Published in final edited form as:

Otolaryngol Clin North Am. 2016 August ; 49(4): 1019–1033. doi:10.1016/j.otc.2016.03.024.

Outcomes after Frontal Sinus Surgery: An Evidence-Based Review

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Synopsis

Endoscopic sinus surgery is an effective intervention at improving quality of life for patients with medically refractory chronic rhinosinusitis. The evidence supporting frontal sinusotomy is limited to single institution case series. However, the data for Draf IIa frontal sinusotomy does demonstrate that the majority of patients experience lasting frontal sinus patency on postoperative endoscopic exam and improvements in quality of life. Salvage endoscopic frontal sinus surgery via a Draf III shows high rates of both neo-ostium patency and subjective improvements in symptoms at a 2-year time point in case series.

Keywords

Draf IIa; Draf III; endoscopic frontal sinusotomy; Endoscopic modified Lothrop; Frontal sinusitis; Frontal sinus obliteration; endoscopic sinus surgery; Frontal sinus drillout

Introduction

Chronic rhinosinusitis (CRS) is a common disease that carries significant impairment of patient quality of life¹ and patient productivity.² Chronic rhinosinusitis (CRS) can frequently be treated successfully with medical therapy, but patients that have persistent bothersome symptoms despite maximal medical therapy can elect to undergo surgical treatment of the

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Potential Conflicts of Interest: None to report

Financial Disclosures: Timothy L. Smith is supported by a grant for this investigation from the National Institute on Deafness and Other Communication Disorders (NIDCD), one of the National Institutes of Health, Bethesda, MD., USA (R01 DC005805; PI/PD: TL Smith). Timothy L. Smith and Adam S. Deconde are consultants for IntersectENT, (Menlo Park, CA, USA) which is not affiliated with or discussed in this manuscript.

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sinuses. The primary goal of endoscopic sinus surgery is to provide improvement in the quality of life (QOL) of patients that have failed medical therapy.^{3,4}

Endoscopic sinus surgery (ESS) is thought to deliver improvements in QOL through improved control of the underlying inflammatory process. Since its inception, ESS has been predicated on creation of durable openings into the sinuses that allow for efficient drainage of sinus secretions.⁵ Our understanding of the underlying pathophysiology of CRS has broadened, and a secondary goal of sinus surgery is control of the intrinsic mucosal inflammation of the sinuses through delivery of topical therapies.⁶ Patent sinusotomies, therefore, are thought to be a critical goal in control of the underlying inflammatory process.

Surgical interventions of the frontal sinus offer a unique surgical challenge because of the idiosyncracies of the frontal sinus outflow tract anatomy. The frontal sinuses rest above the frontal beak in the frontal bone with an outflow tract nestled between the orbits laterally and skull base medially. These fundamental limits of dissection provide what is frequently the most narrow sinusotomy as well as the highest risk for major complications and stenosis. Historical approaches to the frontal sinuses, including the Lynch and Lothrop procedures, had high short-term patency rates, but overtime developed 30% failure rates in the long-term.⁷ These failure rates elevated the osteoplastic flap with frontal sinus obliteration to the putative gold-standard;⁷ however, the osteoplastic flap can be associated with significant morbidity including supraorbital neuralgia, frontal bossing, abdominal fat donor site complications and difficulty with surveillance of the sinus.⁸

With the advent of endoscopic sinus surgery reasonable surgical alternatives to the open approaches were developed. Draf described a range of potential interventions from merely performing a total ethmoidectomy without any intervention on the frontal recess (Draf I), to complete clearing of the frontal recess (Draf IIA), and finally an extended sinusotomy that marsupializes the bilateral frontal sinuses through a transeptal removal of the frontal sinus floors and intersinus septum (Draf III) (Table 1).⁹ A variety of modifications of these techniques exist, but the critical difference between the various techniques would be whether the sinusotomy can be performed with hand instrumentation or requires a drill. Use of a drill requires stripped mucosa, which has been associated with high rates of restenosis⁷ and higher rates of complications on prior surgeries. Therefore for the purposes of this paper, these two types of endoscopic frontal sinus surgery will be evaluated separately.

The goal of this paper is to summarize the evidence underpinning surgical intervention of the frontal sinus. Special attention will be given to the impact of frontal sinus surgery on patient-centered quality of life measures and secondarily whether the surgical goal of creating a lasting frontal sinusotomy as measured by either endoscopic or radiographic data.

