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Outcomes of chronic frontal sinusitis treated with ethmoidectomy: a prospective study

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Abstract

Background—In medically refractory chronic frontal sinusitis, ethmoidectomy without instrumentation of the frontal ostium may resolve frontal disease. Our aim was to determine the efficacy of ethmoidectomy alone for the treatment of chronic frontal sinusitis.

Methods—Adults with chronic rhinosinusitis prospectively enrolled in a multi-center study who demonstrated frontal sinusitis on computed tomography were divided into two groups: 1) endoscopic sinus surgery (ESS) incorporating ethmoidectomy, but excluding frontal sinusotomy; and 2) ESS incorporating frontal sinusotomy. The primary outcome was improvement in SNOT-22 scores. Secondary outcomes included endoscopic scores and use of corticosteroids and antibiotics.

Results—196 cases undergoing frontal sinusotomy and 30 cases treated with ethmoidectomy without frontal sinusotomy were analyzed and were comparable demographically. The prevalence of nasal polyps, previous ESS, asthma, and aspirin intolerance was more common in the frontal sinusotomy group ($p < 0.050$). Preoperative endoscopy and computed tomography scores were higher in the frontal sinusotomy group ($p = 0.001$). Postoperatively, both groups showed

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comparable SNOT-22 scores with worse endoscopy scores in the frontal sinusotomy group ($p=0.038$). Postoperative improvement in SNOT-22 total and subdomain scores was comparable between groups. Nasal endoscopy scores improved to a greater degree in the frontal sinusotomy group ($p=0.023$). Duration of postoperative topical steroid use was higher in the frontal sinusotomy group ($p=0.007$). Revision surgery was needed in 2.6% of frontal sinusotomy patients and 0% of patients without frontal sinusotomy.

Conclusions—The treatment of chronic frontal sinusitis through ethmoidectomy is a potential alternative to frontal sinusotomy achieving similar QOL improvements in patients manifesting less severe sinus disease.

Keywords

Sinusitis; Frontal Sinusitis; Quality of life; Endoscopy; Minimally Invasive Surgical Procedures; Patient selection; Outcome assessment (health care)

INTRODUCTION

The surgical management of chronic frontal sinusitis has evolved from primarily open techniques to transnasal endoscopic procedures that are less morbid but at least as efficacious¹. The goals of surgical treatment are to relieve existing disease and prevent disease recurrence². Among all of the paranasal sinuses, surgery of the frontal sinus is associated with a higher incidence of stenosis and treatment failure, often necessitating revision surgery²⁻⁴. Consequently, surgeons must carefully select the initial surgical approach to maximize treatment relief while minimizing morbidity and treatment failure. Surgeons must also identify patients in whom more conservative, less morbid endoscopic surgical techniques may prove beneficial without compromising outcomes. However, the evidence guiding the selection of patients who may benefit from less aggressive surgery is lacking.

Endoscopic surgical options for chronic frontal sinusitis, generally, fall into three categories: 1) anterior ethmoidectomy without instrumentation of the frontal recess itself (Draf I procedure), 2) unilateral enlargement of the frontal recess outflow tract with or without removal of the frontal sinus floor (Draf IIa or IIB procedure), and 3) trans-septal frontal sinusotomy (Draf III procedure). Typically, this final option is reserved for salvage surgery after failure of more conservative options⁴. The former two options can, potentially, allow for the successful resolution of chronic frontal disease. Since the frontal sinus drains dependently into the frontal recess, endoscopic procedures that avoid instrumentation of the frontal recess itself but address distal obstruction by removal of anterior ethmoid cells—the Draf I procedure—may resolve frontal sinus disease.

To date, only one retrospective study has compared the efficacy of anterior ethmoidectomy alone and frontal sinusotomy in the treatment of chronic frontal sinusitis⁵. Becker et al. demonstrated that in 121 diseased frontal sinuses across 77 patients with chronic frontal sinusitis, initial treatment with anterior ethmoidectomy (Draf I procedure) was associated with resolution of disease in 88.5% of frontal sinuses. Factors that predisposed to failure of this initial surgical approach included a diagnosis of aspirin-exacerbated respiratory disease

(Samter's triad), presence of both nasal polyposis and asthma, or identification of inter-frontal sinus septal cells. The authors concluded that anterior ethmoidectomy could be effective for the initial treatment of chronic frontal sinusitis.

