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"Should Pediatric Septal Surgery and Septorhinoplasty Be Performed for Nasal Obstruction?"—A Systematic Review of the Literature

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Abstract

Corrective septal surgery for children with nasal obstruction has historically been avoided due to concern about the impact on the growing nose, with disruption of midfacial growth. However, there is a paucity of data evaluating complication and revision rates post-nasal septal surgery in the pediatric population. In addition, there is evidence to suggest that failure to treat nasal obstruction in children may itself result in facial deformity and/or developmental delay. The aim of this systematic review is to evaluate the efficacy and safety of septal surgery in pediatric patients with nasal obstruction. A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. MEDLINE, Embase, and the Cochrane Library were searched. Original studies in pediatric patients (<18 years of age) with nasal obstruction were eligible for inclusion. Patients with cleft lip or palate as their primary diagnosis were excluded. Our primary outcomes were patient-reported outcome measures (PROMs), postsurgical complications, and revision rates. Secondary outcomes included surgical technique, anatomical considerations, and anthropometric measurements. Eighteen studies were included (1,080 patients). Patients underwent septoplasty, septorhinoplasty, rhinoplasty, or a combination of procedures for nasal obstruction. Obstruction was commonly reported secondary to trauma, nasal septal deviation, or congenital deformity. The mean age of the patients was 13.04 years with an average follow-up of 41.8 months. In all, 5.6% patients required revision surgery and there was an overall complication rate of 7.8%. Septal surgery for nasal obstruction in children has low revision and complication rates. However, a pediatric-specific outcome measure is yet to be determined. Larger prospective studies with long-term follow-up periods are needed to determine the optimal timing of nasal surgery for nasal obstruction in the pediatric population.

Keywords
- pediatrics
- nasal obstruction
- septal surgery
- septoplasty
- septorhinoplasty
- rhinoplasty
- systematic review

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Correction of nasal septal deformity before or during adolescence has been a well-established concern in the literature due to the possible adverse impact on midfacial growth and long-term functional and/or aesthetic outcomes.[1]

Nasal maturation occurs from designated growth centers and with specific periods of accelerated growth, the two most significant of which are in the first 2 years of life and during puberty.[2] Animal studies dating back to the mid-20th century have supported this notion[3] as well as early descriptions of pediatric septal surgery, in which aggressive techniques such as submucosal resection were employed.[4,5] Gilbert and Segal referred to the quadrangular cartilage as a "keystone in [the] development of the cartilaginous vault," warning against its resection prior to completion of nasal growth.[6,7] This in turn led to apprehension toward performing nasal surgery before completion of midface development.[6]

However, knowledge of the nasal and midfacial growth has advanced over recent decades through animal-based experiments and longitudinal observational studies in children.[3] Later animal studies adopting more conservative techniques describe minimal or no compromise to midfacial growth.[8,9] In addition, recent works conclude that nasal surgery can be safely performed in the pediatric patient using conservative techniques that avoid disruption of key structures such as the sphenodorsal and sphenospinal zones of thick cartilage, growth centers driving craniofacial development[10,11] (►**Fig. 1**). Yet controversy remains, with uncertainty surrounding if and when nasal septal surgery should be performed in children/adolescents with nasal obstruction (NO).[12]

Nasal septum deformity in pediatric patients ranges from 0.93 to 55% depending on the age and type of deformity reported.[13] Most pediatric septal surgeries to date have been performed following destructive pathologies such as nasal abscess, hematoma, or malignancy, as well as in the cleft patient cohort whereby nasal surgery is often completed alongside cleft lip or palate repairs.[11,14] However, evidence suggests that failure to treat NO itself may result in facial deformity due to obligate mouth breathing and sleep disorders.[3–6]

We aimed to conduct a systematic review to investigate the safety and efficacy of septal surgery in pediatric patients with NO.

Methods

A systematic review was undertaken in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines[15] (►**Fig. 2**). All cohort studies and case series were included. Case reports were excluded. The following databases were searched, and abstracts exported to Covidence (Covidence.org; Melbourne) within which initial screening was performed. PUBMED (OVID Medline), EMBASE, the Cochrane Library, and PROSPERO (University of York) were searched from conception to May 1, 2022 to identify any ongoing research studies. A population, intervention, comparison, and outcome (PICO) framework was used to critically assess papers.

To be eligible for inclusion, studies had to include pediatric patients (<18 years old) who had undergone septal surgery (septoplasty, septorhinoplasty [SRP], and rhinoplasty) for treatment of NO. For studies that had a combination of pediatric and adult articles, data were extracted where possible to allow for the inclusion of pediatric patients only. Where pediatric data could not be isolated, the authors were

