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Review

Utility of Nasal Debridement Following Pediatric Functional Endoscopic Sinus Surgery: A Scoping Review

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Abstract: The role of second-look endoscopy and debridement (SLED) remains uncertain in children due to the perceived need for additional general anesthesia following their initial functional endoscopic sinus surgery (FESS) while mitigating risks and healthcare costs. This comprehensive review synthesizes current evidence on SLED in children, focusing on its practice pattern and treatment outcomes. This review was designed and performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews Protocol. Independent queries of the PubMed Central, MEDLINE, and Bookshelf databases were performed. A total of 53 relevant, unique articles were initially identified; 12 articles were ultimately deemed appropriate for inclusion in final analysis. The most common indication for FESS was chronic rhinosinusitis or recurrent sinus infections while that for SLED under general anesthesia varied from institutional practice patterns to surgeon preference. No meaningful comparison of outcomes was possible as the "success rates" of FESS with or without SLED were largely based on unvalidated questionnaires and equally subjective surgeon assessments. Even when looking at outcomes based on revision rates, FESS with SLED was considered successful between 60.5% and 95.6% of the time, with a mean of 84.2%, while FESS without SLED was successful between 71.0% to 96.4% of the time, with a mean of 86.3%. However, no randomized, controlled studies were available in the pediatric literature pertaining to FESS with or without SLED. Moreover, it became apparent that previous conclusions on the utility of SLED were based on the outcomes of FESS following one single SLED under general anesthesia vs. no SLED. As such, there is an unmet need to examine the utility of serial, office-based SLED in children to better elucidate its utility in pediatric FESS.

Keywords: pediatric; sinus surgery; second look; endoscopy; debridement; chronic rhinosinusitis; endoscopic; endonasal; functional endoscopic sinus surgery

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1. Introduction

Chronic rhinosinusitis (CRS) is an inflammatory process involving the paranasal sinuses that leads to a great reduction in the quality of life in children, which is often the driving factor for considering pediatric functional endoscopic sinus surgery (FESS) [1]. Current postoperative management following pediatric functional endoscopic sinus surgery (FESS) chiefly consists of conservative measures such as intranasal corticosteroid sprays, nasal saline sprays/rinses, and second-look endoscopy with debridement (SLED) under general anesthesia, in select cases. In adults, serial postoperative debridement has been clearly associated with improved sinonasal symptoms and endoscopic scores in the short term, whereas the long-term benefit has been less clear [2,3]. Similarly, the efficacy of postoperative debridement in the pediatric population remains uncertain due to many unique patient factors. Pediatric patients, especially those under five years of age, often have developmental and behavioral factors that limit routine postoperative care, making in-office sinonasal debridement and other nasal care regimens more difficult to perform [4]. SLED under general anesthesia remains a significant topic of interest given its perceived benefits and concerns over repeat exposure to general anesthesia, as well as its associated healthcare costs [5–7]. As such, this scoping review aims to synthesize data from a wide range of studies on pediatric FESS performed for chronic rhinosinusitis or recurrent sinusitis with a focus on the factors influencing second-look procedures, the role of postoperative debridement, and its impact on clinical outcomes. In doing so, this work aims to provide an updated review of postoperative debridement following pediatric FESS.

2. Materials and Methods

2.1. Study Protocol

This study was designed and performed in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews Protocol (PRISMA-ScR) [8] and was deemed exempt from institutional review board approval. This study was registered in the Open Science Framework (OSF) under the following number identifier: DOI https://doi.org/10.17605/OSF.IO/NZGMR. Independent searches of the PubMed Central, MEDLINE, and Bookshelf databases were performed from 18 August 2024 to 17 November 2024 by 2 authors (B.A.V.-S. and J.D.K.) to identify studies that described demographics, perioperative care, the postoperative debridement/second look surgery rate, and clinical outcomes following pediatric FESS. Full-length original articles in English and Spanish were assessed for data extraction eligibility. Articles from the 1980s and onward were collected to mirror the experience with endoscopic sinus surgery. All studies that described pediatric FESS were collected using the Boolean method and relevant search term combinations, including "Debridement", "Second-look", "Functional endoscopic sinus surgery", "Pediatric", "Outcome", and "Management". The references of the included articles were also reviewed for eligibility. This material was supplemented with targeted searches to address specific needs identified in writing this comprehensive review. The utilized search strategy is summarized in Figure 1. Studies were included in the analysis if and only if they explicitly addressed the utilization of second-look endoscopy and debridement following pediatric FESS, or a lack thereof. Studies not specifically mentioning or addressing second-look endoscopy and debridement or not involving pediatric population were excluded.