The aim of the current prospective, multi-center study is to evaluate the impact of anterior ethmoidectomy performed with and without frontal sinusotomy in patients with radiologic evidence of frontal sinusitis. We compare disease-specific quality-of-life (QOL) outcomes and use of concurrent medical therapies in the two cohorts. We also investigate disease characteristics which may facilitate the identification of patients with chronic frontal sinusitis who are more likely to benefit from less aggressive surgical treatment.

MATERIALS and METHODS

Patient Population

Adult (≥ 18 years of age) study subjects with a current diagnosis of medically refractory CRS were prospectively enrolled into an ongoing multi-centered, observational cohort investigation between February, 2011 and March, 2014 to assess treatment outcomes of endoscopic sinus surgery (ESS) procedures. Preliminary findings from this cohort study have been described⁶⁻⁸. A diagnosis of chronic rhinosinusitis (CRS) was confirmed by the enrolling physician using the 2007 Adult Sinusitis Guidelines⁹. Medically refractory disease was identified following unsuccessful symptom resolution after previous medical therapy with systemic, broad-spectrum or culture-directed antibiotics (≥ 2 weeks duration) and either topical nasal corticosteroid sprays (≥ 3 week duration) or at least a 5-day trial of systemic corticosteroid therapy during the 12-months preceding enrollment. Study subjects were enrolled from four academic rhinology practices located within Oregon Health & Science University (OHSU, Portland, OR, USA), the Medical University of South Carolina (Charleston, SC, USA), Stanford University (Palo Alto, CA, USA), and the University of Calgary (Calgary, Alberta, Canada). The Institutional Review Board at each enrollment site approved study protocols. Central coordinating services were conducted at OHSU (eIRB#7198). Participants were enrolled in study activities for a total of 18 months and evaluated postoperatively at 6-month intervals.

Study participants were ensured that participation would not alter their normal standard of care. Patients were enrolled after electing ESS as the subsequent treatment modality for the pursuance of symptom resolution. Surgical procedures consisted of either unilateral or bilateral maxillary antrostomy (Current Procedural Terminology, CPT, codes: 31256, 31267), partial (CPT code: 31254) or total ethmoidectomy (CPT code: 31255), sphenoidotomy (CPT codes: 31287, 31288), inferior turbinate reduction (CPT code: 30140), frontal sinus procedures (CPT code: 31276), septoplasty (CPT code: 30520), and use of image guidance when indicated. Study participants were either primary or revision ESS cases. All the study participants underwent either total or partial ethmoidectomy procedures at a minimum. All patients underwent follow up within 1 to 2 weeks of surgery for post-operative debridement. Post-operative regimens included nasal saline irrigations, topical nasal steroid sprays or rinses, oral steroids, and antibiotics. The timing and duration of these postoperative interventions was left to the discretion of the treating physician.

Clinical Disease Severity Measures

During the initial clinical/enrollment visit, all study participants completed a medical history, head and neck clinical examinations, 0 or 30° rigid sinonasal endoscopy, using rigid endoscopes (Karl Storz, Tuttlinger, German), and computed tomography (CT) scan of the sinuses with reformatted coronal plane images derived from the acquired 0.625-3.0mm. axial slices. Sinonasal endoscopic examinations were scored using the Lund-Kennedy scoring system where higher scores represent worse disease severity (score range: 0-20)¹⁰. This staging system grades bilateral, visual characteristics of the sinonasal cavity including polypoid, discharge, edema, scarring, and crusting. CT images were staged in accordance with the Lund-Mackay scoring system where higher scores represent higher severity of disease (score range: 0-24)¹¹. This scoring system quantifies the degree of image opacification in the maxillary, ethmoidal, sphenoidal, ostiomeatal complex, and frontal sinus regions using numerical designations (0 = “no abnormalities”, 1 = “partial opacification”, 2 = “total opacification”). All visualizations were subjectively scored by the enrolling physician at the time of enrollment.