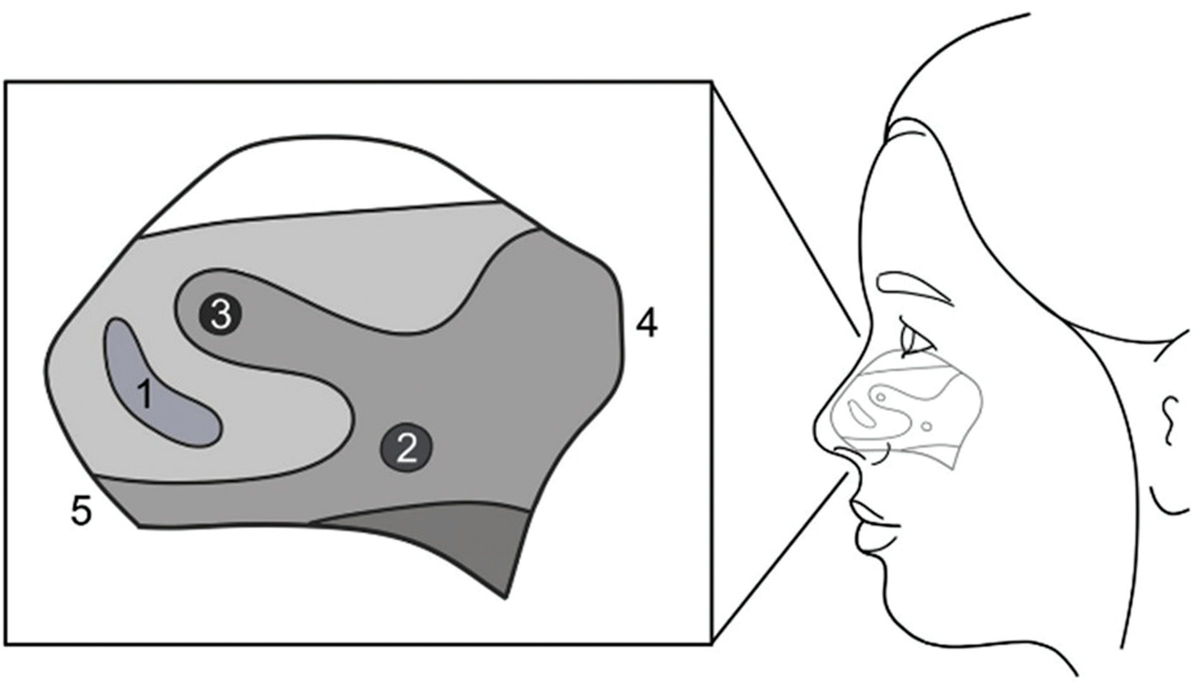

Fig. 1 Schematic representation of the infant septum demonstrating the sphenospinal (2) and sphenodorsal (3) zones. The ventrocentral area of thinner cartilage (1), sphenoid (4), and anterior nasal spine (5).

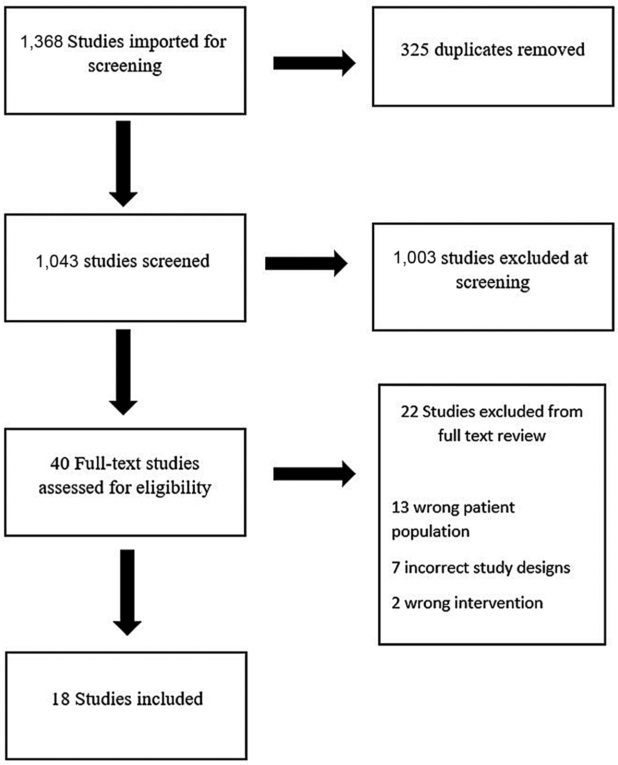

Fig. 2 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flowchart.

contacted. Studies where the primary pathology was cleft lip and palate were excluded. Primary outcomes included patient-reported outcome measures (PROMs), complication, and revision rates. Secondary outcomes included demographic characteristics and surgical approach/procedure(s).

Two primary researchers (T.H. and I.W.) screened the titles and abstracts independently using Covidence.[16] Disagreements were resolved by discussion and a third author (A.N.) was consulted where necessary. All articles that met the inclusion criteria were obtained in full text for further assessment. Data extraction was performed by both primary reviewers independently using a comprehensive, standardized, and piloted extraction template. The authors were emailed when either data were missing or if pediatric patients could not be isolated from the adult patients. Quality assessment was conducted on all included articles following the initial screening and extraction process using the Critical Appraisal Skills Program (CASP) scoring system.[17] Bias assessment was completed using the Risk of Bias in Nonrandomized Studies of interventions (ROBINS-I) tool developed by Cochrane.[18,19]

Data were handled and analyzed using Microsoft Excel version 14.2 for Windows.

Results

In total, 1,043 studies were screened and 18 studies met the inclusion criteria (►**Fig. 2**). The years of publication ranged from 1993 to 2021. Data were extracted from these articles from both lead authors. From these studies, 1,112 patients were included, 1,080 underwent surgical intervention with 32 patients having nonoperative management, thus acting as controls. There were 7 prospective cohort studies, 1 validation study, and 10 retrospective reviews. No randomized control trials (RCTs) were identified to date. The patients were followed up for an average of 41.8 days (standard deviation [SD] $\pm$ 6 months; range: 44 days–10 years; ►**Table 1**).

Assessment of Bias

Studies were assessed using the ROBINS-I. Overall no RCTs were identified and therefore most of the studies demonstrated a moderate level of bias (see ►**Fig. 3**). Kawai et al's[32] validation studies and Din et al's[31] high-quality prospective cohort study had lower degrees of bias. Béjar et al,[42] Dispenza et al,[48] and Bae et al[21] were classified as "critical" risk due to issues arising from missing data, cofounding analysis, and selection of participants, respectively (►**Fig. 3**).

