• Clinical Research •

Endoscopic dacryocystorhinostomy with mucosal anastomosing in chronic dacryocystitis with three categories of ethmoid sinuses

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Received: 2021-12-08 Accepted: 2022-04-21

Abstract

● **AIM:** To evaluate the outcome of endoscopic dacryocystorhinostomy (En-DCR) with mucosal anastomosis in chronic dacryocystitis patients, with various categories of ethmoid sinuses.

● **METHODS:** Between July 2015 and September 2019, 1439 adult patients, representing 1623 affected eyes, presented with chronic dacryocystitis and were scheduled for En-DCR. The categories of ethmoid sinuses were preoperatively determined, using computed tomography-dacryocystography (CT-DCG), and were classified as category 1 (C1), category 2 (C2), and category 3 (C3). No sinuses anterior to the posterior lacrimal crest defined as C1. Sinuses found between the anterior edge of the lacrimal bone and the posterior lacrimal crest defined as C2. Sinuses found anterior to the lacrimal bone suture defined as C3. At the end of surgery, the dacryocyst and nasal mucosa were anastomosed in C1, and the dacryocyst mucosa and anterior ethmoid sinus were anastomosed in C2 and C3 ethmoid sinus patients. The surgical success rate and related complications, in patients with 3 categories of ethmoid cells, were monitored and documented.

● **RESULTS:** Postoperative data was obtained for 179 C1 affected eyes, 878 C2 affected eyes, and 432 C3 affected eyes. The overall success rate of En-DCR was 93.0% (1385/1489). Additionally, the success rates were comparable among the different ethmoid categories at 12mo post operation. We demonstrated that the major reason for surgical failure was intranasal ostial closure, due to granulation or scar tissue.

● **CONCLUSION:** En-DCR is a feasible and highly effective primary treatment for chronic dacryocystitis. To ensure surgical success, the surgery protocol must be designed in accordance with the category of ethmoid sinuses present in individual patient.

● **KEYWORDS:** endoscopic dacryocystorhinostomy; ethmoid sinuses; mucosal anastomosis

DOI:10.18240/ijo.2022.11.06

Citation: Wang YH, Jiang WH, Tu YH, Zhou GM, Wu WC, Yu B. Endoscopic dacryocystorhinostomy with mucosal anastomosing in chronic dacryocystitis with three categories of ethmoid sinuses. *Int J Ophthalmol* 2022;15(11):1765-1771

INTRODUCTION

Endoscopic dacryocystorhinostomy (En-DCR) is a popular procedure, due to its numerous benefits, including, reduced scarring, lower post surgical hematoma, shorter post surgical recovery, and protection of the orbicularis oculi muscle physiology[1-3]. Despite these advantages, a number of factors, including, the anatomical variation in the nasal cavity, can increase the difficulty of En-DCR, leading to surgical failure[4-5].

The ethmoid cell labyrinth is located next to the medial orbital wall. Therefore, its close proximity to the lacrimal sac fossa is an essential factor in lacrimal surgery. The ethmoidal bone stems from the posterior of the lacrimal sac and often extends anterior to the posterior lacrimal crest and, at times, even reaches the anterior lacrimal crest[6-7]. The categories of ethmoid sinuses were intricately classified in 1990 by Blaylock *et al*[8], who divided them into three categories, depending on their anatomic relationship between the ethmoid sinus and the dacryocyst. In brief, Category 1 (C1) refers to the lack

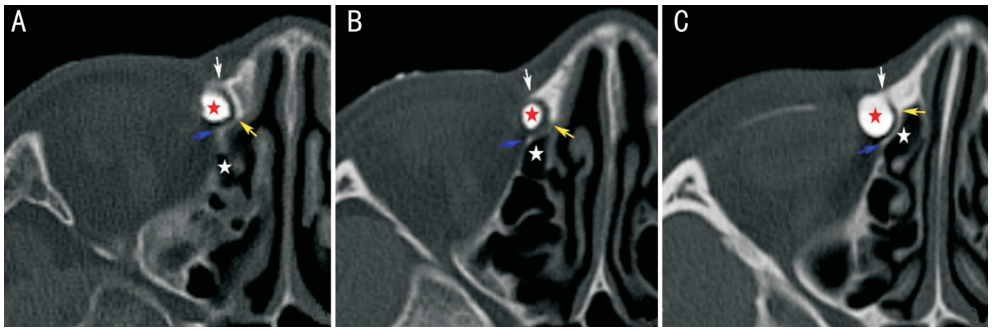

Figure 1 Categories of ethmoid sinuses determined by axial sections of CT-DCG showing the relationship between the lacrimal fossa (red star) and the anterior ethmoid air cells (white star) A: Absence of sinuses anterior to the posterior lacrimal crest (blue arrow); B: Sinuses present anterior to the posterior lacrimal crest (blue arrow), but remain behind the suture of the lacrimal bone (yellow arrow); C: Sinuses found anterior to the lacrimal bone suture (yellow arrow).