Inclusion and Exclusion Criteria

Study subjects with a confirmed surgical date were selected for preliminary cohort analysis. Study patients were excluded from final analyses if they failed to complete either baseline evaluations or a minimum of 6-month follow-up for study-related evaluations. Further exclusions included presence of ciliary dyskinesia, cystic fibrosis, sinonasal malignancy, and/or systemic autoimmune disorders including Wegener’s granulomatosis, systemic vasculitides, and sarcoidosis, due to the known intranasal manifestations of these pathologic processes, disease heterogeneity, and variations in subsequent treatment. All final cohort subjects underwent, at a minimum, either an anterior (partial) or total ethmoidectomy during ESS and had confirmed chronic frontal sinusitis with at least partial opacification (1) in one or both frontal sinus regions on CT imaging. The choice of surgical procedure, including the decision on whether to perform a frontal sinusotomy, was left to the discretion of the treating physician.

Study Data Collection

Study participants were required to complete all necessary baseline surveys in English and were asked to provide demographic, social and medical history cofactors including: age, gender, race, ethnicity, education (years), nasal polyposis, history of prior sinus surgery, asthma, acetylsalicylic acid (ASA) intolerance, chronic obstructive pulmonary disorder (COPD), current tobacco use, alcohol use, depression, known allergies (reported by patient history or objective skin prick or radioallergosorbent testing), autoimmune disorders, ciliary dysfunction/cystic fibrosis, asthma/sinusitis related corticosteroid dependency, and any adjunct surgical intervention.

Study subjects were asked to complete the 22-item Sinonasal Outcome Test (SNOT-22) at the first baseline enrollment meeting and at least 6 months postoperatively. The SNOT-22 is a validated treatment outcome measure of chronic sinonasal conditions (Copyright 2006, Washington University in St. Louis, Missouri). Higher scores on SNOT-22 survey items suggest decreased patient functioning or worse symptom severity (total score range: 0-110).

Scoring is conducted via Likert scale responses where 0="No problem", 1="Very mild problem", 2="Mild or slight problem", 3="Moderate problem", 4="Severe problem", and 5="Problem as bad as it can be"¹². Exploratory factor analysis has previously identified 5 distinct subdomains of the SNOT-22 instrument derived of summarized item responses including: rhinologic symptoms (range: 0-30), extra-nasal rhinologic symptoms (range: 0-15), ear and/or facial symptoms (range: 0-25), psychological dysfunction (range: 0-35), and sleep dysfunction (range: 0-25)¹³.

The secondary outcomes of interest included improvement in duration of antibiotic therapy and route and duration of corticosteroid therapy. Participants were asked to recall the number of days within the preceding 90 day timeframe during which they had used prescription medications for sinusitis including:

- 1) Topical nasal steroid sprays
- 2) Topical nasal steroid drops/irrigations
- 3) Oral/systemic steroids
- 4) Oral/systemic antibiotics

Data Management and Statistical Analysis

Study data was stripped of all protected health information and transferred from each enrollment site to the central coordinating site for data entry into a Microsoft Access database (Microsoft, Redmond, WA, USA). All statistical analysis was performed using SPSS v.22.0 (IBM, Armonk, NY). Study data related to demographics, history, and both primary and secondary outcomes was analyzed to confirm assumptions of normality and linearity when appropriate. After exclusion criteria, final cohort data was dichotomized between participants with and without (unilateral or bilateral) frontal sinusotomy during ESS procedures. The outcomes of interest included postoperative improvement in mean SNOT-22 scores, days of reported concurrent medical therapy, and endoscopy examination scores. Outcomes were operationalized by subtracting preoperative outcome scores from postoperative outcome scores. Last available SNOT-22 scores were used due to previously reported consistency of postoperative scores between 6-month, 12-month, and 18-month follow-up¹⁴.

Differences between all continuous descriptive factors and both preoperative and postoperative outcome measure scores, between participants with and without frontal sinusotomy, were evaluated using Mann Whitney U or chi-square (χ^2) testing where appropriate. Significant improvements in outcome measure scores over time and between preoperative and postoperative scores were evaluated using Wilcoxon signed rank tests. Significant differences were identified at a conventional 0.050 alpha level.

RESULTS

Cohort characteristics

A total of 512 study participants undergoing FESS were enrolled between February, 2011 and March, 2014. A minimum of 6-month follow-up was not available for 193 subjects.