Patient Demographics

The mean age of the patients was 13.04 years with a male predominance (M:F of 1.8:1). NO was commonly due to trauma (300/940; 31.9%), nasal septal deviation (NSD; 247/478; 51.7%), or congenital deformity/anomaly. In all, 117 patients had a history of allergic rhinitis (►**Table 2**).

Surgical Indications

Indications for operative intervention were identified in 13 of the 18 studies, with the most common indications being traumatic deformity and/or obstruction (247, 26.3%), congenital deformity (88, 9.36%), and NSD (70, 7.45%). One hundred and sixty-three patients (17.3%) had NO with an unspecified, nontraumatic cause. Fifty-two patients (5.5%) had a history of previous nasal surgery and 65 patients (6.9%) from two studies primarily underwent surgery for cosmesis (►**Table 2**).

In total, 343 (63.4%) and 198 (36.6%) patients had surgery via an open and a closed approach, respectively. Six hundred and forty patients (62.6%) had septoplasty and 268 patients had SRP (26.2%). Sixteen patients had a "Metzenbaum" septoplasty (2.5% of those receiving septoplasty), a surgery that involves removing deviated portions of the anterior quadrangular cartilage. In one study, 111 patients (17.3%) had "quick" septoplasty via a single tunnel on the left side of the septal cartilage, preserving the mucoperichondrium on one side.[20] Thirty-eight patients (5.9%) had septoplasty in conjunction with bilateral inferior turbinate reduction surgery. In only one study, 64 patients (6.3%) had rhinoplasty, of which 57 (89.1%) had adjuvant septal reconstruction. In two studies, the surgical procedure was not specified (►**Tables 1** and **2**).

Outcomes and Complications

Eleven studies reported complications and seven studies reported revision rates. Of the studies reporting complications, epistaxis was the most reported complication (27/650; 4.2%). Other complications included recurrence of NSD (18/650), postoperative pain (2/650), infection (1/650), abscess (1/650), synechiae (1/650), and vestibular granuloma

Table 1 All studies included in this systematic review with patient demographics and type of study (mean age of 13.04 years, with a total of 1,080 patients undergoing septal surgery)

Study	Type of study	Country	Patients (n)	Mean follow-up (d)	Age (mean), y	Surgical procedure (*n*)	Outcome measure reported	Complication rates (*n*; %)	Revision rates (*n*; %)
Walker et al[26]	Prospective cohort study	Canada	32	NS	11.7	External SRP excision and reimplantation (32)	Anthropometry Nasal airflow studies (head-out volume displacement body plethysmography)	Epistaxis (1; 3.13%)	1; 3.31%
Béjar et al[42]	Retrospective review	Canada	28	1,241	10.4	External SRP excision and reimplantation (28)	Anthropometry	NS	NS
El-Hakim et al[43]	Prospective paired study	Canada	26	1,131	9.5	External SRP excision and reimplantation (26)	Anthropometry	Vestibular granuloma (1; 3.85%) Epistaxis (1; 3.85%)	NS
Dispenza et al[48]	Retrospective review	India	30	3,558	9.0	Septoplasty (16); SRP (14)	Photographic evaluation of recurrence of septal deviation and effect(s) of surgery on nasal pyramid Subjective reports of patient satisfaction	Recurrence of NSD (6; 20%)	NS
Tasca and Compadretti[47]	Retrospective review	Italy	44	4,453	9.5	Endonasal septoplasty via hemitransfixion incision (44) *Quadrangular cartilage left in situ* (22)*; excision and reimplantation* (22)	Anthropometry	Recurrence of NSD (4; 9.09%)	4; 9.09%
Bae et al[21]	Retrospective review	Korea	64	1,788	16	Rhinoplasty (64) ± septal reconstruction (57)	Patient satisfaction (VAS score) Anthropometry	Postoperative NO (8; 12.5%) Recurrence of NSD (6; 9.38%) Postoperative pain (2; 3.13%;) Aesthetic dissatisfaction (14; 21.9%)	6; 9.38%
Costa et al[44]	Retrospective review	Brazil	16	1,569	12.9	Metzenbaum septoplasty (16)	Anthropometry Cephalometry	Postoperative NO (3; 18.8%) Aesthetic dissatisfaction (4; 25%)	NS

Table 1 (*Continued*)

Study	Type of study	Country	Patients (n)	Mean follow-up (d)	Age (mean), y	Surgical procedure (*n*)	Outcome measure reported	Complication rates (*n*; %)	Revision rates (*n*; %)
Yilmaz et al[27]	Retrospective review	Turkey	35	335	13.4	Septoplasty (35)	Anterior rhinometry NOSE/VAS scores	NS	NS
Adil et al[41]	Retrospective review	USA	54	646	12.2	Septoplasty (43)	Complication and revision rates	0	0
Anderson et al	Retrospective cohort study	Netherlands	29	NS	13	NS	GCBI and PedsQL scores	NS	NS
Lee et al[34]	Retrospective review	United States	28	44	NS	NS	SN-5 survey VAS scores	NS	NS
Manteghi et al[33]	Prospective cohort study	United States	136	110	15.7	Septoplasty (52); SRP (84)	NOSE scores	NS	NS
Kalantar-Hormozi et al	Prospective cohort study	Iran	40	898	16.1	SRP (40)	Complication and revision rates Subjective reports of patient satisfaction	Infection (1; 2.5%) Epistaxis (1; 2.5%)	0
Fuller et al[28]	Prospective cohort study	United States	39	259	15.9	Septoplasty (39)	NOSE and Eq. 5D scores PNIF measurements	Nasal septal abscess (1; 2.56%)	2
Din et al[31]	Prospective cohort study	United States	136	1,314	15.7	Septoplasty (52); SRP (84)	NOSE scores	NS	NS
Bishop et al[40]	Retrospective review	United States	194	629	14.6	Septoplasty (194)	Complication and revision rates	Septal perforation (1; 0.52%) Epistaxis (24; 12.4%)	13; 6.7%
Kawai et al[32]	Validation study	United States	38	NS	16.7	Septoplasty plus bilateral inferior turbinate reduction (38)	NOSE scores	NS	NS
Ori et al[29]	Prospective cohort study	Italy	111	NS	9.4	"Quick" single-tunnel septoplasty (111)	AAR and NOSE scores Cephalometric measures Complication rates	Recurrence of NSD (2; 1.8%) Synechiae (1; 0.9%)	NS