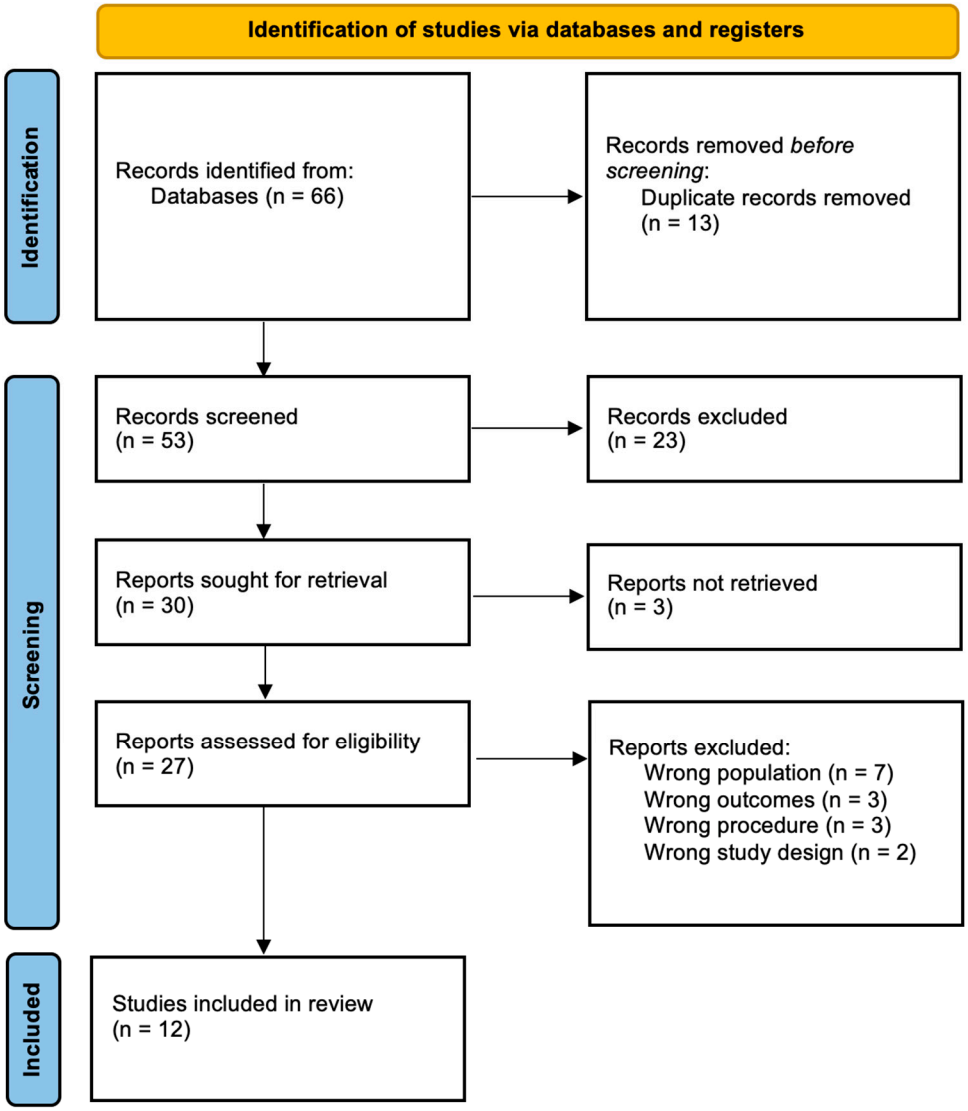


Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram reflects our independent searches of the PubMed, MEDLINE, and Bookshelf databases.

2.2. Data Collection and Synthesis

Studies were categorized by lead author, year of publication, country of origin, and study type. The quality and level of evidence for each article were assessed using the Methodological Index for Nonrandomized Studies (MINORS) instrument [9]. Baseline characteristics included the study sample size, age at presentation, gender, country/setting, underlying diagnosis, surgical details, and perioperative care. In addition, clinical outcomes were also analyzed given the availability of published clinical data. This includes the rate/reason for second-look endoscopy and debridement, rate/reason for revision surgery, success rate, and presence of endoscopic findings including synechiae, adhesions, and granulation tissue formation. Missing data were excluded from the quantitative synthesis.

2.3. Statistical Analysis

Descriptive statistical analyses were performed using Microsoft Excel version 15.32. Formal statistical analysis was precluded by this study's heterogeneity.

3. Results

3.1. Study Characteristics

This search strategy, as described above, yielded 53 articles for title/abstract screening. Thirty articles met the eligibility criteria for a full-text review. The lead author (JDK) reviewed all articles; 12 articles were deemed eligible for inclusion in the final analysis. Of note, three articles (Gross et al., 1989; Lazar et al., 1992; and Lazar et al., 1993) appeared to contain overlapping data from the same patient population [10–12]. Therefore, these articles were considered as one in this analysis. As shown in Table 1, there were 10 retrospective and 2 prospective studies from four countries between 1989 and 2020. All studies were from tertiary academic centers. The study quality, as assessed by the MINORS criteria, yielded a mean score of 8.58, with a range between 6 and 12. The number of patients studied ranged from 7 to 210, with the mean follow-up ranging from 12 to 42 months. All articles except for one study reported baseline demographic data. The mean age of the pediatric patients undergoing FESS ranged from 5.7 to 14.5 years.

Table 1. Study characteristics.

Authors	Year of Study (Study Period)	Country	Study Design	N *	Age Range (Mean, Y)	Follow-Up Range (Mean, M)	MINORS
Gross et al. [10]	1989 (1986–1987)	U.S.	Retrospective	57	3–15	3–13	6
Lusk and Muntz [13]	1990	U.S.	Prospective	31	(6.6)	(12)	10
Lazar et al. [11]	1992 (1986–1989)	U.S.	Retrospective	210	1.2–16	3–36 (18)	6
Lazar et al. [12]	1993 (1986–1990)	U.S.	Retrospective	260	1.2–81 **	3–48 (20)	10
Stankiewicz [14]	1995 (1985–1991)	U.S.	Retrospective	83	1–18	24–84 (42)	6
Ramadan and Rosen [15]	1996 (1991–1994)	U.S.	Retrospective	7	2–17 (10)	7–30 (17.3)	7
Michell et al. [16]	1997 (1993–1995)	U.S.	Retrospective	100	3–16 (6.8)	6–52 (17.1)	12
Walner et al. [17]	1998 (1993–1994)	U.S.	Retrospective	147	1–20 (5.7)	6–48 (19)	9
Fakhri et al. [18]	2001 (1987–1997)	Canada	Retrospective	35	NR	3–60 (16.4)	7
Chang et al. [19]	2004 (1995–2002)	Taiwan	Retrospective	101	8–18 (14.5)	6–51 (23.6)	9
El Sharkawy et al. [20]	2012 (2005–2010)	Egypt	Prospective	87	(9.9)	6–55 (28.2)	12
Helmen et al. [6]	2020 (2013–2016)	U.S.	Retrospective	61	(8.7)	>6	9

* Abbreviations—N: number of patients; Y: years; M: months; MINORS: Methodological Index for Nonrandomized Studies; U.S.: United States; NR: not reported. ** Of note, this study included both adults and children; however, only the data pertaining to children were analyzed.