Evidence Supporting Use of Endoscopic Sinus Surgery for CRS

In determining the efficacy or effectiveness of an intervention one should consider how that intervention does relative to a comparison group. In the case of frontal sinusotomy, and ESS in general, one could consider that medical therapy is a reasonable comparison. With this in mind, prior to an investigation of the evidence underlying frontal sinusotomy, a quick review

of the evidence supporting endoscopic sinus surgery over continued medical therapy is warranted.

A randomized controlled trial of medical therapy vs ESS might ideally compare outcomes and differences between these two interventions but several important barriers exist to executing such a trial. Patients being considered for ESS have failed medical therapy, and randomizing patients to an already failed therapy would likely impair enrollment. Furthermore, one could argue that such an issue is past clinical equipoise given that multi-institutional prospective cohort studies have demonstrated that patients that have failed medical therapy improve after ESS.^{10–12}

It has only been in the last handful of years that comparative effectiveness studies comparing endoscopic sinus surgery to medical therapy have begun to emerge.^{13–15} Comparative effectiveness studies are a more pragmatic real-world approach to comparing two interventions that are observational in nature. Selection treatment bias exists since there is no randomization protocol, but this is the reality of the application of medicine and therefore offers greater external validity. The early comparative effectiveness data does support that patients with medically recalcitrant CRS are approximately three times more likely (odds ratio {OR} 3.37; 95% confidence interval {CI}, 1.27–8.90; $p=0.014$) to experience improvement on disease-specific validated QOL outcome measures.¹³ Patients electing surgical therapy are more likely to resolve thick nasal discharge, nasal obstruction and facial pain/pressure than patients pursuing only continued medical therapy,¹⁴ but no difference for olfaction outcomes.¹⁵

Given the growing body of literature favoring ESS over continued medical management in patients with medically refractory CRS, perhaps, ideally, a study designed to determine the efficacy of frontal sinusotomy would randomize patients to endoscopic sinus surgery with or without frontal sinusotomy. Problems exist with this methodology as well, in that it could be fairly argued that it is unethical to randomize patients with frontal sinus disease present on pre-operative imaging or intraoperative endoscopy away from frontal sinusotomy based on prior retrospective case series showing that persistent frontal sinus disease can lead to persistent symptoms.¹⁶ There may just be such a large effect size associated with addressing the other sinuses on QOL measures, that the differential impact of presence or absence of a frontal sinusotomy could be obfuscated on a QOL questionnaire.¹⁷ Endoscopic data may be the key to determining the difference in the outcomes, but this is admittedly not a patient-centered outcome measure as this found to be different patients undergoing surgery with and without frontal sinusotomy.¹⁷

With these limitations in mind, the following review of the evidence underlying frontal sinusotomy can be placed into adequate context. The evidence level consists entirely of single institution retrospective case series. The outcomes include both subjective measures of QOL of a variety of qualities as well as frequency of patency of the frontal sinusotomy at follow-up on either endoscopy or imaging.

Key Points

- Level 2 evidence supports use of endoscopic sinus surgery for patients with CRS with inadequately controlled symptoms on maximal medical therapy
- Understanding the impact of the extent of endoscopic sinus surgery with or without frontal sinusotomy on quality of life measures is challenging to capture because of the large effect size of any surgical intervention

Evidence of supporting use of Draf IIa frontal sinusotomy

All of the data examining the outcomes of frontal sinusotomy (specifically, Draf IIa) are level IV evidence (Table 2).^{16,18–31} A wide range of methodologies was used to capture subjective and objective outcomes. Unfortunately, validated disease-specific measures were rarely employed even in the later studies by which time such instruments were widely available. Patency rates for the most part were determined by postoperative nasal endoscopy with visualization of some portion of the frontal sinus cavity as the requirement for a patent sinusotomy. Furthermore, comparison across these studies is impaired by a lack of consistent reporting of patient baseline characteristics. Given these caveats, the majority of patients undergoing frontal sinusotomies in the literature report symptomatic improvement (68.5%–92%). Patency rates of frontal sinusotomy ranged widely (27.3%–92%), but within the last 10 years the range narrowed to 67.6%–92% with most studies reporting endoscopic patency in the mid-80% endoscopic success rates.

