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ORIGINAL RESEARCH

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Mucosal flaps prevent neo-osteogenesis after frontal drill-out procedures: A computer-assisted study

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Abstract

Objective: Although several mucosal flap techniques have been reported to improve the outcomes in Draf IIb and Draf III procedures, there is scant knowledge on frontal ostium neo-osteogenesis after reconstruction with mucosa flap. This study evaluates the potential benefits of mucosa flaps on frontal ostium neo-osteogenesis after frontal sinus drill-out procedures.

Methods: Forty-three patients who underwent extended Draf IIb and Draf III were enrolled. Among them, 20 patients had frontal neo-ostium (FNO) reconstructed by mucosal flap (group A), and 23 patients did not have neo-ostium reconstruction (group B). The cross-sectional area of FNO, frontonasal bone, and the amount of frontal neo-osteogenesis (FNOG) were measured with OsiriX®. In addition, the Global Osteitis Scoring Scale (GOSS), Lund–Mackay score (LMS), and Lund–Kennedy score (LKS) were also evaluated.

Results: At one year postoperatively, the remaining neo-ostium area was significantly larger in group A ($p = .001$), and group A had significantly less FNOG ($p < .05$). The month 12 postoperative GOSS score was significantly decreased in group A. In contrast, it slightly increased in group B. Both the average LKS and LMS were significantly reduced in groups A and B at month 12 postoperatively. Still, the average LKS of group A significantly decreased than that of group B at month 12 postoperatively.

Conclusion: Coverage of the bare frontal bone with the mucosal flap could prevent excessive neo-osteogenesis and keep the neo-ostium open widely.

Level of Evidence: 2b

KEYWORDS
computed tomography, Draf procedure, frontal sinus, mucosal flap, neo-osteogenesis

Ting Ye and Bing Zhou contributed equally to this work. The author's order was determined by order of increasing seniority.

1 | INTRODUCTION

Draf I-III procedures were first described by Draf in 1991.[1] The Draf IIb, extended Draf IIb,[2] and Draf III procedures are also called frontal sinus drill-out procedures because they require the removal of the frontal process of the maxilla and frontal beak. These procedures have been proven safe and effective for managing recalcitrant frontal sinus pathology.[3–5] However, these procedures technically require the extensive removal of bone and mucosa, resulting in large areas of exposed bone. Thus, patients may experience higher rates of postoperative scarring, neo-osteogenesis, and stenosis.[6] In addition, in our previous study by CT measurement, neo-osteogenesis had been proven to have a significant impact on the patency of frontal neo-ostium.[7]

By draping the mucosal flap across the exposed bone, the frontal neo-ostium attempts to maintain open by preventing neo-osteogenesis, scar, and granulation tissue formation. Several types of mucosal flaps have been recently designed to reduce stenosis after frontal sinus drill-out procedures, and good outcomes have been reported.[8–11] We have conducted three types of pedicled nasal mucosal flaps in the frontal sinus drill-out procedures since 2013. Nevertheless, little is known about the impact of mucosal flaps on neo-osteogenesis, partly because of the lack of adequate and accurate methods to measure postoperative bony changes. Therefore, based on the prospectively collected data, a computer-assisted imaging study was organized. This computer-assisted study aimed to investigate whether using mucosal flaps after frontal sinus drill-out procedures provides better outcomes in neo-osteogenesis by our previously reported method.[7] In addition, our experience of reconstruction of the frontal neo-ostium with mucosal flaps was also discussed.

2 | MATERIALS AND METHODS

The study protocol was approved by the Institutional Review Board of Beijing Tongren Hospital (No. TRECKY2020-048). Patients who underwent extended Draf IIb or Draf III procedures at the Department of Otolaryngology of Beijing Tongren Hospital were prospectively enrolled from May 2014 to May 2019. All patients signed the informed consent. Inclusion criteria for the enrolled patients were recalcitrant frontal sinusitis, mucoceles, and benign tumors (osteomas and inverted papillomas) with a minimum of 12 months postoperative follow-up. All patients underwent spiral scans preoperatively, 7 days, and 12 months postoperatively. Patients who underwent frontal neo-ostium reconstruction with mucosal flaps were considered the mucosal flap group (group A). Patients not using the mucosal flap were considered the control group (group B). The endoscopic severity of the disease was assessed by the Lund–Kennedy score (LKS), while the radiologic extent of the disease was assessed by the Lund–Mackay score (LMS) and Global Osteitis Scoring Scale (GOSS).[12–14]