3.2. Underlying Pathology, Associated Conditions, and Operative/Perioperative Interventions

The underlying pathology, associated conditions, and perioperative measures are shown in Tables 2 and 3. The most common indication for FESS was CRS or recurrent sinus infections. CRS was generally described as sinonasal symptoms lasting for longer than 3 months and refractory to medical management for a minimum of 3 to 4 weeks. Only one author specified recurrent sinus infection as acute rhinosinusitis lasting at least 10 days six times per year [19]. Fakhri et al. did not specify the underlying pathology as CRS but only included patients who failed antibiotics and a topical nasal steroid spray for at least 2 months in their study [18]. In one of the studies, there were incongruencies in the reported underlying pathology, but CRS and recurrent sinus infection appeared to be the majority of cases undergoing FESS [14]. The most common comorbidity was allergy, affecting 14–49% of patients, followed by asthma, affecting between 16 and 52% of patients. Immunodeficiency was described as affecting 7–24% of patients. The most common prior surgical interventions included tonsillectomy, adenoidectomy, myringotomy, and tympanostomy tube placement. In the early years of pediatric FESS, antral windows were described at a rate between 29% and 48%. Operative details were reported in all but two studies [16,20]. Most studies describe FESSs involving maxillary antrostomies and ethmoidectomies (partial/total), with selective frontal and sphenoid sinus interventions.

However, Chang et al. describe a "limited approach" to FESS in which a minimal anterior opening of the maxillary sinus, as well as fenestration of the basal lamella, was performed in lieu of posterior ethmoidectomy [19]. Concomitant septoplasty, adenotonsillectomy, and tympanostomy tube placements were also reported [9–11,13,17]. Postoperative CT was not routinely obtained except by El Sharkawy et al., who obtained the imaging 8 weeks following the FESS and again in some cases at the 3-to-6-month mark [20]. Given the available data, it appears that in-office debridement in awake patients was not routinely described or reported in the pediatric literature following FESS.

Table 2. Patient characteristics.

Authors	N *	Indications for FESS	Associated Conditions	Prior Surgeries
Gross et al. [10]	57	CRS or RSI (94.7%), Complications of ARS (3.5%), NPC (1.7%)	Allergy (53.7%), CF (3.7%), PCD (3.7%) **	BMTT (48%), T&A (57%), Adenoidectomy (9%), Antrostomies (43%)
Lusk and Muntz [13]	31	CRS or RSI	Allergy (23%), asthma (26%), immune deficiency (24%)	BMTT (38%), Adenoidectomy ** (35%), Tonsillectomy (26%), NAW (48%)
Lazar et al. [11]	210	CRS or RSI	Allergy (49.5%) $^{\Phi}$, asthma (21.4%)	T&A (54%), BMTT (48%), NAW (29%), Septoplasty (10%), Partial Inferior Turbinectomy (8%), Intranasal Ethmoidectomy (1.4%)
Lazar et al. [12]	260	CRS or RSI	Allergy (49%), asthma (20%)	T&A (55%), BMTT (51%), NAW (30%), Septoplasty (11%), Partial Inferior Turbinectomy (9%), Intranasal Ethmoidectomy (2%)
Stankiewicz [14]	83	Sinusitis	Allergy (27%), asthma (16%), CF (6%), immune deficiency (7%)	Not Reported
Ramadan and Rosen [15]	7	CRS or RSI	Allergy (14%)	BMTT (86%), Adenoidectomy (43%), Tonsillectomy (43%), NAW (29%)
Michell et al. [16]	100	CRS	Not reported $^{\Delta}$	Not Reported
Walner et al. [17]	147	CRS	Allergy (55.8%), asthma (19%), immune deficiency (8.8%)	Not Reported
Fakhri et al. [18]	35	Sinusitis	Asthma (31.4%), CF (8.6%), ALL (2.9%), PCD (2.9%), Kartagener's syndrome (2.9%)	T&A (31%), BMTT (11%), Maxillary Lavage and Septoplasty (6%)
Chang et al. [19]	101	CRS or RSI	Not reported ^{K}	Not Reported
El Sharkawy et al. [20]	87	CRS	Allergy (51.7%), polyposis (6.9%)	Adenoidectomy (7%)
Helmen et al. [6]	61	CRS	Cystic fibrosis (100%)	Not Reported

* Abbreviations—N: number of patients; FESS: functional endoscopic sinus surgery; CRS: chronic rhinosinusitis; RSI: recurrent sinus infection; ARS: acute rhinosinusitis; NPC: nasopharyngeal carcinoma; CF: cystic fibrosis; PCD: primary ciliary dyskinesia; BMTTs: bilateral myringotomy and tympanostomy tubes; T&A: adenotonsillectomy; NAW: nasal antral window; ALL: acute lymphoblastic leukemia. ** Out of 54 patients undergoing FESS for CRS or RARS. $^{\Phi}$ Out of 196 patients tested for allergies. $^{\Delta}$ Patients with systemic disease or undergoing revision surgery were excluded. ^{K} Patients with asthma, immunodeficiency, or antrochoanal polyps were excluded.

Table 3. Perioperative interventions.