These studies span 25 years of investigation of the topic, which is remarkable considering how much technology and technique have evolved over that time. Since the first study was performed, a variety of new technologies have become near ubiquitous. The first study describing use of the microdebrider emerged in 1997.²² Other innovations that are not always explicitly mentioned in the studies but have permeated the specialty over this timeline include mucosal-sparing technique, introduction of image guidance, topical steroid irrigations, drug-eluting stents, and high-definition cameras. The clinical significance of any one of these interventions is not always clear, but some permutation of each of these innovations likely exists in a modern day surgical armamentarium. It is encouraging to see a general trend in improvement in outcomes between the studies from the 1990s and from the 2000s and 2010s. It does appear that the endoscopic patency rate postoperatively is more reliable with 67.6%–92% reported in the last 10 years in contrast to the first 10 years which ranges from 27.3%–100% (Table 2).

Patency rates for the most part were determined by postoperative nasal endoscopy with angled scopes with direct visualization into the cavity for the most part as a binary outcome. Postoperative frontal sinus outflow tracts though, can obstruct with either swelling of soft tissue and/or polyp recurrence or through cicatricial scar formation. This may be an important distinction, because it could be argued that sinuses failing from cicatricial scar may be secondary to technique and may benefit from an intervention such as refined surgical technique and/or possible stenting, whereas polyp recurrence may result from failure to control intrinsic mucosal disease, which might improve with control of mucosal

inflammation and may benefit from refinement of topical therapies. Future study would ideally clarify how stenosis occurs in order to better guide interventions.

There may also be some threshold of sinusotomy dimensions that are sufficient to maintain an open sinus, and Chandra et al. postulate that a diameter of 4–5-mm results in a sinus that is likely to maintain patency.²⁸ Naidoo et al. examined the size of endoscopic sinusotomy and found statistically significant difference in mean smallest dimension of the frontal sinusotomy in patients that went on to stenose and those that remained patent (95% confidence interval, respectively: 2.94–4.47 and 4.60–5.15, $p=0.0068$).¹⁶ The only difference identified was in the size of frontal sinusotomy and based on the confidence intervals the likelihood of closure of a sinusotomy greater than 4.5-mm is quite unlikely.

There does appear to be a threshold of sinusotomy size beyond which the likelihood of closure drops significantly. Hosemann et al. found that when the diameter of the ostium dropped below 5-mm the stenosis rate increased from 16% to 30%.²³ Stenosis rates rapidly increased as the diameter dropped with sinuses with 2-mm diameters resulting in stenosis in 50% of the sinusotomies. When comparing the intraoperative and postoperative diameters, a mean decrease of 1.1-mm was observed (from 5.6-mm to 3.5-mm), representing a relative reduction of 37.5% of the diameter. Preoperative imaging often can clue the surgeon into the fundamental limits of a frontal recess dissection and inherently narrowed anatomy may be one variable that can preoperatively forecast failure.

Maximization of the frontal sinusotomy is a critical goal of surgical intervention, but this opening must not come at the expense of mucosal preservation. This dogma is not based on a large evidence base, but early experience with mucosal trauma via external approaches, led to high frontal sinus failure rates.⁷ The findings are reiterated in some of the early Draf IIa surgeries prior to the complete evolution of modern surgical endoscopic technique. Wigand and Hosemann reported high rates of frontal sinus stenosis (40%), but report using a drill in approximately 50% of the cases.¹⁹ There was a relatively low-threshold to use a diamond drill in unilateral procedures in an effort to maximize the outflow tract that may explain the high rate of stenosis. The impact of mucosal trauma may be reflected in increasing stenosis rates of the small diameter frontal sinusotomies. As sinusotomies approach the diameters of instrumentation the risk of iatrogenic mucosal trauma increases. Careful technique and appropriate instrumentation may decrease the risk of cicatricial stenosis.