Eighty-four additional participants were excluded due to the absence of frontal sinusitis on CT evaluation. Seven participants with cystic fibrosis and 2 with sarcoidosis were eliminated following exclusion criteria. A total of 226 subjects were selected for final analysis and dichotomized into participants with (n=196; 86.7%) or without (n=30; 13.3%) unilateral or bilateral frontal sinusotomy as a component of interventional ESS, and were found to have comparable follow-up (12.6[5.4] months vs. 13.8[6.7] months, respectively; $p=0.366$). Bivariate comparisons of baseline characteristics are described in **Table 1**. Participants with unilateral or bilateral frontal sinusotomy procedures during ESS were found to have significantly higher prevalence of nasal polyposis, history of prior sinus surgery, asthma, and ASA intolerance, but a significantly lower prevalence of turbinate hypertrophy.

Functional endoscopic sinus surgery procedures

The frequency of each distinct surgical procedure type was compared between participants with and without unilateral or bilateral frontal sinusotomy (**Table 2**). Participants with frontal sinusotomy underwent a significantly lower frequency of partial ethmoidectomy surgery and inferior turbinate reduction compared to participants without frontal sinus surgery. The same subgroup was significantly more likely to undergo total ethmoidectomy, sphenoidotomy, middle turbinate resection, and use of image guidance during ESS. The prevalence of all frontal sinusotomy procedures was significantly greater in that group by definition.

Mean preoperative outcome evaluations

Study participants with and without frontal sinusotomy reported statistically comparable preoperative SNOT-22 scores and average days of prior concurrent medical therapy before ESS, with the exception of greater mean days of oral/systemic steroid use in those participants requiring frontal procedures (**Table 3**). The mean duration of oral/systemic steroid use was likely influenced by differing prescribing patterns amongst clinicians participating in this study. Average preoperative sinonasal endoscopy and CT scores were both significantly higher in participants undergoing frontal sinusotomy indicating slightly more overall visualized disease severity.

Mean postoperative outcome evaluations

Study participants with and without frontal sinusotomy reported statistically comparable postoperative SNOT-22 scores and average days of prior concurrent medical therapy before ESS, with the exception of greater mean days of topical nasal steroid drops/irrigation use and slightly worse postoperative sinonasal endoscopy scores in those requiring frontal procedures (**Table 4**).

Comparisons of mean postoperative improvements

Significant postoperative improvement for all mean SNOT-22 and endoscopy scores was reported for both subgroups with and without frontal sinusotomy. The magnitudes of improvement were also comparable between subgroups ($p=0.396$). Concurrent medical therapy in the frontal sinusotomy subgroup significantly improved after ESS for all medications, with the exception of days of topical nasal steroid drops/irrigations which

significantly increased postoperatively. Participants without frontal sinusotomy procedures during ESS reported significant reductions in the number of days during which they used oral/systemic steroids and oral/systemic antibiotics. These patients did not, however, report any significant change in the number of days during which topical steroid sprays or steroid drops/irrigations were used postoperatively.

Across all enrollment locations, a total of 5 participants undergoing unilateral or bilateral frontal sinusotomy required adjunct surgery within the 18-month study duration including revision frontal sinusotomy (2.6%). That subgroup was observed for a total of 2,474 person-months which represents an incidence density rate of 2.0/1,000 person-months, indicating a very minor risk of needing adjunct surgical intervention having undergone frontal sinusotomy during ESS procedures. No adjunct surgical therapy was required for the subgroup without initial frontal sinusotomy procedures.

DISCUSSION

The primary objective of this study was to determine the efficacy of anterior or total ethmoidectomy, without frontal sinusotomy, in improving QOL measures and adjunct medical therapy usage in patients with chronic frontal sinusitis. The secondary objective of the study was to identify patient characteristics that are associated with successful outcomes following the use of ethmoidectomy without frontal sinusotomy for the treatment of chronic frontal sinusitis. By avoiding direct instrumentation of the frontal recess, this Draf 1 approach has the theoretical advantage of avoiding mucosal injury and resultant stenosis within the frontal recess⁵.

This study indicates that QOL symptom scores improved to a similar degree in chronic frontal sinusitis patients undergoing ethmoidectomy without frontal sinusotomy compared to those undergoing the mainstay technique of frontal sinusotomy. At six months follow up, the magnitude of improvement in quality-of-life SNOT-22 was comparable between these two groups (24.9% vs 25%, respectively). There was no comparable difference between the postoperative scores achieved in any of the previously described SNOT-22 quality-of-life subdomains between the frontal sinusotomy and ethmoidectomy groups¹³.