2.1 | Surgical technique

Surgery was performed under general anesthesia. The senior author performed all procedures. In group A, we used three types of pedicled mucosal flaps, including the lateral nasal wall flap (LNWF), the lateral nasoseptal flap (LNSF), and the septal flap (SF) (Figure 1A–C). The inverted U-shape pedicled LNSF, LNWF, and SF were harvested using a needle monopolar cautery under a 0° endoscope after ethmoidectomy and the removal of the anterior portion of the middle turbinate. LNWF was harvested from the roof of the nasal cavity to the dorsum of the inferior turbinate (Figure 1D,I). LNSF was the extension of the LNWF through the nasal vault toward the septum (Figure 1E,G). SF was obtained from the nasal septum on the side of LNWF to repair the posterior wall of the frontal outflow tract (Figures 1F and 2D). Different combinations of mucosal flaps were chosen according to the range of exposed bone area. The LNSF was used in extended Draf IIb, while the combination of LNSF and LNWF was used in Draf III. The SF was used when the mucosa of the posterior wall was removed as part of inverted papilloma or osteoma resection, or when the bone of frontal T was required to remove to obtain a maximum anteroposterior diameter. In the control group, no graft material or pedicle flaps were acquired (Figure 3). Rubber finger stalks were used for postoperative nasal packing in every case.[15]

2.2 | Postoperative care

The finger stalks were removed 5 days after surgery. Follow-up visits began 2 weeks after the operation, then at 1 month and every 3 months after that as needed. The Nasal corticosteroids spray and saline irrigation were prescribed for at least 3 months and then tailored to symptoms and endoscopic findings after that. The crust clearing and granulation debridement were done under nasal endoscope periodically at the postoperative visits.

2.3 | CT measurements

Paranasal sinus CT scans were performed on a 64-slice multidetector-row CT scanner (Brilliance 64, Philips Medical System, Cleveland, OH; scan parameters: 120 kV; 300 mA; matrix size of 512 × 512; and axial slice thickness of 1 mm). Images were reconstructed and measured using OsiriX® software (Pixmeo, Geneva, Switzerland).

Three aspects of the frontal neo-ostium were measured: (1) the cross-sectional area of the frontal neo-ostium airway, excluding the surrounding bone and soft tissue (Figures 2F and 3F); (2) the cumulative cross-sectional area of the bone surrounding the neo-ostium, termed the frontonasal bone (FNB) area (Figures 2I and 3I); and (3) the cross-sectional area of soft tissue. Reconstruction parameters and methods were consistent with those mentioned in our previous studies, as well as the measurement level of the frontal ostia.[7,16]

CT scans were taken after the removal of the rubber finger stalks to measure the cross-sectional area of the original intraoperative frontal neo-ostium. The extent of frontal neo-osteogenesis was calculated