Authors	Preoperative Care	Surgical Intervention	Postoperative Care
Gross et al. [10]	3 wks of PO abx, nasal steroids, decongestants	FESS ± T&A; steroid/antibiotic ointment packing	2 wks of PO abx, nasal steroids, decongestants, saline mist; SLED 2 wks post-FESS
Lusk and Muntz [13]	4 wks of PO abx, nasal steroids	FESS; Silastic stent	4 wks of PO abx; SLED 2 wks post-FESS to remove Silastic stent and replace with Gelfilm
Lazar et al. [11]	3 wks of PO abx ± mucolytics/decongestants; 5 days of nasal steroids	FESS ± T&A (18%), partial middle turbinectomy (7%), limited septoplasty (9%); steroid/antibiotic ointment packing	6 wks of broad-spectrum PO abx, nasal steroids, decongestants, saline mist (weaned therapy during the last 2 wks); SELD 2–3 wks post-FESS
Lazar et al. [12]	3 to 4 wks of broad-spectrum PO abx, nasal steroids, mucolytics, decongestants	FESS ± BMTT (25%), T&A (18%), partial middle turbinectomy (8%), limited septoplasty (9%); steroid/antibiotic ointment packing	6 wks of broad-spectrum PO abx, nasal steroids, decongestants, saline mist (weaned therapy during the last 2 wks); SLED 2–3 wks post-FESS
Stankiewicz [14]	>8 wks of anti-β-lactamase abx ± nasal steroids, antihistamines, immunotherapy for allergy	FESS ± septoplasty (16%), adenoidectomy (26%)	Not reported
Ramadan and Rosen [15]	4 wks of abx	FESS	Aggressive nasal irrigation

Table 3. *Cont.*

Authors	Preoperative Care	Surgical Intervention	Postoperative Care
Michell et al. [16]	6 wks of broad-spectrum PO abx, nasal steroids, decongestants	FESS; steroid/antibiotic ointment packing until 1993	Broad-spectrum PO abx, nasal steroids, saline mist, decongestants; SLED 3 wks post-FESS (50%)
Walner et al. [17]	6 wks of PO abx, >3 wks of nasal steroids	FESS	SLED 2–3 wks post-FESS (63.9%)
Fakhri et al. [18]	>8 wks of PO abx and nasal steroids ± antihistamines/decongestants for allergy	FESS ± adenoidectomy (3%), BMTT (6%), septoplasty (9%); Gelform packing (83%), Gelfilm stent (14%)	Follow-up visits at 2 wks, 1 month, and 6 months post-FESS, then as needed
Chang et al. [19]	>4 wks of PO antibiotics, decongestants, antihistamines, and intensive local debridement	"Limited approach" FESS $^{\Delta}$	Weekly follow-up visits for the first month, then bi-weekly follow-up for the second month, then monthly follow-up; SLED in select patients 3–6 wks post-FESS
El Sharkawy et al. [20]	Broad-spectrum PO abx, decongestants, and nasal suction/wash ± antihistamines for allergy	FESS	>2 wks of PO abx, nasal steroids, irrigation ± PO steroids for asthma
Helmen et al. [6]	Multiple trials of abx for 3–6 wks, nasal steroids (72.1%), nasal/sinus irrigations	FESS	Culture-directed or broad-spectrum abx, nasal steroids (90.2%), saline irrigations and sprays

Abbreviations—N: number of patients; wks: weeks; abx: antibiotics; FESS: functional endoscopic sinus surgery; PO: per os; b/l: bilateral. $^{\Delta}$ Described as maxillary sinus opening without dilation, unless concerning for ostial obliteration, partial removal of ethmoid bulla, or a small window through basal lamella in lieu of posterior ethmoidectomy depending on disease severity.

3.3. Outcome Measures

Five studies used caretaker and parental responses to assess the success of pediatric FESS [9,11,12,17,18], while four studies utilized symptomatic relief and physical examination findings to determine the outcomes [11,14,16,18]. The revision rate was reported in nine studies, but only Walner et al. utilized it as the sole determinant of FESS success [6,10,11,13,15–18,20]. Given the uniqueness of their study population, involving solely CF patients, Helmen et al. evaluated outcome measures including changes in FEV1, the number of sinonasal and CF exacerbations, and the time to these exacerbations [6]. No standardized method of determining the success rate following pediatric FESS was apparent.

The overall success rate, if reported, of primary pediatric FESS based on parental survey, clinical exam, or a combination thereof, ranged from 71% to 93%, with a mean of 85.1%. When excluding patients with systemic disease, the favorable outcome rate was between 71.4% and 100%, with a mean of 88.2%. When further excluding the study by Ramadan and Rosen, where authors only included patients with developmental delay, the overall success ranged from 80% to 93%, with a mean of 86.8%. When considering the need for revision surgery as the determinant of success, the reported success rate was between 70.5% and 92.4%, with a mean of 81.5%. However, the success rate based on revision surgery ranged from 80% to 100%, with a mean of 89.4% when excluding patients with systemic disease and developmental delay.

The outcome of pediatric FESS with respect to patients' SLED status was clearly reported in eight studies. Although Stankiewicz et al. did not explicitly describe in-office debridement, given that the reason for SLED being performed under general anesthesia is an inability to debride or cleanse the nose in the office, an assumption was made that all patients in their study underwent postoperative debridement and the study was included in our qualitative analysis [14]. A summary of the SLED status and findings are shown in Table 4.

Table 4. Post-operative debridement and findings.

Authors	In-Office Debridement	SLED *	Timing	Findings	Reason for SLED
Gross et al. [10]	Not reported	100%	2 wks post-FESS	Not reported	Routine debridement
Lusk and Muntz [13]	Unclear $^{\Phi}$	100%	2 wks post-FESS	Not reported	To remove Silastic stents and place rolled Gelfilm at the time of debridement
Lazar et al. [11]	Not reported	100%	2–3 wks post-FESS	Adhesions (20%), significant crusting (11%), granulation tissue (10%), persistent polyposis (7%)	Routine debridement
Lazar et al. [12]	Not reported	100%	2–3 wks post-FESS	Synechiae (20%), polyposis (9%)	Routine debridement
Stankiewicz [14]	Unclear $^{\Delta}$	41% $^{\varnothing}$	3–6 wks post-FESS	Normal healing/patent ostia (47%), closing/closed antrostomy (44%), granulation tissue (26%), early synechiae/scarring (28%)	Inability to debride or cleanse nose after FESS
Ramadan and Rosen [15]	Not reported	0%	N/A	N/A	N/A
Michell et al. [16]	Unclear ^{ß}	50%	3 wks post-FESS	Not reported	Routine debridement prior to institutional practice change
Walner et al. [17]	Not reported	63.9%	2–3 wks post-FESS	Clean cavity (16%), synechiae (35%), granulation tissue (50%), inflammatory/polypoid mucosa (15%), mucoid/mucopurulent drainage (15%), scarring (1%)	Out of 4 staff surgeons, 3 performed routine SLED and 1 did not
Fakhri et al. [18]	Not reported	0%	N/A	N/A	N/A
Chang et al. [19]	Not reported	28%	3–6 wks post-FESS	Not reported	Localized synechiae, polypoid tissue, or copious discharge on anterior rhinoscopy; extensive disease during surgery; revision cases
El Sharkawy et al. [20]	Unclear $^{€}$	29% † ≤5 years (71.4%) 6–10 years (35.5%) 11–14 years (33.3%)	Not reported	Synechiae: ≤5 years (57.14%) 6–10 years (14.28%) 11–14 years (10%)	Difficult in-office exam or abnormal exam findings
Helmen et al. [6]	Not reported	62.3%	~3 wks	Synechiae (26.3%), recurrent polyp (23.7%), maxillary antrostomy obstruction (7.9%), lateralized middle turbinate (7.9%), mucopurulent drainage (5.3%)	Out of 2 staff surgeons, 1 performed routine SLED and 1 did not