Although both cohorts saw significant improvements between their pre- and post-operative Lund-Kennedy endoscopic scores, the magnitude of improvement in endoscopic score was greater in the frontal sinusotomy group relative to the ethmoidectomy without frontal sinusotomy group ($p=0.023$). Both the frontal sinusotomy and ethmoidectomy groups saw significant and comparable decreases in their postoperative use of oral steroids (8.5% vs 1.8%, respectively) and oral antibiotics (9.6% and 11.6%, respectively). Interestingly, although patients in the ethmoidectomy group did not see a significant change in their use of topical nasal steroids, patients who underwent frontal sinusotomy noted a significant increase in their use of topical nasal steroids – this is difficult to interpret in the context of differing prescribing patterns amongst clinicians across participating centers.

The above findings must be interpreted in the context of key differences between the two treatment cohorts. The endoscopic frontal sinusotomy population had a significantly higher

prevalence of nasal polyposis, history of prior sinus surgery, asthma, and ASA intolerance. Taken together, the outcomes of this study suggest that in patients with chronic frontal sinusitis who do not have nasal polyposis, asthma, or ASA intolerance, and who are undergoing primary sinus surgery, ethmoidectomy without frontal sinusotomy is an effective procedure, achieving similar QOL improvements and comparable decreases in the use of oral steroids and antibiotics as frontal sinusotomy.

There is evidence that owing to their spatial proximity, inflammation in the frontal sinus may affect the adjacent anterior ethmoid sinus. The density of sinus opacity on CT scan reflects the intrinsic properties of the underlying sinusitis and correlates with symptom severity¹⁵⁻¹⁷. Furthermore, the radiodensity characteristics of disease in the frontal and anterior ethmoid sinuses are closely correlated and consistently approximate one another—this is not the case in spatially distinct sinuses¹⁷. This finding suggests that CRS occurring in these adjacent sinuses may arise from a common pathogenesis. Taken together with the correlation between high-density opacification of the sinuses and severe sinonasal symptoms, the frontal-ethmoid linkage may explain our finding that, in select patients, ethmoidectomy without frontal sinusotomy can often resolve chronic frontal sinusitis. There is also evidence that certain anatomic characteristics such as the site of superior attachment of the uncinate process and the presence of frontal recess cells may predispose to frontal sinusitis¹⁸⁻²². These anatomic details were not accrued in our study and their influence on treatment outcomes was not evaluated.

There are limitations to our study. There were significant differences between the treatment arms with the frontal sinusotomy group demonstrating significantly greater rates of nasal polyposis, history of previous sinus surgery, asthma, and ASA intolerance. However, none of these factors had a significant effect on the primary outcome quality-of-life scores and controlling for these differences was not warranted. Furthermore, subgroup analysis that excludes patients with nasal polyposis, prior surgery, asthma, or ASA intolerance would introduce a significant risk of false positive outcomes. In order to directly compare the efficacy of ethmoidectomy versus frontal sinusotomy in all patients with chronic frontal sinusitis, a randomized controlled trial would be necessary that could inherently control for preoperative characteristics, selection of surgical procedure, and postoperative management, but the design of such a study could raise ethical concerns.

The follow up period was relatively short with an average duration of 12.6 and 13.8 months in the frontal sinusotomy and ethmoidectomy groups, respectively. Only 5 patients, all in the frontal sinusotomy group, required further surgery for persistent chronic frontal sinusitis. This low surgical revision rate of 2.6%—markedly lower than the 10 to 30% revision rates reported in the literature—may not be representative of outcomes achieved outside of the centers participating in this study^{3,4,23}. A consequence of this low revision rate was an inability to compare the efficacy of endoscopic frontal sinusotomy versus less extensive endoscopic procedures for persistent chronic frontal sinusitis after failed surgical intervention. Objective radiologic evidence for the resolution of chronic frontal sinusitis was not obtained as this would necessitate postoperative CT scans which were not clinically indicated.

