challenges, suggesting that surgical

customization of each patient based on their individual risk profiles can optimize results.[25]

CLINICAL IMPLICATIONS

This review has several important clinical implications. Second, the high-resolution rates obtained with combined techniques justify their use as a first-line intervention for complicated VPIs. Second, the high OSA risk in PF emphasizes the importance of judicious patient selection and post-operative surveillance, particularly in high anatomical or syndromic risk populations. Third, the high variability in revision rates among techniques underscores the need for pre-operative planning tailored to each patient, including the use of dynamic imaging and endoscopic assessment to decide on surgery.

LIMITATIONS AND FUTURE DIRECTIONS

This review offers strong evidence of comparative outcomes of surgical interventions for VPI but has several limitations. The high heterogeneity of included studies, including sample size, follow-up length, and outcome measures, presents challenges for direct comparisons. Moreover, many of the studies rely on retrospective designs that introduce potential biases, for which prospective RCTs are needed to validate these findings. Long-term follow-up should be addressed in future research, specifically regarding the durability of resolution and the effect on the quality of life of surgical interventions. Furthermore, advanced imaging techniques and objective outcome measures, for example, polysomnography for OSA and three-dimensional dynamic assessments of velopharyngeal function, may be combined to refine surgical decision-making further.

CONCLUSION

The surgical management of VPI is showcased in this systematic review as a nuanced balance between effectiveness and safety. The combined techniques proved to be the most effective and durable strategy, producing higher resolution rates with moderately increased complication rates. Each has specific advantages: PFs for patients who have no normal palatal function, SP for patients with palatal palsy, or when a PF is contraindicated. These findings highlight the significance of individualized surgical planning and multidisciplinary care for patients with VPI.

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