Abbreviations: A, position of deepest concavity on the anterior profile of the maxilla; al, alar rim; AAR, anterior active rhinomanometry; B, position of deepest cavity on the anterior profile of the mandibular symphysis; c', apex of the columella; GCBI, Glasgow children's benefit inventory; gn, gnathion (menton; most inferior soft-tissue contour point of the chin); Me, menton; n/N, nasion (midpoint of the nasofrontal suture line); NO, nasal obstruction; NS, not stated; NSD, nasal septal deviation; Percent NH, (N-palatal plane)/(N-Me); PedsQL, Pediatric Quality of Life Inventory; Pg, pogonion; prn, pronasale (most protruding point of the nasal tip); S, sella; sn, subnasale (midpoint of the base of the columella); sn', columella edge; SN-5, Sinus and Nasal Quality of Life Survey; SRP, septorhinoplasty; sto, stomion; VAS, visual analog scale; zy, zygion.

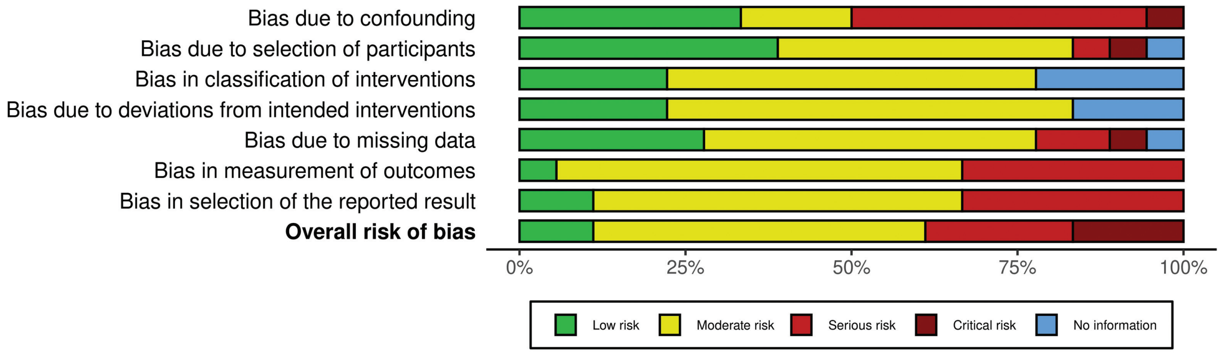

Fig. 3 Risk of Bias in Non-randomized Studies of interventions ((ROBINS-I) tool demonstrating the risk of bias for included studies.

Table 2 Patient-reported outcome measures from six selected studies, indicating the different outcome measures used and the NOSE score comparisons

Study	Outcome	Results: preintervention (NOSE)	Postintervention (NOSE)	*p*-value (from individual study)
Manteghi et al[33]	NOSE	Preintervention = 75 (median)	Postintervention = 20 (median)	< 0.001
Sinan Yilmaz et al[27]	NOSE score at 3 and 12 mo and VAS	Preintervention = 71.0 ± 18.9	3 mo postintervention = 22.6 ± 19.7 12 mo postintervention = 23.7 ± 22.8	< 0.001 0.03
Kawai et al[32]	NOSE	Preintervention = 96.7 ± 6.2	Postintervention = 8.8 ± 7.8	< 0.001
Fuller et al[28]	NOSE, EQ-5D, and VAS	Preintervention = 59.0 ± 9.1	Postintervention = 21.2	< 0.001
Din et al[31]	NOSE	Preintervention = 75 (median)	Postintervention = 20	< 0.001
Ori et al[29]	NOSE	Preintervention = 75.80 ± 11.09	Postintervention = 14.57 ± 12.12	< 0.001

Abbreviations: NOSE, Nasal Obstruction Symptom Evaluation; VAS, visual analog scale.

(1/650) (overall complication rate of 7.8% [50/650]). Fourteen patients from a single study reported aesthetic dissatisfaction.[21] Of the study reporting revision surgery rates, 26/467 patients (5.6%) underwent revision procedures. Objective measures included nasal airflow measurements (1/18), peak nasal inspiratory flow (PNIF) rates (1/18), and anterior rhinometry (1/18; ►**Table 3**). Eleven studies reported patient satisfaction, the Nasal Obstruction Symptom Evaluation (NOSE) scale being the most used PROM (6/11 studies). Other PROMs used included the visual analog scale (VAS), EQ-5D, Glasgow children's benefit inventory (GCBI), Pediatric Quality of Life Inventory (PedsQL), and Sinus and Nasal Quality of Life Survey (SN-5; ►**Table 4**). Seven studies used anthropometry and/or cephalometry to assess the effect(s) of nasal septal surgery on craniofacial growth (►**Table 5**).