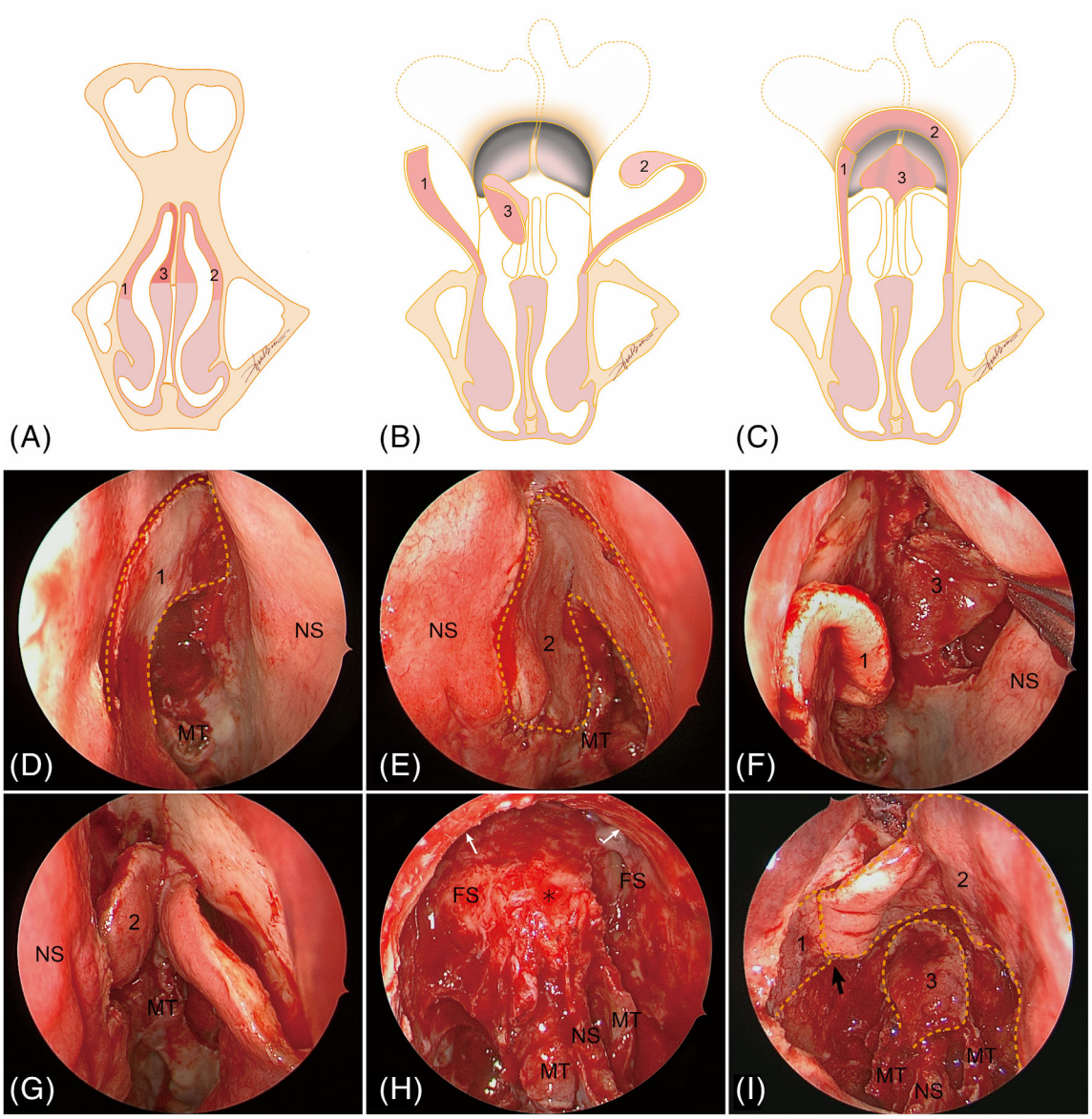

FIGURE 1 Illustration of the three types of mucosal flaps. (A) This image illustrates the original location of the lateral nasal wall flap (LNWF, 1), lateral nasoseptal flap (LNSF, 2), and septal flap (SF, 3). (B) All the mucosal flaps have been harvested, and the common frontal drainage pathway has been created. (C) The bared bone of neo-ostium has been covered by mucosal flaps completely. (D) The patient's right side of the nose illustrates the incision for the LNWF (dotted lines). (E) The patient's left side of the nose illustrates the incision for the LNSF (dotted lines). (F) The LNWF and SF have been harvested. (G) The LNSF has been harvested. (H) The anterior and lateral bone of frontal ostium (white arrow) and the posterior bony wall of ostium (*) have been drilled to maximize the frontal neo-ostium. (I) The anterior and lateral bared bone of neo-ostium is covered by LNWF and LNSF edge to edge (black arrow). The posterior neo-ostium wall is covered by SF. FS, frontal sinus; MT, middle turbinate; NS, nasal septum.

as the difference in the FNB area between 7 days and 1 year after the operation.