* Abbreviations—SLED: second-look endoscopy and debridement (under general anesthesia); wks: weeks; FESS; functional endoscopic sinus surgery; N/A: not applicable. $^{\Phi}$ Reports of nasal endoscopy in cooperative patients older than 5 years of age during follow-up visits. $^{\Delta}$ Assumed to be yes as the reason for SLED under general anesthesia was reported to be due to inability to debride or cleanse nose after surgery. $^{\varnothing}$ 74% of children requiring SLED under general anesthesia were under 12 years old; 41% is the reported number for SLED under general anesthesia, but the assumption was made that all children in the study underwent post-operative debridement. ^{ß} Reports anterior rhinoscopy and removal or crusting depending on patient's age and cooperation. $^{€}$ Reports regular in-office exam of nasal cavity and paranasal sinus mucosa, but does not discuss debridement. † Overall rate of SLED under general anesthesia was 29%, but there was a proportionally higher rate in younger age groups.

The success rate when considering the need for revision in the SLED group was between 60.5% and 95.6%, with a mean rate of 84.2%. In the group where SLED was not performed (i.e., NoSLED), the success rate in terms of revision surgery ranged from 71% to 96.4%, with a mean of 86.3%. When excluding patients with systemic disease and/or developmental delay, the success rate in terms of the need for revision surgery was 90% and 91% in the SLED and NoSLED groups, respectively. The outcome data are shown in Table 5.

Table 5. Reported outcomes.

Authors	Revision Rate	Reason for Revision	Reported Outcome	Outcome Metrics
Gross et al. [10]	SLED *: 3.5% NoSLED: N/A	Persistent/recurrent disease	SLED: Surgery was helpful (92%) Symptoms improved/resolved (92%) Would undergo surgery again (88%) NoSLED: N/A	Survey of parents via mail or telephone interview
Lusk and Muntz [13]	SLED: 23% vs. 0% ** NoSLED: N/A	Unsatisfactory results	SLED: Symptoms improved/resolved (71% vs. 80%) ** NoSLED: N/A	Reported symptoms during follow-up visits and parental report at 1 year post-FESS
Lazar et al. [11]	SLED: 7.6% vs. 4.5% ** NoSLED: N/A	Failed response to FESS and additional medical management, middle meatal stenosis	SLED: Successful (79%) Successful with additional medical therapy (92%) Would recommend surgery (88%) Symptoms improved (83–85%) NoSLED: N/A	Surgeons' assessment and survey of primary caretakers via mail
Lazar et al. [12]	SLED: Unclear $^{\Phi}$ NoSLED: N/A	Failed to respond to FESS and additional medical management, significant adhesion leading to ostiomeatal occlusions/stenosis of maxillary antrostomies	SLED: Successful (81%) NoSLED: N/A	Patients' and parental feedback during follow-up visits
Stankiewicz [14]	SLED: Not reported NoSLED: N/A	Not reported	SLED: Cured (38%) Improved (55%) NoSLED: N/A	SLED findings and subjective report
Ramadan and Rosen [15]	SLED: N/A NoSLED: 28.6%	Not reported	SLED: N/A NoSLED: Marked improvement (71%)	Caretaker report
Michell et al. [16]	SLED: 14% NoSLED: 4%	Not reported	SLED: Improved (48%) or resolved (36%) symptoms NoSLED: Improved (50%) or resolved (40%) or symptoms	Parents' feedback and exam findings during follow-up
Walner et al. [17]	SLED: 21.3% NoSLED: 18.9%	Recurrent CRS refractory to medical management	SLED: Successful (78.7%) NoSLED: Successful (81.1%)	Need for revision FESS
Fakhri et al. [18]	SLED: N/A NoSLED: 14% vs. 3.6% **	Recurrent symptoms	SLED: N/A NoSLED: Improved or resolved symptoms (74% vs. 86%) **	Patients' and parental feedback during follow-up visits, physicians' evaluation
Chang et al. [19]	Not reported	Not reported	Overall $^{\Delta}$: Improved or resolved symptoms (89–97%) Satisfied with surgery (86%)	Parental questionnaire
El Sharkawy et al. [20]	≤5 years (28.6%) 6–10 years (10.7%) 11–14 years (10%)	Not reported	Overall $^{\Delta}$: Successful (87.7%)	Based on postoperative CT, nasal exam, and subjective symptom changes
Helmen et al. [6]	SLED: 39.5% NoSLED: 13% ($p = 0.06$)	Not reported	No significant difference between SELD and NoSLED groups except for average number of days to cystic fibrosis exacerbations ($p = 0.01$) -SLED: 113.9 ± 45.5 -NoSLED: 47.4 ± 34.1	FEV1, number and time to postoperative sinonasal exacerbation within 6 months, number and time to postoperative CF exacerbation, time to revision FESS

* Abbreviations—SLED: second-look endoscopy and debridement (under general anesthesia); NoSLED: SLED not performed. ** Overall rate vs. rate in patients without systemic disease. $^{\Phi}$ Overall revision rate was 71 out of 513 adults and 260 children, but the specific revision rate for children was not reported. $^{\Delta}$ Does not specify outcomes for SLED vs. NoSLED.