CONCLUSIONS

This is, to our knowledge, the first multicenter, prospective study demonstrating the efficacy of ethmoidectomy, without frontal sinusotomy, in the treatment of chronic frontal sinusitis. In chronic frontal sinusitis patients who do not definitively require frontal sinusotomy—specifically those without ASA intolerance, nasal polypsis, asthma, or previous sinus surgery—ethmoidectomy could be considered a first-step procedure, achieving comparable symptom improvements and reductions in postoperative medication usage, as ethmoidectomy with frontal sinusotomy.

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Table 1

Comparison of baseline demographic, social and medical history, and clinical measures of disease severity between study participants with and without unilateral or bilateral frontal sinusotomy during FESS

	Unilateral or bilateral frontal sinusotomy (n=196)		Without frontal sinusotomy (n=30)		
Descriptive factors:	Mean [SD]	N(%)	Mean [SD]	N(%)	p-value
Age (years)	53.6 [15.1]		50.7 [15.9]		0.346
Male		99 (50.5)		14 (46.7)	----
Female		97 (49.5)		16 (53.3)	0.695
Education (years)	14.9 [2.6]		14.4 [3.1]		0.451
Nasal polyposis		101 (51.5)		3 (10.0)	<0.001
Prior sinus surgery		113 (57.7)		11 (36.7)	0.031
Asthma		89 (54.6)		5 (16.7)	0.003
ASA intolerance		23 (11.7)		0 (0.0)	0.048
COPD		12 (6.1)		0 (0.0)	0.164
Current tobacco use		11 (5.7) *		1 (3.3)	0.593
Alcohol use		93 (47.4)		18 (60.0)	0.200
Diabetes Mellitus (type I or II)		15 (7.7)		2 (6.7)	0.849
Allergies (history)		31 (15.8)		5 (16.7)	0.906
Allergies (mRAST confirmed)		80 (40.8)		12 (40.0)	0.932
Depression		31 (15.8)		5 (16.7)	0.906
Corticosteroid dependency		15 (7.7)		0 (0.0)	0.230
Turbinate hypertrophy		19 (9.7)		12 (40.0)	<0.001
Septal deviation		85 (43.4)		17 (56.7)	0.173

SD, standard deviation; ASA, acetylsalicylic acid; COPD, chronic obstructive pulmonary disease; mRAST, modified radioallergosorbent testing;

* valid percentages are reported for missing data.

Table 2

Comparisons of surgical procedures between study participants with and without unilateral or bilateral frontal sinusotomy during FESS

	Unilateral or bilateral frontal sinusotomy (n=196)		Without frontal sinusotomy (n=30)		
Surgical procedures:	Left side N(%)	Right side N(%)	Left side N(%)	Right side N(%)	p-value
Maxillary antrostomy	182 (92.9)	179 (91.3)	28 (93.3)	27 (90.0)	0.910
Partial ethmoidectomy	9 (4.6)	12 (6.1)	9 (30.0)	7(23.3)	<0.001
Total ethmoidectomy	178 (90.8)	173 (88.3)	19 (63.3)	20 (66.7)	<0.001
Sphenoidotomy	162 (82.7)	161 (82.1)	13 (43.3)	15 (50.0)	<0.001
Middle turbinate resection	29 (14.8)	27 (13.8)	0 (0.0)	0 (0.0)	<0.001
Inferior turbinate reduction	14 (7.1)	12 (6.1)	11 (36.7)	11 (36.7)	<0.001
Septoplasty	77 (39.3)		14 (46.7)		0.443
Frontal sinusotomy <i>Draf</i> IIa	128 (65.3)	131 (66.8)	0 (0.0)	0 (0.0)	<0.001
Frontal sinusotomy <i>Draf</i> IIb	26 (13.3)	29 (14.8)	0 (0.0)	0 (0.0)	0.002
Frontal sinusotomy <i>Draf</i> III *	9 (4.6)		0 (0.0)		0.231
Image guidance	163 (83.2)		6 (20.0)		<0.001

p-values reflect differences between summarized total (right and left) sides when appropriate.