2.4 | Statistical analysis

Statistical analysis was performed using the SPSS 23.0 software (SPSS Inc., Chicago, IL). The Kolmogorov–Smirnov test was used to assess the normality of distribution. Mean and standard deviation (SD) values were used to describe parametric data. We performed the *t*-test for the unpaired comparisons of continuous variables. Fisher's exact test was used for odd comparisons of categorical variables. *p* values less than .05 were regarded as statistically significant.

3 | RESULTS

3.1 | Patient characteristics

Forty-three patients were included in this analysis (Table 1). There were 12 females and 31 males, with a mean age of 47 years (range: 19–63 years). Group A had 20 patients, and group B had 23 patients.

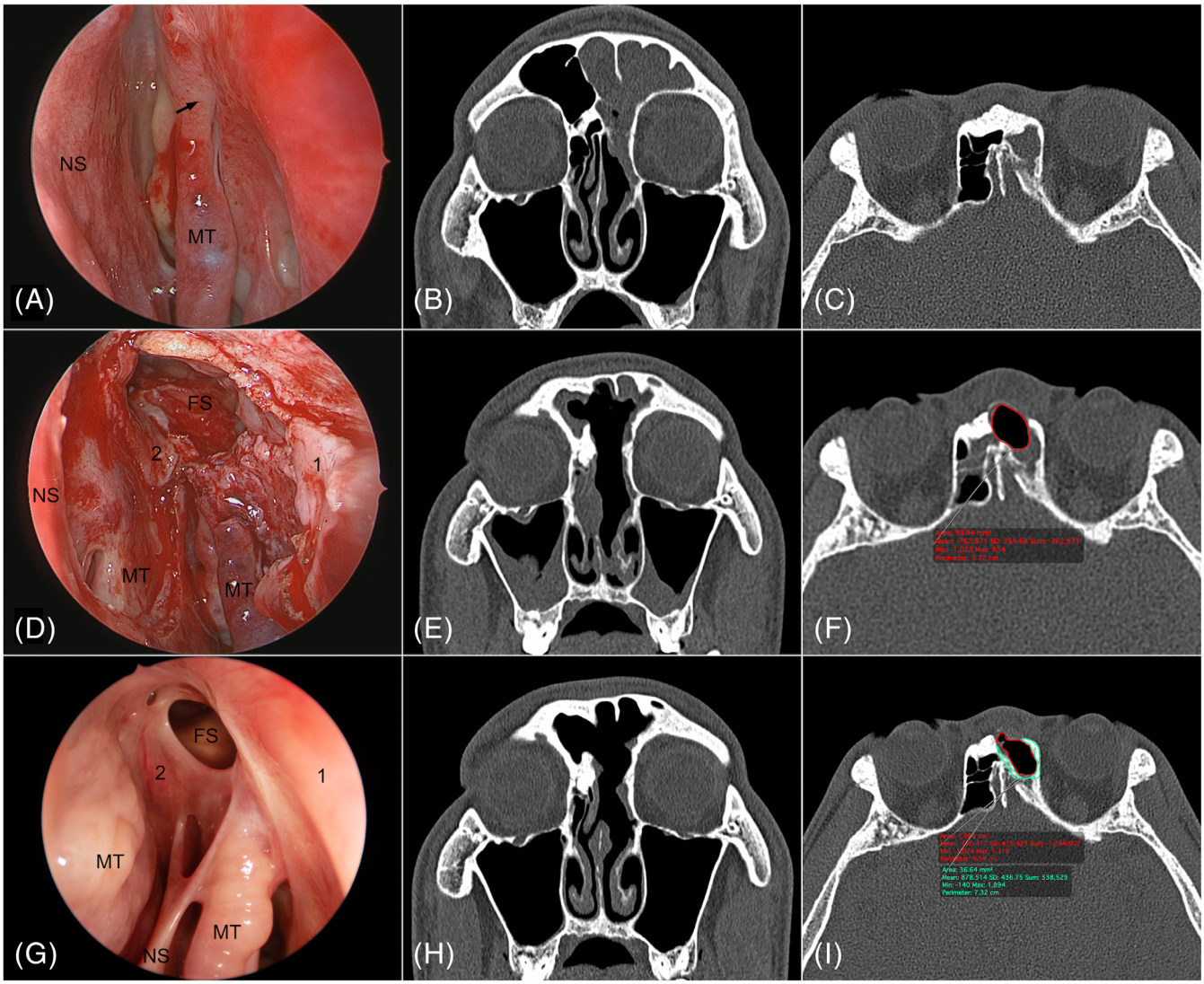

FIGURE 2 Extended Draf IIb with mucosal flap case. (A) Preoperative view of the left frontal recess shows frontal ostium stenosis due to scarring (black arrow). (B) Preoperative coronal CT image. (C) The preoperative cross-sectional image of frontal ostium. (D) Intraoperative view after placement of LNSF (1) and contralateral septal flap (2) onto the bare bone. (E) Coronal CT image taken at 7 days postoperatively. (F) Illustration of measurement of frontal neo-ostium area (red circle). This cross-section was taken at 7 days postoperatively. (G) Endoscopic view at 12 months postoperatively. (H) Coronal CT image taken at 12 months