Discussion

The growing cartilaginous septum of the nose is a significant organizer of the developing facial skeleton[22] and thus surgical treatment for NO secondary to NSD in pediatric patients has historically been delayed until adulthood. However, there have been reports that children with uncorrected NSD and obligate mouth breathing can develop facial and dental anomalies in comparison to controls,[23] with such deformities becoming heightened with growth, increasing the incidence of sinonasal disease in later life.[24]

While absolute indications for pediatric nasal surgery include malignancy, septal hematoma, and abscess formation, to date NO has been seen as a relative indication for surgical management, despite its impact upon sleep, development, and schooling, all of which affect later physical, social, and mental health.[25] The paucity of well-designed clinical studies looking at the long-term outcomes of pediatric septal surgery may deter clinicians from undertaking the procedure in children, even in cases of severe NO.

Improvement in Patient Symptoms

Objective assessments of pediatric septoplasty have rarely been reported in the literature. In this review, nasal airflow studies (head-out volume displacement body plethysmograph), PNIF rates, and active anterior rhinometry[26–28] were used to demonstrate clinically significant

Table 3 Anthropometry measures from relevant studies included in this review reporting the pre- and postoperative means and standard deviations (SDs) with *p*-values

Study	Anthropometric measures	Preoperative mean (SD)	Postoperative mean (SD)	*p*-value (from individual study)	Summary of data reported (if NS)	Key findings
Walker et al[26]	Nasal dorsum length (n-prn); nasal height (n-sn); nasal tip protrusion (sn-prn); face height (n-gn); inclination of columella/nasal dorsum	NS	NS	NS	Compared with age-specific normative data mean ± 1 SD	No delay in growth for all anthropometric measurements
Béjar et al[42]	Nasal dorsum length (n-prn); nasal height (n-sn); nasal tip protrusion (sn-prn); nasal width (al-al); columella width (sn'-sn'); columella length (sn-c'); upper face height (n-sto); face height (n-gn); face width (zy-zy); inclination of the upper face/nasal dorsum/columella	NS	NS	NS	No. of patients with measurement in ranges based on of published North American age-related norms for white males and females reported: <2 SDs below mean, mean ± 2 SD, mean ± 1 SD, 2 SDs above the mean	External septoplasty may affect the nasal dorsum length but it does not appear to influence other aspects of the nasal or facial growth
El-Hakim et al[43]	Nasal dorsum length (n-prn)	NS	NS	0.007*	Measurements either as subnormal, borderline small, optimal, borderline large, or supernormal when compared with North American White population —where optimal is within ± 1 SD from the mean	No clinically significant growth delay after external approach septoplasty using quadrangular cartilage as free graft
	Nasal height (n-sn)	NS	NS	0.85		
	Columella length (sn-c')	NS	NS	0.48		
	Nasal tip protrusion (sn-prn)	NS	NS	0.04*		
	Face height (n-gn)	NS	NS	0.80		
	Face width (zy-zy)	NS	NS	0.53		
	Upper face height (n-sto)	NS	NS	0.83		
	Nasal index	NS	NS	0.20		
	Facial index	NS	NS	0.84		
	Columellar length–nasal tip protrusion index	NS	NS	0.74		
	Nose–upper face height index	NS	NS	0.23		Septoplasty performed via the endonasal approach does not interfere with the normal growing nasal process apart from the nasolabial angle measure that seems to become reduced

(*Continued*)

Table 3 (*Continued*)

Study	Anthropometric measures	Preoperative mean (SD)	Postoperative mean (SD)		*p*-value (from individual study)	Summary of data reported (if NS)	Key findings
Tasca and Compadretti[47]	Nasal height (n-sn)	NS	M	55 (3.0)	0.79		
			F	50.7 (2.8)	0.83		
	Nose width al-al		M	35.2 (2.1)	0.43		
			F	31.5 (2.0)	0.80		
	Nasal dorsum length (n-prn)		M	49.8 (3.4)	0.81		
			F	44.5 (3.3)	0.79		
	Nasal tip protrusion (sn-prn)		M	19.8 (1.9)	0.50		
			F	19.8 (1.7)	0.82		
	Columella length (sn-c')		M	11.6 (1.5)	0.18		
			F	11.4 (1.7)	0.54		
	Inclination of columella		M	79.8 (8.7)	0.54		
			F	78.4 (7.5)	0.91		
	Nasal tip angle		M	72.8 (7.3)	0.45		
			F	68.8 (7.4)	0.41		
	Nasolabial angle		Male				
			Extracorporeal septoplasty	91.8 (11.7)	0.002*		
			Conservative septoplasty	99.8 (10.5)	0.17		
			Female				
			Extracorporeal septoplasty	89.1 (10.1)	0.002*		
			Conservative septoplasty	105.6 (9.0)	0.63		
	(al-al)/(n-sn)		M	0.623 (0.046)	0.26		
			F	0.619 (0.065)	0.73		
	(n-prn)/(n-sn)		M	0.619 (0.065)	0.25		
			F	0.862 (0.053)	0.22		
	(sn-c)/(sn-prn)		M	0.567 (0.074)	0.99		
			F	0.589 (0.068)	0.64		
Bae et al[21]	Nasal tip projection (mm)	24.6 ± 3.1	28.3 ± 2.8		<0.001*		Significant improvement in nasal tip projection, nasal length, dorsum height, and radix index
	Nasal length (mm)	60.4 ± 5.0	62.9 ± 4.4		<0.001*		
	Dorsal height (mm)	19.3 ± 4.0	21.2 ± 3.3		<0.001*		
	Radix height (mm)	7.3 ± 3.3	9.2 ± 3.2		<0.001*		
	Nasofrontal angle (degree)	137.9 ± 7.3	137.4 ± 6.4		0.535		
	Nasolabial angle (degree)	93.9 ± 9.3	93.0 ± 7.6		0.324		

Table 3 (*Continued*)