Although the size of the frontal sinusotomy likely plays an important role in patent frontal sinuses, it's conceivable that the underlying inflammatory process also influences success and failure. Remarkably, there was no difference between patients with patent and stenosed frontal sinusotomies in rates of nasal polyposis, eosinophilic mucin, asthma, LM (overall and frontal sinus-specific) and prevalence in allergy in the study by Naidoo et al.¹⁶ Askar et al. did no statistical analysis of the subtypes of disease, but the patency rate appears comparable across the board regardless of statistical significance with 88.4% of patients with CRS with nasal polyps, 91.9% of patients with CRS without nasal polyps, 88.9% of patients with allergic fungal sinusitis and 100% of mucocoeles remaining patent.³¹ These data are somewhat surprising as there has really been such an emphasis on the importance of controlling intrinsic mucosal inflammation with topical steroids,⁶ and there is optimism that

control of dysbiosis may prevent sinusitis recurrence and/or persistence.³² One could speculate that perhaps the effect size of a large sinusotomy washes out the impact of the severity of the mucosal inflammation. Or perhaps the studies have not identified the best variables to measure intrinsic mucosal inflammation or scar formation. No data exists on the impact of the tissue eosinophilia or osteoneogenesis on frontal sinusotomy stenosis, both of which have been linked together and to diminished postoperative gains in quality of life.^{33,34} Larger sample sizes that could power the detection of differences on multivariate analysis patient characteristics on endoscopic outcomes would be required to clarify this issue.

Understanding the impact of frontal sinusotomy on subjective outcomes is challenging to capture and isolate since so frequently frontal sinusotomy is combined in conjunction with other surgical interventions. Achieving a clinically meaningful difference on a disease-specific outcome measure is a higher bar to clear and a prospective cohort analysis did not find that the extent of surgery achieved clinical significance.¹⁷ A comparison of patients that had frontal sinusotomies that stenosed found they were more likely to have persistent sinonasal symptoms.¹⁶ An examination of patients electing revision sinus surgery demonstrated that retained cells narrowing the frontal recess and/or middle turbinate lateralization was present in the majority of patients.³⁵ Although the data on the subjective outcomes of frontal sinusotomy of CRS cannot demonstrate efficacy, there is concern that failure to completely address the sinuses may lead to increased stenosis, increased symptoms, and potentially revision surgery.

Although the level of evidence remains low, and the volume of patients studied remains low, there are some critical learning points from the frontal sinusotomy Draf IIa literature. Maximization of the frontal sinusotomy is critical to prevent stenosis, and really one of the few variables in the control of the surgeon. This opening should ideally be greater than 4.5-mm, as such a sinusotomy is unlikely to stenose regardless of the underlying pathology. Subjects with inherently narrow outflow tracts that cannot be augmented to such a size secondary to close orbits and/or close frontal beak are at high risk of failure with a Draf IIa technique. These patients can be recognized preoperatively on imaging, and should be counseled that they are at increased risk for possibly needing an extended sinusotomy as a salvage operation. Furthermore, the optimization of the frontal sinusotomy diameter should not come at the cost of mucosal stripping as this can predispose to cicatricial scarring. Appropriately and surgically successfully addressing the frontal sinus may decrease postoperative symptom burden as frontal sinusotomy stenosis is associated with persistent symptoms. Retained frontal sinus cells have also been reported at high rates seeking revision surgery.

The decision to perform a frontal sinusotomy, then, is likely different in the hands of each surgeon as the risk benefit-analysis of potential gains must be weighed against each surgeon's comfort level with frontal sinusotomy. Induction of iatrogenic cicatricial scarring, or worse, orbital or neurological complications is a risk that is unique to each surgeon and as a profession currently rely on each individual surgeon to judge what intervention optimizes patient outcomes.

Key Points

- The level of evidence for the effectiveness of Draf IIa frontal sinusotomy is entirely composed of case series.
- The available evidence demonstrates that Draf IIa mucosal-sparing openings greater than 4.5-mm in diameter have a very high patency rate postoperatively.
- Stenosis of the frontal sinus is associated with persistent symptoms

Evidence supporting use of Draf III frontal sinusotomy

Although the draf IIa has shown high rates of patency, a variety of situations may arise that might make a draf IIa not feasible or eventually fail. Therefore, a clear understanding of the optimal salvage surgery is critical to any surgeon embarking on surgical treatment of the frontal sinus. An open approach to the frontal sinus with removal of the frontal bone was first described by Reidel in 1889, and modified in the 1950s with preservation of the osteoplastic flap and stripping of the sinus mucosa with subsequent obliteration of the sinus.³⁶ The goal of frontal sinus obliteration is to achieve a scarred and non-functional sinus while preserving cosmesis and achieves such a success in 75–93% of patients.³⁷ Frontal sinus obliteration, however, is not without morbidity. The procedure takes longer and has higher blood loss than the Draf III,³⁷ and late mucocoele formation can be detected on MRI in 10% of patients.³⁸ Other late complication include numbness of V1 (8.5%), frontal embossment (3.4%), insufficient esthetic results (5.1%), extrusion of allograft obliteration material (3.4%) and depression of the frontal table (6.8%).³⁸