postoperatively. (I) Illustration of measurement of frontal neo-ostium area (red circle) and bone area (green circle). This cross-section was taken at 12 months postoperatively. CT, computed tomography; FS, frontal sinus; LNSF, lateral nasoseptal flap; MT, middle turbinate; NS, nasal septum.

The detailed reconstruction methods are listed in Table 2. As a result, no mucosal flap or graft was missing, and no infection occurred.

During the average follow-up period of 51.6 months, two of the 20 patients in group A required reoperation for reasons unrelated to the patency of the neo-ostium. In contrast, three of the 23 patients in group B required revision surgery. The indication for revision surgery was symptomatic restenosis due to scarring and recurrent polyps. Two patients had revision surgery 3 years after the operation, and one underwent revision surgery 4 years after the surgery. The revision rate was higher in the control group (13%, 3 of 23) than in the mucosal group (0%, 0 of 20); however, the intergroup difference was not significant ($p = .144$).

3.2 | Endoscopic outcomes

The average pre-op and month 12 post-op LKS of groups A and B are listed in Table 3. There was no significant difference in preoperative LKS between the two groups ($p = .066$), while the average LKS in the two groups at month 12 postoperatively was 1.21 ± 1.18 and 2.35 ± 2.19, respectively ($p = .001$). The average LKS of month