Study	Anthropometric measures	Preoperative mean (SD)	Postoperative mean (SD)	*p*-value (from individual study)	Summary of data reported (if NS)	Key findings
Costa et al[44]	**Linear parameters**: nasal height/width, dorsum length, tip protrusion, columella length/width **Proportional measures**: nasal length/width, columella length/tip projection, nasal length/upper portion of face, facial index **Cephalometric measures**: palatal length, linear facial protrusion, angular facial protrusion, length of the middle third	NS	NS	NS	Measurements were compared with normal values published in the literature. Normal rate within ± 2 SD, optimal ± 1 SD. Values above the mean ± 2 SD normal and below 2 SD below normal	In the majority of cases, the anthropometric measures were within normal. 1/16 (6%) measurements at lower limit of normal
Ori et al[29]	N-palatal plane	50.22 ± 3.69	53.37 ± 2.77	<0.01*		The quick septoplasty technique is practical and conservative—cephalometric measurements demonstrated a correction of some cephalometric alterations in the patient's mouth breathing due to nasal obstruction
	N-Me	111 ± 3.71	116.95 ± 5.58	<0.01*		
	Percent NH	0.43 ± 0.03	0.46 ± 0.03	<0.01*		
	Gonial angle values (°)	134.02 ± 3.52	130.10 ± 4.10	<0.01*		
	S-N-A values (°)	76.62 ± 3.27	81.36 ± 2.29	<0.01*		
	S-N-B values (°)	74.71 ± 3.27	78.09 ± 1.88	<0.01*		
	S-N-Pg values (°)	75.66 ± 3.24	78.20 ± 2.04	<0.01*		
	Palatal height values (mm)	16.47 ± 2.34	17.31 ± 3.12	0.05		
	Overjet values (mm)	5.49 ± 1.59	4.79 ± 1.26	<0.01*		
	Overbite values (mm)	3.41 ± 0.89	3.56 ± 1.04	<0.01*		
	Maxillary intermolar width (T6–T6; mm)	48.14 ± 2.00	51.20 ± 3.00	<0.01*		

Abbreviations: A, position of deepest concavity on the anterior profile of the maxilla; al, alar rim; B, position of deepest cavity on the anterior profile of the mandibular symphysis; c', apex of the columella; gn, gnathion (menton; the most inferior soft-tissue contour point of the chin); Me, menton; n/N, nasion (midpoint of the nasofrontal suture line); NS, not stated; percent NH, (N-palatal plane)/(N-Me); Pg, pogonion; prn, pronasale (most protruding point of the nasal tip); S, sella; sn, subnasale (midpoint of the base of the columella); sn', columella edge; sto, stomion; zy, zygion. *results where statistical significance was demonstrated.

Table 4 Comparison between the different objective outcome measure used. Three different measures were used in the different included studies with one study demonstrating significance (Ori et al[29])

Study	No. of patients	Surgical procedure	Airflow measure	Preintervention	Postintervention	*p*-value
Walker et al[26]	32	External septoplasty	Nasal airflow studies: head-out volume displacement body plethysmograph	Total airway resistance 6.1 cm^3/s	2.5 cm^3/s	Not available
Fuller et al[28]	39	Functional septoplasty	Peak nasal inspiratory flow	66.2 ± 13.8 L/min	90.8 L/min	0.006
Ori et al[29]	111	"Quick" septoplasty ($n = 111$)	Active anterior rhinometry	0.92 ± 0.47 $Pa/cm^3/s$	0.24 ± 0.09 $Pa/cm^3/s$	< 0.001

improvements in NO postseptoplasty[29] (►**Table 3**). One study (not meeting inclusion criteria) assessed the minimal cross-sectional areas (MCSA) and total volume (TV) in patients who had either anterior or posterior obstruction or both (following previous septoplasty) against a control group, demonstrating significant postoperative benefit ($p < 0.005$, paired *t*-test and analysis of variance [ANOVA]).[30]

Assessment of surgical outcomes has shifted from objective mortality and morbidity measures toward the use of PROMs. Tools such as the NOSE scale have been validated for use in pediatric patients[31,32] and Manteghi et al demonstrate improvements in disease-specific quality of life in pediatric patients who had either septoplasty or functional SRP.[33] Moreover, Lee et al show improvement in the SN-5 and VAS scores for pediatric patients after septoplasty[34] (►**Table 4**).

These findings strengthen support for the rationale that nasal surgery in pediatric populations is effective and safe. However, there lacks a uniform measure to assess outcomes in children with NO undergoing septal surgery; this review highlights the need for a pediatric-specific PROM that is both valid and reliable.

Safety

Eleven of 18 studies in this review commented on postoperative complications and 7/18 reported revision rates. The authors find an epistaxis rate of 4.2%, similar to the rate of 6% reported in the adult population.[35,36] Yet epistaxis is more significant in children due to their smaller circulating volumes. Indeed, a study of 175 children with epistaxis found that 20.6% of 131 pediatric patients who had laboratory testing were anemic, with the median age being statistically younger ($p = 0.001$) when compared with those with normal laboratory results and to those with abnormal coagulation studies.[37] Similar trends are noted by Elden et al.[38]

Our review illustrates lower infection (1/650) and perforation (1/650) rates in children in comparison to those reported post-nasal septal surgery in adult populations[35,36] (►**Table 1**) and a revision rate of 5.6%. While not included in this review, in their large retrospective cohort analysis, Spataro et al quote a revision rate of 3.3% of 842 patients undergoing SRP.[39] The authors found that patients aged 13 to 18 years were more likely to undergo revision surgery (5.9%) in comparison to their adult counterparts, which corresponds to our overall revision rate. Corroborating these findings, Bishop et al find that septoplasty performed in patients under the age of 14 years is associated with higher revision rates.[40] This contrasts with findings from Adil et al whereby no patient (<16 years) required a revision procedure.[41] It is important to note that some of these patients will require further surgery, which can be more complex and have greater complications.