The Draf III seeks to provide a less morbid approach with comparable efficacy. Draf described the procedure in 1991⁹ and its application was reported in 1995 by Gross et al.³⁹ as an alternative to frontal sinus obliteration. The modern day Draf III is a modification of Draf's description of removing of the superior septum and frontal intersinus septum along with all frontal recess cells. Removal of the frontal beak with a drill provides a much larger opening to the frontal sinus, but does come at the trade-off of mucosal stripping. The true fundamental limits of the Draf III are from the first olfactory fiber posteriorly and the periosteum laterally and anteriorly.⁴⁰

The literature on Draf III frontal sinusotomies is similar to that on the Draf IIa consisting predominantly of case series from single institutions (Table 3)^{24,26,39,41–61} with similar outcomes. In some ways, though, more evidence has been published on this salvage surgery that is required in only a minority of patients with CRS. A systematic review on the safety and efficacy of the Draf III found that endoscopic patency rates were high (95.9% of 354 available for endoscopic evaluation) at 28.5 months postoperatively.⁶² Similarly, improvement in symptoms was achieved in 82.2% of patients. These are impressive results for a salvage operation. However, long-term data shows that the neo-ostium decreases in size for up to 2-years after surgery,^{60,61} which requires at least as long of follow-up to draw conclusions about patency outcomes. There is a trend in longer follow-up for the endoscopic patency rates in the recent literature, which is critical data given the need to leave exposed bone when drilling out the frontal beak. Therefore, the discussion of this review will be

focused on truly long-term data (defined by greater than 2-year follow-up as the long-term results of the Draf III is where the controversy remains.

Two recent studies examining the long-term endoscopic outcomes vary widely in patency rates. Naidoo et al.⁶⁰ reported on 229 patients that underwent Draf III procedures with mean follow-up of 45 months. Endoscopic patency rates of the neo-ostium occurred in 221/229 (97%) of patients. Measurements of the neo-ostial axes found mean dimensions of 21.0 × 19.5-mm. Neo-ostia stabilized after 2 years. Ting et al.⁶¹ report another long-term study examining outcomes of 143 patients with a mean follow-up of 10.2 years. Although the retrospective nature of this study precluded endoscopic measurement of neo-ostia over time, the endpoint need for revision surgery found that 29.9% of patients went on to require revision surgery. Although the Ting study does report on a longer timeline, the vast majority of these revision occurred within the first 5-years. This experience is in stark contrast to the 5.2% revision surgery rate reported by Naidoo et al.⁶⁰ The experience of Ting et al. is more in line with the prior study with Casiano and Livingston⁴² reporting 43% stenosing by more than 50% within six months of surgery. Tran et al. also reported a mean stenosis of 33% of the neo-ostium cross-sectional area that continued out to 1 year.⁵⁴

Subjective outcomes mirror the objective findings. The long-term data reported by Naidoo et al.⁶⁰ used a validated sinus-specific subjective measure that found 47% of patients were asymptomatic postoperatively and another 27% reporting only mild symptoms. A minority of subjects had severe symptoms (8%), but there was no worsening of symptoms after Draf III. These data are again in stark contrast to the high rate of patients electing revision surgery in the Ting study.

Naidoo et al. offer some theories as to the success of their Draf III's.⁶⁰ The large neo-ostium achieved may allow for increased delivery of topical therapies and increase the volume of irrigation preventing accumulation of discharge. The large neo-ostium's reported by Naidoo et al. may also allow for greater cicatricial scarring or tissue edema without leading to a complete stenosis. An examination of the mean neo-ostium created intraoperatively between the Naidoo and Ting study, there does appear to be a difference in operative endpoints. Although the methods of measurement and reporting are different between the two studies, Naidoo et al. reported a 21.0 mm by 19.5 mm opening in contrast to a total mean area of 98.4 mm². Maximizing the extent of the neo-ostium carries little downside⁴⁰ and is a critical variable in both the subjective and objective outcomes that the surgeon has the capability of influencing.⁶³

Key Points

- Draf III is an effective way to salvage recalcitrant frontal sinusitis
- Symptoms are improved in approximately 85% of patients
- Although long-term patency rates vary, high patency rates (97%) are maintained and stable beyond 2-years in cases with large neo-ostia (20 × 20-mm).