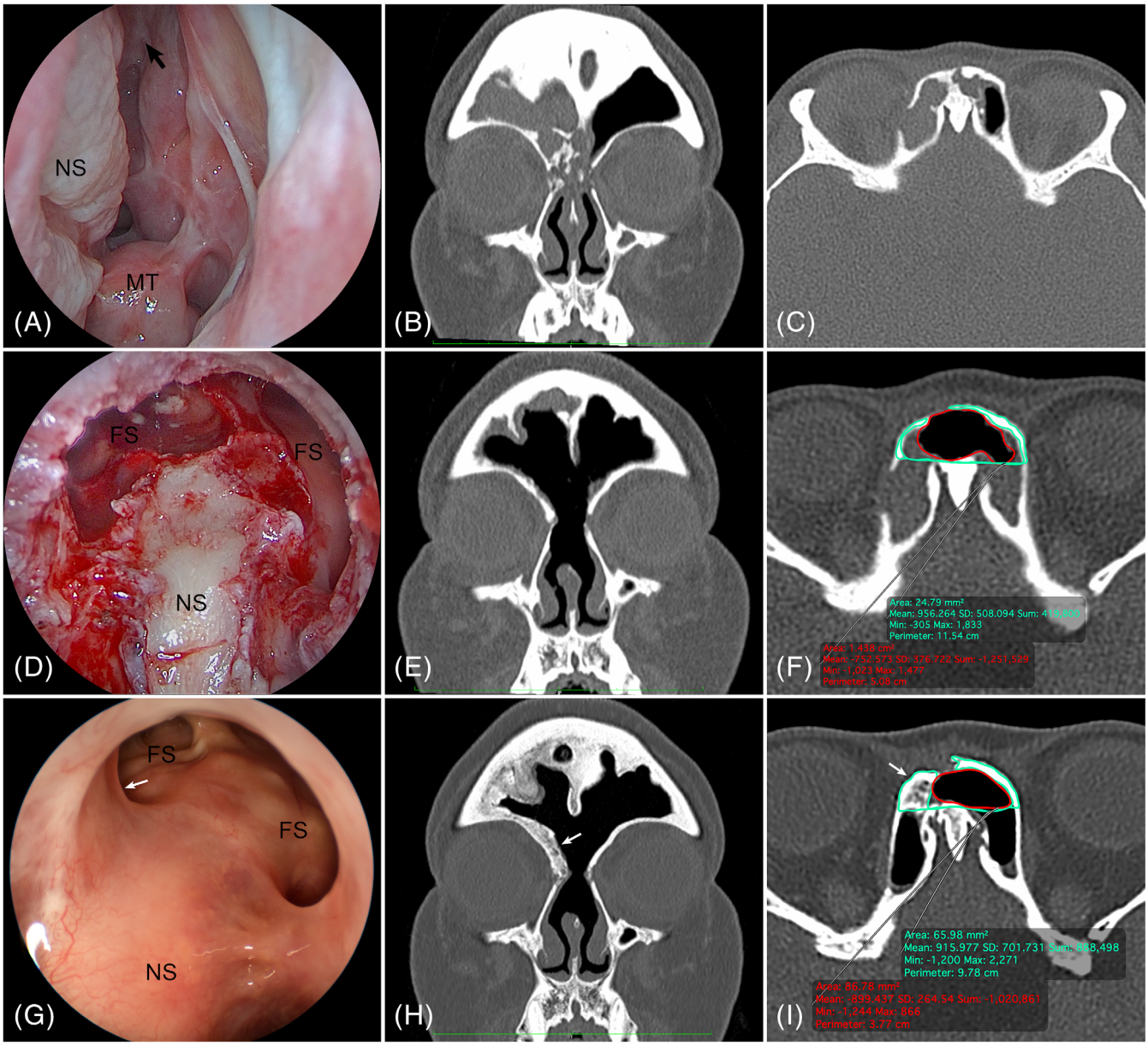

FIGURE 3 Draf III without mucosal flap case. (A) Preoperative view of the left frontal recess shows frontal ostium stenosis (black arrow). (B) Preoperative coronal CT image. (C) The preoperative cross-sectional image of frontal ostium. (D) Intraoperative view after the common frontal drainage pathway has been created. (E) Coronal CT image taken at 7 days postoperatively. (F) Illustration of measurement of frontal neo-ostium area (red circle) and bone area (green circle). This cross-section was taken at 7 days postoperatively. (G) Endoscopic view at 12 months postoperatively. Frontal neo-ostium restenosis due to scarring (white arrow). (H) Coronal CT image taken at 12 months postoperatively. Neo-osteogenesis (white arrow) affects the patency of frontal neo-ostium. (I) Illustration of measurement of frontal neo-ostium area (red circle) and bone area (green circle). This cross-section was taken at 12 months postoperatively. Frontal neo-ostium restenosis secondary to neo-osteogenesis (white arrow). CT, computed tomography; FS, frontal sinus; MT, middle turbinate; NS, nasal septum.

12 post-op was significantly lower than pre-op in the two groups (both $p < .001$).

3.3 | Radiologic outcomes

The average LMS significantly decreased in two groups at month 12 postoperatively (both $p < .001$). There was no significant difference in LMS between the two groups preoperatively ($p = .168$) and postoperatively ($p = .081$, Table 3).

In addition, there was no significant difference in GOSS between the two groups preoperatively ($p = .958$) and postoperatively ($p = .068$). The average pre-op and month 12 postoperative GOSS in group A was 9.95 ± 6.25 and 6.21 ± 4.50, respectively ($p = .010$), and the average pre-op and month 12 postoperative GOSS in group B was 9.29 ± 5.81 and 10.29 ± 7.99, respectively ($p = .460$).

TABLE 1 Patient characteristics.