Impact on Midfacial Growth

The seven anthropometric studies included in this review do not report significant distortion in midfacial growth as a result of pediatric septal surgery for NO. There are conflicting findings regarding the impact of pediatric septoplasty on the

Table 5 Surgical indications, approach, and technique(s)

Study	Surgical indication (*n*)	Surgical approach (*n*)	Surgical procedure (*n*)	Adjuvant procedure		
Walker et al[26]	NS	Open (32)	External SRP excision and reimplantation (32)	Osteotomy^{10} Supratip onlay of morselized cartilage^{8} Reduction of dorsal hump^{5} Insertion of columella strut^{3}		
Béjar et al[42]	NS	Open (28)	External SRP excision and reimplantation (28)	NS		
El-Hakim et al[43]	Isolated cleft lip and/or palate^{7} Crouzon's syndrome (1) Previous septoplasty (16)	Open (26)	External SRP excision and reimplantation (26)	Rhinoplasty^{26} Free graft septoplasty^{26} Dorsal graft^{14} Columellar strut^{4} Dome suture^{4} Lower lateral cartilage trimming^{2} Tip graft^{2} Osteotomy (0)		
Dispenza et al[48]	Posttraumatic NSD (30)	Open (30)	Septoplasty (16); SRP (14)	NS		
Tasca and Compadretti[47]	Severe NO (44) Recurrent infection (30) Nighttime storing (15) Dental malocclusion (10) Allergy (8) Recurrent OM (7) Cottle I, II, III NSD (22)	Closed (44)	Endonasal septoplasty via hemitransfixion incision (44) *Quadrangular cartilage left in situ* (22)*; excision and reimplantation* (22)	NS		
Bae et al[21]	NSD (21; 32.8%) Nasal bone fracture (12; 18.8%) Nasal mass (3; 4.7%) Dermoid cyst (1; 1.6%) Flat nose (4; 6.3%) Additional cosmetic rhinoplasty for planned septoplasty (21; 32.8%)	Open (61; 95.3) Endonasal (3; 4.7%)	SRP (64)	Septal reconstruction (57; 89.1%) Osteotomy (41; 64.1%) Hump reduction (21; 32.8%) Cephalic resection (9; 14.1%) Alar base resection (8; 12.5%) Vertical dome division (1; 1.6%)	Graft type: septal cartilage (57; 87.1%); processed facial lata (42; 65.6%); conchal cartilage (10; 15.6%); pericardium (6; 9.4%); Gore-Tex (4; 6.3%); costal cartilage (3; 4.7%); perichondrium (3; 4.7%); homologous rib cartilage (2; 3.1%)	Grafting technique: dorsal onlay graft (60; 93.8%); tip onlay graft (43; 67.2%); spreader graft (36; 56.3%); septal extension graft (35; 54.7%); shield graft (33; 51.6%); columellar strut graft (18; 28.1%), backstop graft (11; 17.2%); caudal batten graft (6; 9.4%), cap graft (2; 3.1%), alar batten graft (1; 1.6%)
Costa et al[44]	NS	NS	Metzenbaum septoplasty (16)	Adenoidectomy^{2}; adenotonsillectomy and inferior turbinate reduction^{3}		
Yilmaz et al[27]	NS	Closed (35)	Septoplasty (35)	Nil		

(*Continued*)

Table 5 (*Continued*)

Study	Surgical indication (*n*)	Surgical approach (*n*)	Surgical procedure (*n*)	Adjuvant procedure
Adil et al[41]	Traumatic NO (36) Nontraumatic NO (16) Postsurgical deformity (2)	Open (19); closed (35)	Septoplasty (43)	Osteotomy^{34} Vestibular stenosis repair^{8} Spreader grafts^{7} Dorsal onlay^{6} Septal perforation repair^{2}
Anderson et al	NS	NS	NS	NS
Lee et al[34]	Traumatic NO (18) NSD (10)	NS	NS	NS
Manteghi et al[33]	Traumatic NO (88) Allergic rhinitis (50)	NS	Septoplasty (52); SRP (84)	NS (44 had additional procedures)
Kalantar-Hormozi et al.	Cosmesis (40); 14 patients also had NO	Closed (40)	SRP (40)	NS
Fuller et al[28]	NSD (31) Nasal valve narrowing/collapse (48) Previous nasal surgery (10)	Open (36); closed (3)	Functional SRP (39)	Dorsal hump reduction,^{16} swinging door,^{9} correction of medial crural flair,^{7} turbinoplasty,^{5} cephalic trim,^{4} osteotomies^{3} Grafts used^{36}: septal,^{31} PDS,^{11} cadaveric rib^{1} Graft type: spreader graft,^{33} columellar strut,^{12} alar rim,^{2} lateral crural strut^{1}
Din et al[31]	Traumatic NO (68) Previous nasal surgery (12)	NS	Septoplasty (52); SRP (84)	NS
Bishop et al[40]	NO (147) Traumatic NO (23)	NS	Septoplasty (194)	Nil
Kawai et al[32]	Congenital NO (36) Traumatic NO (2) Allergic rhinitis (10)	Closed (38)	Septoplasty plus bilateral inferior turbinate reduction (38)	NS
Ori et al[29]	Chronic NO with severe NSD (111)	Closed (111)	“Quick” single-tunnel septoplasty (111)	NS

Abbreviations: NO, nasal obstruction; NS, not specified; NSD, nasal septal deviation; OM, otitis media; SRP, septorhinoplasty.