4. Discussion

4.1. A Brief History of FESS

FESS was first performed in Europe by Messerklinger and Stammberger and popularized in the United States by Kennedy et al. in the 1970s and 1980s [21–24]. Reserved for sinonasal disease refractory to appropriate medical management or rhinosinusitis with

acute complications, Kenney et al. asserted that the goal of FESS was to restore normal sinus physiology (i.e., functional physiology) and not to ablate or exenterate diseased sinuses [21]. While Stammberger emphasized the importance of frequent postoperative debridement for a successful outcome following FESS (i.e., SLED), Kennedy later concluded that the only relevant prognostic factor for FESS was the extent of the sinus disease [23–25]. When considering pediatric FESS, the technique and practice did not gain traction until the late 1980s and early 1990s when Gross et al., as well as Lusk and Muntz, began reporting their experiences, which demonstrated its safety and efficacy in children [10,13]. Prior to their reports, operative procedures for CRS in children were taught to be avoided, likely due to poor outcomes associated with "classic sinus surgeries" such as nasal antral windows, Caldwell–Luc surgery, internal/external ethmoidectomy, frontal sinus trephinations, obliterations, and sphenoidotomies [26,27]. Moreover, there remained concerns about the negative impact on pediatric craniofacial development, especially midface, of FESS based on several animal studies and a small case series in humans [28–30]. However, multiple long-term reports in children later demonstrated no such deleterious effects on facial skeletal development following pediatric FESS [31–33].

4.2. Early Experiences in Pediatric FESS with Routine SLED (1980s–Early 1990s)

Between 1989 and 1993, Gross et al. and Lazar et al. published a series of papers pertaining to pediatric FESSs performed at Le Bonheur Children's Medical Center in Memphis, TN [10–12]. In their iterative retrospective analysis, the authors looked at pediatric patients who underwent FESS and routine SLED under general anesthesia between 1986 and 1990. Gross and colleagues' 1989 report was the first of its kind describing the application of FESS in children, where they reported 54 surgeries performed for CRS and 3 for complicated acute sinusitis between 1986 and 1987 [10]. All patients underwent FESS as described in adults at the time and were discharged home with a two-week course of nasal steroids, saline mist, decongestants, and oral antibiotics. Following this, all children underwent SLED under general anesthesia two weeks postoperatively to remove synechiae, clots, and granulation tissue. Maxillary sinus lavage and generous steroid/antibiotic ointment packing were performed at the time of the SLED as well. It should be noted that the use of a second general anesthesia session for debridement represented a deviation from the adult protocol, in which debridement was generally performed on awake patients, in-office, and under local anesthesia. When surveying the parents of 50 children who underwent FESS for CRS, 92% responded that the surgery was helpful, while 94% reported that the surgery improved or resolved CRS symptoms. Of note, this study included two children with cystic fibrosis (CF) and two patients with primary ciliary dyskinesia (PCD), but it did not break down its outcomes in terms of underlying conditions. Although the follow-up period was short (3 to 13 months), a high success rate was reported, with no significant complications, suggesting the safety and efficacy of pediatric FESS. In 1992, Lazar et al. expanded their retrospective analysis to include 210 children who underwent FESS between 1986 and 1989 [11]. In their analysis, Lazar and colleagues also included their findings at the time of SLED, which revealed that 20% of patients had adhesions, 10% granulation tissue, 11% significant crusting, and 7% persistent polyposis. That is, the majority of children had no significant findings upon SLED. Moreover, during the follow-up period of 3 to 36 months (mean 18 months), Lazar et al. reported a 7.6% revision rate within the first year for a failed response to additional medical treatment for recurrent CRS and/or middle meatal stenosis following FESS. Of note, when excluding patients with immunodeficiency (four), CF (two), and PCD (one), the revision rate drops to 4.5%. However, this analysis is limited due to the unknown total number of patients with CF and PCD in the cohort who did or did not require revision surgery. However, the authors do report that nearly 6% of children tested

positive for immunodeficiency. FESS was considered successful by the treating team in 79% of patients and in an additional 14% after "additional medical treatment", presumably a course of antibiotics, nasal steroids, and decongestants. This was comparable to 88% of 103 responders who stated they would recommend FESS to others. Moreover, symptom improvement was reported in between 83 and 85% of patients in the domains of chronic nasal obstruction, cough, nasal discharge, and headaches. In 1993, Lazar et al. expanded their analysis to include one additional year and demonstrated a success rate of 81% in 260 children treated with FESS between 1989 and 1990 [12].

In 1990, Lusk and Muntz also published their experience of performing pediatric FESS at Washington University Medical Center in St. Louis, Missouri, where they performed the procedure in 31 children (mean age 6.6 years) with rhinosinusitis symptoms lasting between 4 and 90 months (mean 26 months) [13]. In this study, all patients underwent a 4-week course of oral antibiotics, nasal steroid sprays, and CT scans prior to being considered for FESS. All patients also underwent a second, short period of general anesthesia 7 to 10 days after their FESS to remove the Silastic stents placed during the initial surgery and to clean the ethmoid cavities and antral ostia of any granulation tissue (i.e., SLED). Although the revision rate was reported to be 23%, it is important to note that all the patients requiring revision surgeries had either a documented or strong suspicion of underlying immunodeficiency or CF. Thus, when considering only patients who required one surgery, 80% of the caregivers/respondents believed the intervention was successful, 12% believed their child's condition improved but persistent symptoms remained, and 8% reported failure when asked 1 year after surgery.