	Group A ($n = 20$)	Group B ($n = 23$)
Age, years (mean ± SD)	45.3 ± 11.9	45.8 ± 8.7
Gender		
Male, *n* (%)	15 (75%)	16 (69.6%)
Female, *n* (%)	5 (25%)	7 (30.4%)
Diagnosis		
Chronic frontal sinusitis, *n* (%)	8 (40%)	14 (60.9%)
Frontal mucocele, *n* (%)	4 (20%)	2 (8.7%)
Osteomas, *n* (%)	2 (10%)	2 (8.7%)
Inverted papilloma, *n* (%)	6 (30%)	5 (21.7%)
Previous sinus surgeries		
Yes, *n* (range)	14 (1–3)	19 (1–5)
No, *n*	6	4
Operation		
Extended Draf IIb, *n* (%)	7 (35%)	2 (8.7%)
Draf III, *n* (%)	13 (65%)	21 (91.3%)

TABLE 2 Types of neo-ostium reconstruction.

Operation	Mucosal flap	Cases
Extended Draf IIb	LNSF	4
	LNSF + SF	3
Draf III	LNSF + LNWF	6
	LNSF + LNWF + SF	7

Abbreviations: LNSF, lateral nasal wall; LNWF, lateral nasoseptal flap; SF, septal flap.

TABLE 3 Endoscopic and radiologic assessment.

		Pre-op	Post-op	*p*
Group A	LKS	4.31 ± 2.31	1.21 ± 1.28	.000
	LMS	7.84 ± 6.01	3.00 ± 2.51	.000
	GOSS	9.96 ± 6.25	6.21 ± 4.48	.010
Group B	LKS	6.29 ± 3.38	2.35 ± 2.19	.000
	LMS	12.24 ± 7.91	5.24 ± 4.05	.000
	GOSS	9.29 ± 5.81	10.29 ± 7.99	.460

Abbreviations: GOSS, Global Osteitis Scoring Scale; LKS: Lund–Kennedy score; LMS, Lund–Mackay score.

In further analysis, the average day 7 and month 12 postoperative neo-ostium area, the soft tissue area, and the average amount of neo-osteogenesis were compared between the two groups (Table 4). At 1 year postoperatively, the average neo-ostium area was reduced in groups A and B (from 2.76 ± 0.42 cm^2 to 2.05 ± 0.73 cm^2 and from 3.30 ± 0.95 cm^2 to 1.67 ± 0.74 cm^2, respectively), but group A showed a significantly less decreased area than group B ($p = .004$). The average amount of neo-osteogenesis at month 12 was 0.18 ± 0.08 cm^2 in group A and 0.38 ± 0.15 cm^2 in group B, and the difference between the two groups was significant ($p = .008$). The average soft tissue area increased in groups A and B, but the difference between the two groups was not significant ($p = .152$). The differences in the neo-ostium area, FNB area, and soft tissue area between day 7 and month 12 post-op were statistically significant in both groups (all $p < .05$).

Frontal ostium bony changes are shown on CT images: preoperatively (Figures 2B,C and 3B,C); 7 days postoperatively (Figures 2E,F and 3E,F); and 12 months postoperatively (Figures 2H,I and 3H,I).

4 | DISCUSSION

In this study, our interest is mainly focused on the bony changes of frontal neo-ostium after experiencing the frontal drill-out procedures. These procedures technically required mucosa stripping and drilling of a broad area of the frontal bone. Although enrolled patients had different pathologies, such as chronic rhinosinusitis (CRS) and benign tumors, mucosal and bone remodeling would happen during wound healing after surgery, particularly the frontal ostium neo-osteogenesis. Our prospectively collected data revealed that postoperative neo-osteogenesis and mucosal scarring were universal phenomena (Figure 3H,I). Furthermore, we found that using the mucosal flaps significantly reduced frontal neo-ostium stenosis and neo-osteogenesis in the first postoperative year. This contrasts with Omura et al., who found that neo-osteogenesis was not observed after frontal sinus drill-out procedures with the neo-ostium reconstruction.[17] One key attribute of the Omura et al. study was that the assessment of the extent of neo-osteogenesis was not across the entire neo-ostium. In addition, the measurement plane of the frontal neo-ostium was not standardized, whereas we performed exact measurements of the standardized reference plane of the neo-ostium.[7,16] By this computer-assisted reconstruction technique, we could assess postoperative bony changes that might have been difficult if we had relied solely on endoscopic examination.