* indicates bilateral sinusotomy

Table 3

Comparison of preoperative outcome evaluations between study participants with and without unilateral or bilateral frontal sinusotomy during FESS

	Unilateral or bilateral frontal sinusotomy (n=196)	Without frontal sinusotomy (n=30)	
Preoperative outcome measures:	Mean [SD]	Mean [SD]	p-value
SNOT-22 total	53.6 [20.1]	54.3 [16.2]	0.910
Rhinologic symptoms	17.1 [6.2]	16.4 [5.1]	0.441
Extra-nasal rhinologic symptoms	8.5 [3.6]	8.2 [3.2]	0.557
Ear and/or facial symptoms	9.1 [5.1]	10.7 [4.2]	0.060
Psychological dysfunction	16.0 [8.6]	16.6 [7.4]	0.680
Sleep dysfunction	13.6 [7.0]	13.6 [6.0]	0.921
Topical nasal steroid sprays (days)	42.6 [38.9]	38.3 [38.4]	0.665
Topical nasal steroid drops/irrigations (days)	14.1 [30.0]	9.6 [28.3]	0.246
Oral/systemic steroids (days)	16.2 [24.0]	5.4 [7.2]	0.014
Oral/systemic antibiotics (days)	18.6 [24.2]	16.5 [21.6]	0.882
Sinonasal endoscopy score	7.4 [3.8]	4.1 [2.3]	<0.001
Computed tomography score	14.7 [5.3]	11.3 [3.9]	0.001

SD, standard deviation; SNOT-22, 22-item Sinonasal Outcome Test

Table 4

Comparison of postoperative outcome evaluations between study participants with and without unilateral or bilateral frontal sinusotomy during FESS

	Unilateral or bilateral frontal sinusotomy (n=196)	Without frontal sinusotomy (n=30)	
Postoperative outcome measures:	Mean [SD]	Mean [SD]	p-value
SNOT-22 total	28.6 [21.5]	29.3 [24.4]	0.913
Rhinologic symptoms	8.6 [6.4]	8.4 [6.0]	0.957
Extra-nasal rhinologic symptoms	4.5 [3.6]	4.0 [3.9]	0.399
Ear and/or facial symptoms	4.6 [4.7]	5.2 [5.5]	0.760
Psychological dysfunction	9.0 [8.8]	9.5 [9.4]	0.860
Sleep dysfunction	7.9 [7.0]	8.1 [7.3]	0.970
Topical nasal steroid sprays (days)	36.2 [41.5]	41.3 [41.3]	0.447
Topical nasal steroid drops/irrigations (days)	33.5 [40.6]	13.1 [30.2]	0.007
Oral/systemic steroids (days)	7.6 [21.5]	3.4 [16.7]	0.134
Oral/systemic antibiotics (days)	8.6 [18.8]	5.2 [13.8]	0.146
Sinonasal endoscopy score	4.0 [2.9]	2.4 [2.1]	0.038

SD, standard deviation; SNOT-22, 22-item Sinonasal Outcome Test

Table 5

Comparison of postoperative improvements between study participants with and without unilateral or bilateral frontal sinusotomy during FESS

	Unilateral or bilateral frontal sinusotomy (n=196)	Without frontal sinusotomy (n=30)	
Outcome measures:	Improvement Mean [SD]	Improvement Mean [SD]	p-value
SNOT-22 total	-24.9 [22.6] **	-25.0 [22.8] **	0.826
Rhinologic symptoms	-8.4 [7.5] **	-8.0 [7.2] **	0.588
Extra-nasal rhinologic symptoms	-3.9 [4.0] **	-4.2 [3.8] **	0.951
Ear and/or facial symptoms	-4.5 [5.0] **	-5.5 [5.9] **	0.396
Psychological dysfunction	-7.0 [8.9] **	-7.2 [7.9] **	0.976
Sleep dysfunction	-4.6 [8.5] **	-4.1 [8.3] *	0.793
Topical nasal steroid sprays (days)	-7.5 [47.7] *	1.3 [44.2]	0.413
Topical nasal steroid drops/irrigations (days)	20.1 [45.8] **	4.1 [29.1]	0.049
Oral/systemic steroids (days)	-8.5 [25.8] **	-1.8 [19.9] *	0.294
Oral/systemic antibiotics (days)	-9.6 [28.4] **	-11.6 [19.7] *	0.327
Sinonasal endoscopy score	-3.6 [4.4] **	-1.4 [2.4] *	0.023

SD, standard deviation; SNOT-22, 22-item Sinonasal Outcome Test.

** indicates significant improvement over time with matched pairings (p<0.001).

* indicates significant improvement over time with matched pairings (p<0.050).