Further evidence that supports pediatric FESS came from Stankiewicz et al. at Loyola University Medical Center in 1995, where 77 children between 1 and 18 years of age underwent FESS for CRS with a minimum follow-up period of 2 years (mean 3.5 years) [14]. All patients underwent a minimum of 2 months of antibiotics and decongestant therapy before FESS. Although not explicitly stated, it was implied that all patients underwent SLED either in-office or under general anesthesia, as Stankiewicz reports that "thirty-four of the 77 sinus endoscopic surgery patients were examined 3 to 6 weeks after endoscopic surgery for examination and debridement because they could not be examined in the clinic". Of the 34 patients, nearly 50% had the closure of an antrostomy and one-third had significant granulation or early synechia formation. It is important to note that the vast majority of children requiring SLED under general anesthesia were under 12 years of age (25/34), inferring a generally difficult postoperative examination and awake nasal debridement in younger patients. The overall success rate was 93% (38% cured, 55% improved), with a minimal complication rate of 1.4%. Stankiewicz attributed the lower cure rate to a longer follow-up period compared to previous studies. However, it should also be noted that this was a single-center, single-surgeon study. Moreover, the study reports a total of five patients with CF and six with immunodeficiency (IgA and IgG), which may confound the results.

4.3. Changing the Practice Pattern with SLED (Late 1990s–2000s)

Perhaps the first report to suggest that SLED in pediatric patients may not be necessary, or even recommended, came from Ramadan and Rosen at West Virginia University Children's Hospital in 1996 [15]. In their report, Ramadan and Rosen looked at the outcomes of seven developmentally delayed children between the ages of 2 and 17 years who underwent FESS for CRS. All patients' CRS symptoms were refractory to a repeated course of oral or intravenous antibiotics, mucolytics, and nasal steroids. The decision to perform FESS was based on symptom correlation with CT findings after a 4-week course of antibiotics. Postoperatively, five of seven children had a protracted/complicated recovery due to respiratory and feeding difficulties, thus leading to the authors' reluctance to perform

second-look procedures under general anesthesia on these children. Instead, aggressive nasal irrigation was employed. Only two children underwent SLED with general anesthesia 2 weeks postoperatively due to recurrent sinus infections. During the follow-up period of 7 to 30 months (mean 17.3 months), the caretakers of five children (71%) who did not undergo SLED reported marked improvement in symptoms, whereas two children requiring SLED under general anesthesia continued to have recurrent sinus infections, albeit less frequently. As Kennedy alluded in 1992, the authors attributed the persistent/recurrent symptoms in these two children to the severity of their initial disease and concluded that "omission of the second-look procedure did not seem to impair the final results" [15,25].

It was not until 1997 that Mitchell et al. formally questioned if SLED was necessary for pediatric FESS [16]. Born out of a changing practice pattern at Le Bonheur Children's Medical Center around 1994, where SLED under general anesthesia was no longer routinely performed, the authors looked at the outcomes of 50 consecutive children treated with FESS and routine SLED under general anesthesia between January 1993 and December 1994 and those of 50 consecutive children treated with FESS without SLED (NoSLED) between January 1994 and December 1995. All patients had CRS and were treated with a 6-week course of a broad-spectrum antibiotic, nasal steroid spray, and decongestant before CT and subsequent FESS. The postoperative regimen included steroid nasal spray, decongestant, saline mist, and a broad-spectrum oral antibiotic. Of note, compared to previous reports from the author's institution, patients with systemic diseases such as CF, PCD, or immunoglobulin deficiency and revision cases were excluded from the analysis. When comparing the NoSLED group to the SLED group, the success rate was reported to be 90% (40% complete resolution, 50% improved) vs. 84% (36% complete resolution, 48% improved), respectively. The authors reported no statistical difference in the improvement in nasal obstruction, drainage, or chronic cough between groups. The revision rate was 4% in the NoSLED group, whereas it was 14% in the SLED group. The difference was attributed to a longer follow-up period for the SLED group. Accordingly, the authors concluded that "in the majority of children, a second look under general anesthesia may not alter the outcome of FESS for pediatric sinusitis and avoids the risks of an additional general anesthetic, with its associated morbidity and costs". However, the several shortcomings of this study include the short follow-up period for the NoSLED group and a lack of an age-matched analysis, as pointed out by the authors. Moreover, it is unclear whether SLED was selectively performed in patients with "a high risk of requiring revision surgery" during the transitional period, thus raising the question of selection bias.

Another comparative study of SLED vs. NoSLED groups came from Walner et al. in 1998 [17]. Conducted at Cincinnati Children's Hospital, the authors looked at the revision rate of FESSs performed between 1993 and 1994. A comparative study was possible as three of the four surgeons at the practice routinely performed SLED under general anesthesia 2–3 weeks postoperatively, whereas one surgeon did not. Revision surgery was performed in 21.3% (20/94) of the patients who underwent SLED previously, compared to 18.9% (10/53) in patients who did not. The authors contend that there was no statistical difference in associated medical conditions, the severity of sinus disease on preoperative CT, or types of FESS performed between the groups. The only statistically significant finding leading to revision surgery was the disease severity on CT, as well as a younger age. Based on the findings of their study, three surgeons who previously performed routine postoperative debridement reportedly changed their practice pattern to perform SLED under general anesthesia more selectively. This study further questioned the need for SLED on the basis of repeat general anesthesia in a short time period, as well as the added tangible and intangible costs of a second procedure. The findings are compelling, but it should be noted that the study was ultimately a comparison of one surgeon's outcomes to those of

other three. Moreover, the SLED findings are notable in that only 16% of patients had clean cavities while nearly 35% already showed evidence of synechiae. Unfortunately, the endoscopic findings of the NoSLED group were not available, limiting a comparative analysis. Lastly, although it is difficult to draw statistical conclusions, it should be noted that only 30% of the SLED group had synechiae, whereas 80% of the NoSLED group did at the time of revision surgery for recurrent disease.