We have found that the preoperative GOSS score could predict the postoperative development of neo-osteogenesis.[7] In this study, the preoperative GOSS score between groups A and B was not significantly different. Interestingly, the month 12 postoperative GOSS score significantly decreased in group A and slightly increased in group B. The bony changes mainly occurred in the frontal sinus. Besides, we also found that the extent of frontal ostium neo-osteogenesis in group A significantly less than group B within the first year postoperatively. These findings indicate that mucosal flaps significantly reduced frontal ostium neo-osteogenesis. Moreover, the change of the cross-sectional soft tissue area of frontal neo-ostium was increased in groups A and B without a significant difference between the two groups. In contrast, the declined area of the neo-ostium and the extent of neo-osteogenesis were significantly less in group A. These findings suggested that the mucosal flap has more influence on neo-osteogenesis.

Although the average LKS significantly decreased in groups A and B at month 12 postoperatively, the average LKS of group A significantly reduced than that of group B at month 12 postoperatively. We

TABLE 4 Radiologic measurement of frontal ostium.

	Neo-ostium area (cm^2)			Bone area (cm^2)			Soft tissue area (cm^2)		
	Group A	Group B	*p*	Group A	Group B	*p*	Group A	Group B	*p*
7 days post-op	2.76 ± 0.42	3.30 ± 0.95	.033*	0.46 ± 0.24	0.52 ± 0.20	.468	0.24 ± 0.05	0.36 ± 0.13	.404
1 year post-op	2.05 ± 0.73	1.67 ± 0.74	.224	0.63 ± 0.28	0.90 ± 0.39	.028*	0.64 ± 0.22	1.09 ± 0.49	.128
Changes of neo-ostium[a]	0.70 ± 0.25	1.63 ± 0.70	.004*	0.18 ± 0.08[b]	0.38 ± 0.15[b]	.008*	0.41 ± 0.15	0.73 ± 0.26	.152

[a]Difference between 1 year and 7 days postoperation.
[b]Frontal neo-osteogenesis area.
*Significant at $p < .05$.

also found a significant difference in the average percentage of day 7 postoperative cross-sectional area of the frontal ostium between groups A and B, with 24.5% narrowing in the area in group A compared with 48.9% in group B at month 12 postoperatively. These findings suggested that the mucosal flap might help speed up mucosal epithelization and keep the neo-ostium open widely. Therefore, we recommend selecting LNSF, LNWF, SF, or any combination of them to cover the denuded bone in the frontal neo-ostium as possible at the end of the drill-out surgeries. In this study, mucosa disease was assessed using the LMS, which was associated with the extent of neo-osteogenesis.[18] We found no significant difference in the change of LMS preoperation and postoperation between groups A and B. This is perhaps because we removed the bone surrounding the frontal sinus ostium during surgery; osteitis in the other parts of the frontal sinus or other sinuses might cause consistent inflammation of sinus mucosa, affecting the result of LMS.

Because of the relatively small sample size, the heterogeneity of the enrolled patients, such as CRS and non-CRS patients were included, and patients underwent different surgical methods (Draf IIb and Draf III), would potentially influence the study results, even if groups A and B were matched statistically. Also, the relatively small sample size limited the analysis of the influence of other aspects on the neo-ostium's patency after mucosal flap application, such as smoking and previous surgery. Therefore, a randomized control design with large samples will be subsequently needed to address these issues.

5 | CONCLUSION

Using a standardized radiologic measurement method, we have shown that the mucosal flap can prevent excessive neo-osteogenesis, speed up mucosal epithelization, and keep the neo-ostium open widely. Applying different combinations of mucosal flaps to repair the exposed bone surfaces after frontal sinus drill-out procedures is an effective surgical intervention.

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CONFLICT OF INTEREST STATEMENT

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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