	Walker et al	Bejar et al	El-Hakim et al	Tasca et al	Bae et al	Costa et al	Ori et al
***Linear* Measurements**							
Nasal height	X	X	X	X	X	X	
Dorsal Length	X	X	X	X	X	X	
Nasal Tip projection	X	X	X	X	X	X	
Columella length		X	X	X		X	
Columella width		X				X	
Nose width		X		X		X	
Face height	X	X	X			X	
Upper Face Height		X	X			X	
Facial Width		X	X			X	
Protrusion of the midface						X	
N-Palatal Plane							X
N-ME							X
Percent NH							X
Gonial angle values							X
Palatial height							X
Overjet values							X
Overbite Values							X
Maxillary intermolar width							X
Mandibular intermolar width							X
Indexes							
Palatal length						X	
Nasal index			X	X		X	
Nasal dorsum index				X			
Columella length-nasal tip protrusion index			X	X		X	
Nasal length-upper face length index			X			X	
Facial index			X			X	
Angular measurements							
SNA angle						X	
ANS Angle						X	X
SNB Value							
SNPg Value							X
Inclination of the upper face		X					X
Inclination of the nasal dorsum	X	X					
Inclination of the columella	X	X		X			
Nasal tip angle				X			
Nasolabial angle				X	X		
Nasofrontal angle					x		

Fig. 4 Anthropometric and cephalometric measurements used in the included studies.

nasal dorsal length, with Béjar et al[42] and El-Hakim et al[43] reporting an overall reduction, while Tasca and Compadretti and Bae et al do not replicate this trend.[21,47]

Costa et al[44] highlighted that in most cases, anthropometric measures were within normal range and patient satisfaction was high[44] (►**Table 5**). It is difficult to compare the anthropometric studies given the variation in the exact measures used, the time points pre- and postoperatively, as well as surgical approach (open vs. endonasal). Moreover, some studies did not perform statistical analysis on their data[44] (►**Fig. 4**).

This review theorizes that by respecting the structures guiding nasal and midfacial growth, pediatric septal surgery can be performed safely via either external or endonasal approaches. However, the significance of anthropometric variation on midfacial growth and later development remains to be elucidated.

Surgical Technique to Minimize Risk

It has been theorized that the long-lasting impact of pediatric septoplasty on midfacial growth has a lot to do with surgical technique, including cartilage preservation with its sphenospinal and sphenodorsal growth zones[10,45,46] as well as dorsal preservation and protection of the septospinal ligament.[10]

Given the small internal and external dimensions of the pediatric nose, an open approach offers maximal exposure to the nasal tip as well as cartilaginous and bony vaults.[21] However, Tasca and Compadretti,[47] Costa et al,[44] and Ori et al[29] all support a closed, conservative approach. Indeed Ori et al favor a “quick septoplasty” technique (a conservative endonasal procedure), reporting excellent outcomes with improvement in nasal breathing and cephalometric parameters on follow-up at the age of 18 years.[29] In addition, Dispenza et al[48] and Yilmaz et al[27] advocate for the use of the hemitransfixation incision approach, another conservative approach, maintaining mucoperichondrium integrity.

Both local application of growth factors and use of tissue-engineered cartilage may be useful adjuncts to nasal surgery in cases of injured or deformed cartilaginous frameworks.[49–51] Future work must be directed at understanding the genetic and environmental factors that affect nasal growth to develop a safe surgical technique for pediatric septoplasty.

Limitations

Despite rigorous assessment of the literature, significant heterogeneity between studies in this review in terms of patient population, age, surgical indication, technique, and outcome measures made comparison between cohorts challenging. In addition, data were lacking regarding the age of the patients at the time of surgery, observed deformities, and surgical procedure(s) performed.

This review highlights the need for prospective trials with long-term follow-up periods to gain consensus on whether surgical intervention for pediatric NO is safe and effective. Seven of the 18 studies in this review use anthropometric indices as outcome measures. However, standardization of the anthropometric methods is needed to facilitate direct comparison.[52] In addition, studies used North American White (NAW) data to draw conclusions despite demographic variations in their cohorts. It remains to be elucidated if normative NAW anthropometric data can be universally applied across patient groups, irrespective of the ethnic or demic heritage of patient populations.

Another methodological limitation was the use of calipers as well as two-dimensional (2D) photogrammetry to obtain facial data, assessment of which is subjective and fraught with human error.[53] More recently, 3D laser and digital scanning has been used to measure body composition.[46,54] Such technology could be utilized in future to offer precise, individualized measurements of craniofacial indices or even predict growth and facial development.

While revision rates are reportedly low in this review, this may well be in part due to short follow-up periods. For example, the Lee et al study had a follow-up period of only 44 days[34] and Tasca and Compadretti report a revision rate of 0%, despite four patients being referred for revision surgery at the time of publication.[47]

PROMs are now routinely used in the assessment of surgical interventions, evaluating the patient experience as well as providing objective evidence of benefit to incentivize policymakers. Despite increasing used of PROMs in pediatric surgery, validated and individualized tools are absent.[55] While the NOSE score was utilized in 6/18 studies, answers may be influenced by the children’s maturity and psychological development.

Conclusion

This review provides tentative evidence that nasal septal surgery for pediatric NO can be performed safely and effectively, highlighting the need to weigh up the risks of surgery with the benefit of early treatment of pediatric NO. Large prospective studies with long follow-up of nasal form and function, at least till after the adolescent growth spurt, will be paramount in corroborating our findings.

In addition, further studies evaluating child self-reporting with inclusion of patients and families in PROM development and selection are needed to develop a gold standard outcome measure for use in the pediatric population.

Conflict of Interest
None declared.

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