In the early 2000s, several studies further raised the question about the need for SLED. One of these studies, Ramadan's comparison of preoperative IV steroids vs. placebo, suggested that IV steroids were safe and helpful in reducing the incidence of synechiae formation, maxillary sinus swelling, and maxillary sinus ostium narrowing [34]. Moreover, Fakhri et al. described 35 pediatric FESS cases without postoperative debridement over a 10-year period, with success rates comparable to that of previous studies [18]. Not surprisingly, when surveying the 3-year practice patterns of 175 members of the American Society of Pediatric Otolaryngology (ASPO) in 2004, Sobol et al. noted that 72% of respondents did not routinely perform second-look surgery [35]. They attributed this trend to advances in office-based management techniques, although reports detailing in-office debridement in pediatric patients were lacking. Nevertheless, the debate on the best practices in pediatric FESS seemed to continue for the better part of the early 2000s. For instance, Ramadan argued that pediatric FESS should be reserved for children older than 6 years of age, given the poor outcomes in younger children [36]. Chang et al. suggested a limited approach to FESS and reserving SLED under general anesthesia for "(1) cases in which recurrence was strongly suspected during wound debridement, (2) diffuse sinonasal polyposis was present before operation, and (3) revision cases with extensive disease" [19]. Similarly, Younis recommended SLED under general anesthesia in cases of (1) incomplete primary surgery, (2) children < 7 years of age, (3) cystic fibrosis, (4) allergic fungal sinusitis, (5) PCD, and (6) the need for cultures in a toxic or septic child [37].

4.4. Current Practice Patterns in Pediatric FESS (2010s–Present)

While the interest in discerning the utility of serial postoperative debridement seems to continue in adults, as evidenced by multiple randomized clinical trials (RCTs), there has been a paucity of similar investigations in children over the last two decades [38–43]. This is likely due to the relative ease of measuring and reporting outcomes in adults, as serial endoscopic exams can be performed readily in-office and because RCTs are inherently easier to perform and more acceptable in adults than in children. Moreover, aggregating and synthesizing data are also easier in adults due to the existence of widely accepted and validated measures such as the sino-nasal outcome test (SNOT-22) [44]. On the contrary, controlled studies, validated outcome measures, long-term follow-up, and uniform reporting remain lacking in the pediatric literature, thus making any consequential comparisons and conclusions challenging. However, despite the current clinical consensus on pediatric CRS asserting that postoperative debridement after endoscopic sinus surgery is not essential for treatment success, there are several recent studies suggesting the need for further exploration of the utility of postoperative debridement in children [45].

In 2020, Helmen et al. published a retrospective cohort study assessing the efficacy of SLED under general anesthesia following pediatric FESS in cystic fibrosis patients [6]. Borne out of happenstance, where one surgeon performed routine SLED under general anesthesia while another surgeon did not, the study looked at the outcome of SLED and NoSLED in pediatric CF patients undergoing FESS for CRS from 2013 and 2016 at the Children's Hospital of Wisconsin. Out of the 61 patients included in the study, 38 underwent SLED under general anesthesia on average 22.4 days following their initial FESS. At the time of debridement, 26.3% had synechiae, 23.7% had polyp recurrence, and 7.9% had

maxillary antrostomy obstruction. Moreover, 7.9% had lateralized middle turbinate and 5.3% had mucopurulent drainage at the time of SLED. Within the first 6 months after FESS, there was no significant difference between the incidence and number of days to onset of postoperative sinonasal exacerbation, number of CF exacerbations, or revision rates. However, it is notable that the days to CF exacerbation were significantly longer in the SLED group (113.9 $\pm$ 45.5 days) compared to the NoSLED group (47.4 $\pm$ 34.1 days). Although this study does not clearly establish the utility of SLED in pediatric FESS among CF patients, some key observations are noted. For instance, the rate of early synechiae formation in CF patients is comparable to that reported in the general pediatric population undergoing SLED (i.e., approximately 20%) [11,12,14,17,20]. When considering the purpose of SLED is to facilitate proper healing by removing scar and granulation tissue, thorough sinus irrigation, and the early identification of unfavorable anatomy for medication delivery (i.e., antrostomy closure or lateralized middle turbinates), abnormal findings in over 20% of patients at the time of SLED is not insignificant. Moreover, delaying postoperative CF exacerbations with SLED may have long-term health and healthcare cost benefits and may offset the short-term cost of SLED under general anesthesia. Similarly, Chang et al. suggested that SLED under general anesthesia may be helpful in the early identification of and intervention into sinonasal pathology following endoscopic skull base surgery, particularly in children $\leq$ 12 years old or those with pedicled flap reconstruction [7].

5. Conclusions

Postoperative FESS management in pediatric patients is nuanced due to a lack of controlled studies with established and validated outcome measures, as well as limited uniformity in data reporting. Moreover, many of these studies were short-term retrospective reviews of institutional experiences that often lacked appropriate control groups or randomization. When considering the heterogeneity of the outcomes, many of which were subjective in nature, drawing any meaningful conclusion becomes even more challenging, not to mention the low evidential weight of some studies that included less than 50 subjects. Nevertheless, some insights were made possible through this scoping review. For instance, while early studies promoted the use of SLED under general anesthesia to address postoperative granulation tissue, synechiae, and/or stenosis, later studies questioned the utility of SLED given the lack of the clear benefits of SLED in terms of subjective outcomes or revision rates, in addition to concerns about the increased morbidity of an additional procedure, repeat general anesthesia, and increased costs. Moreover, the existing literature in the pediatric population on the utility of SLED is based only on one single SLED under general anesthesia, not on serial in-office SLED, as described in adults. This may be due to the traditional adage that children cannot tolerate in-office debridements. On the contrary, at the senior author's (VAP) institution, serial in-office SLEDs are routinely performed following FESS and are generally well tolerated in over 90% of children over 5 years of age, while SLED under general anesthesia is reserved for children 5 years old and younger. There remains a continued need to examine the utility of postoperative debridement following FESS, especially serial, in-office SLEDs in the pediatric population.

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