Summary

Endoscopic sinus surgery is an effective intervention at improving quality of life for patients with medically refractory chronic rhinosinusitis. The data supporting endoscopic Draf IIa frontal sinusotomy as part of endoscopic sinus surgery is limited to single institution case series. However, the data does demonstrate that the majority of patients experience lasting frontal sinus patency on postoperative endoscopic exam and improvements in quality of life. Salvage endoscopic frontal sinus surgery via a Draf III shows high rates of both neo-ostium patency and subjective improvements in symptoms at a 2-year time point. The long-term data is mixed and more study is warranted to establish the long-term efficacy at salvaging the most recalcitrant cases of frontal sinusitis.

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Key Points

- Frontal sinusotomy via Draf IIa is effective for the majority of patients with medically refractory frontal sinusitis based on reported case series.
- Endoscopic postoperative patency rates of Draf IIa surgery is significantly higher in patients who intraoperatively achieved diameter no smaller than 4.5-mm
- Frontal sinus closure by either cicatricial stenosis or polypoid edema is associated with persistent symptoms after Draf IIa
- Draf III is an effective salvage operation for patients that avoids some of the morbidities associated with frontal sinus obliteration.
- Short-term (2-year) neo-ostial patency rates are high and are associated with high rates of symptom control

Table 1
Summary of evidence of types of frontal sinusotomies

Description and terminology of frontal sinusotomies

Frontal Sinusotomies	Description
Draf I	Total ethmoidectomy with no instrumentation of the narrowest part of the frontal recess
Draf Iia	Mucosal-sparing clearance of the frontal recess of tissue
Draf Iib	Removal of the superior anterior attachment of the head of the middle to the septum turbinate and the floor of the frontal sinus
Extended Draf IIB/Unilateral drillout	A draf Iib that includes unilateral drilling away of the frontal beak
Draf III	Removal of the frontal intersinus septum, the frontal beak and the superior septum

Table 2

Summary of evidence for Draf IIa

Evidence summary of Draf IIa frontal sinusotomy

Study	Year	Study design	LOE	Number of Subjects	Procedures	Mean follow-up (months)	Objective Outcome	Objective Outcome Success Rate	Subjective outcome	Subjective outcome success rate
Schaefer and Guse ¹⁸	1990	RCS	IV	36	Frontal sinusotomy	16.4	Endoscopy and/or CT	21/36 patent	Non-validated measures	21/36 resolved, 11/36 improved
Wigand and Hosemann ¹⁹	1991	RCS	IV	220	126 sinus drillouts	41	Endoscopic patency	40%	NA	NA
Moriyama et al. ²⁰	1994	RCS	IV	57	Frontal sinusotomy	6-41 (range)	Endoscopic patency	73.40%	NA	NA
Christmas and Krouse ²¹	1996	RCS	IV	30	Frontal sinusotomy	NA	Endoscopic patency	100%	NA	NA
Jacobs ²²	1997	RCS	IV	101	Frontal sinusotomy	16	Endoscopic patency	27.3% of patients with polyps, 76.9% without polyps	Non-validated	85% reported improvement
Hosemann et al. ²³	1997	RCS	IV	110	Frontal sinusotomy	13	Endoscopic probing	81%	Non-validated	87% report improvement
Metson and Glicklich ²⁴	1998	PCS	IV	63	24 frontal drillouts	22.7	Need for revision surgery	87.5% did not require obliteration	CSS and SF-36	Statistically significant improvement in CSS and SF-36
Wormald ²⁵	2002	PCS	IV	64	Frontal sinusotomy	15.4	Endoscopic patency	82%	Non-validated measures	82% resolved symptoms
Wormald and Chan ²⁶	2003	RCS	IV	44 (13 Draf IIIs)	13 Draf IIIs	12	Endoscopic patency	100%	Non-validated measures	82% resolved symptoms
Chiu and Vaughn ²⁷	2004	RCS	IV	67	Frontal sinusotomy	32	Endoscopic patency	86.60%	RSOM-31	Mean improvement of 57% on RSOM-31 (30% = clinically meaningful)
Chandra et al. ²⁸	2004	RCS	IV	66	Frontal sinusotomy	8.3	Endoscopic patency	82.30%	Non-validated measures	NA
Friedman et al. ²⁹	2006	RCS	IV	157	Frontal sinusotomy	72.3	Endoscopic patency	67.60%	Non-validated measures	92% improved
Chan ³⁰	2009	RCS	IV	161	Frontal sinusotomy	45.9	Endoscopic patency	88%	SNOT-20	68.5% improved
Naidoo et al. ¹⁶	2012	RCS	IV	109	Frontal sinusotomy	16.2	Endoscopic patency	92%	Non-validated measures	85/109 resolved, 78%
Askar ³¹	2015	PCS	IV	60	Frontal sinusotomy	10	Endoscopic patency	90%	RSDI	

LOE = Level of evidence, RSOM-31 = Rhinosinusitis Outcome Measures (RSOM-31), CSS=Chronic sinusitis survey, SF-36=Short Form 36, RCS = retrospective case series, PCS = prospective case series, NA = not available

Data from Refs 16,18-31.

Table 3

Summary of evidence for Draf III

Evidence summary of Draf III frontal sinusotomy

Study	Year	Study design	LOE	n	Study groups	Mean follow-up (months)	Revision surgery (n { %})
Gross ³⁹	1995	RCS	IV	10	Draf III	7	0 (0)
Gross ⁴¹	1997	Comparative OPF cohort	III	20	OPF, Draf III	12	0 (0)
Casiano and Livingston ⁴²	1998	RCS	IV	21	Draf III	NA	2 (9.5)
Metson and Gliklich ²⁴	1998	RCS	IV	9	Draf III	22.7	0 (0)
Kikawada ⁴³	1999	RCS	IV	16	Draf III	23.3	2 (13) *
McLaughlin et al ⁴⁴	1999	RCS	IV	20	Draf III	12	0 (0)
Ulualp ⁴⁵	2000	Comparative OPF cohort	III	15	OPF, Draf III	6-30 (range)	2 (13)
Schulze et al ⁴⁶	2002	RCS	IV	13	Draf III	34.5	2 (15)
Schlosser et al ⁴⁷	2002	RCS	IV	54	Draf III	40.3	17 (32)
Samaha et al ⁴⁸	2003	RCS	IV	66	Draf III	49.2	10 (15)
Stankiewicz and Wachter ⁴⁹	2003	RCS	IV	10	Draf III	34	5 (50)
Wormald et al ⁵⁰	2003	RCS	IV	16	Draf III	18.9	1 (6.3)
Wormald and Chan ²⁶	2003	RCS	IV	13	Draf III	NA	0 (0)
Wormald ⁵¹	2003	RCS	IV	83	Draf III	21.9	6 (7.2)
Khong et al ⁵²	2004	RCS	IV	21	Draf III	NA	2 (9.5)
Banhiran et al ⁵³	2006	RCS	IV	72	Draf III	22	5 (6.9)
Tran et al ⁵⁴	2007	RCS	IV	77	Draf III	29.2	10 (13)
Shirazi et al ⁵⁵	2007	RCS	IV	97	Draf III	18	22 (23)
Nakagawa and Ito ⁵⁶	2007	RCS	IV	6	Draf III	24.5	0 (0)
Eloy et al ⁵⁷	2011	RCS	IV	120	Draf III	24.6	15 (13) *
Georgalas et al ⁵⁸	2011	RCS	IV	122	Draf III	NA	39 (32)
Hildenbrand et al ⁵⁹	2012	RCS	IV	24	Draf III	25.6	1 (4.2)
Naidoo et al ⁶⁰	2014	RCS	IV	229	Draf III	45	12 (5.2)
Ting et al ⁶¹	2014	RCS	IV	204	Extended Draf Iib (n=61), and Draf III (n=143)	120	61 (30)

LOE = level of evidence, RCS = retrospective case series, OPF = osteoplastic flap,

* endpoint reported is endoscopic closure, not revision surgery

Data from Refs 24,39,26,41-61.

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