of sinuses anterior to the posterior lacrimal crest. Category 2 (C2) sinuses can be found anterior to the posterior lacrimal crest, but they remain behind the suture at the anterior edge of the lacrimal bone. Finally, category 3 (C3) sinuses reach into the frontal process of the maxilla, anterior to the lacrimal bone suture. This classification of sinuses has been adopted by many scholars, who also acknowledge the importance of the ethmoid sinuses and the lacrimal sac fossa in lacrimal surgery. In fact, initiation of osteotomy during En-DCR begins with the entrance and enlargement of the anterior ethmoid air cells[9-11]. However, there are limited reports on the management of the lacrimal sac flap during En-DCR. One approach is to generate a single nasal flap and a single lacrimal sac flap and appose them during DCR. In another report, the anastomosis of nasal mucosa between lacrimal sac flaps was shown to elevate surgical success, both in primary nasolacrimal obstructions and in revision cases[12-13].

Anatomically, C1 is a perfect candidate for anastomosis of the nasal mucosa to the lacrimal sac flap. However, in case of well-developed ethmoid sinuses, such as C2 and C3, the lacrimal sac remains partly or entirely within the anterior ethmoid sinus. As a result, after osteotomy and lacrimal sac incision, the flattened posterior lacrimal flap remains within the anterior ethmoid sinus, positioning the lacrimal sac flap far from the nasal flap, thus making anastomosing impossible. Given that sinus mucosa lies along the nasal cavity and that sinus mucosa, and the anterior ethmoid sinus mucosa are histologically similar[14], anastomosing the posterior lacrimal sac flap to the sinus mucosa may be possible.

Here, we evaluated the feasibility of multiple mucosal anastomosing approaches during En-DCR, based on the categories of ethmoid sinus present in the patient. Furthermore, we assessed the outcomes of anastomosing all 3 categories of ethmoid sinuses over a 1-year period.

SUBJECTS AND METHODS

Ethical Approval This was a prospective interventional investigation, performed at the Department of Orbital and Oculoplastic Surgery, Eye Hospital of Wenzhou Medical University from July 2015 and September 2019. The Eye Hospital of Wenzhou Medical University and the Institutional Ethics Committee (No:2021-204-k-178-01. Medical Ethics Committee, Wenzhou Medical University, Wenzhou, Zhejiang, China) approved this research, which was in accordance to the Declaration of Helsinki (2008). All patients provided informed consent to participate in this study.

Patients were eligible for inclusion if they had been diagnosed with chronic dacryocystitis and elected to undergo En-DCR. The diagnosis was performed based on a history of epiphora with purulent discharge, lacrimal pathways irrigation, and computed tomographic-dacryocystography (CT-DCG). The lacrimal system was evaluated *via* CT, following topical iopromide application (300 mg iodine/mL), as a radiopaque material. Prior to the contrast material application, the medial canthus was gently massaged to empty the lacrimal sac to facilitate contrast material entry into this compartment. The contrast agent was instilled into the sac through an inferior canalicular at a 1-2 drop/min rate until the agent overflowed from the superior canalicular. Spiral CT examinations were conducted in the horizontal plane with a spiral CT instrument (SOMATOM Emotion 16) with a 1 mm/rotation table index and 1.5 mm reconstruction thickness. Categories of ethmoid sinuses were determined by CT-DCG as C1, C2, and C2, as mentioned above (Figure 1).

Those excluded from this study included patients <18 years of age, having received prior endoscopy or external DCR, suffered from severe nasosinusitis, canalicular stenosis or obstruction, exhibited history of nasal trauma, severe deviation of the nasal septum, primary nasolacrimal neoplasms, lacrimal tube intubation during surgery, and systemic diseases resulting in bleeding disorders or coagulopathy. In addition, patients with incomplete medical information or with follow-up period <12mo were also excluded.

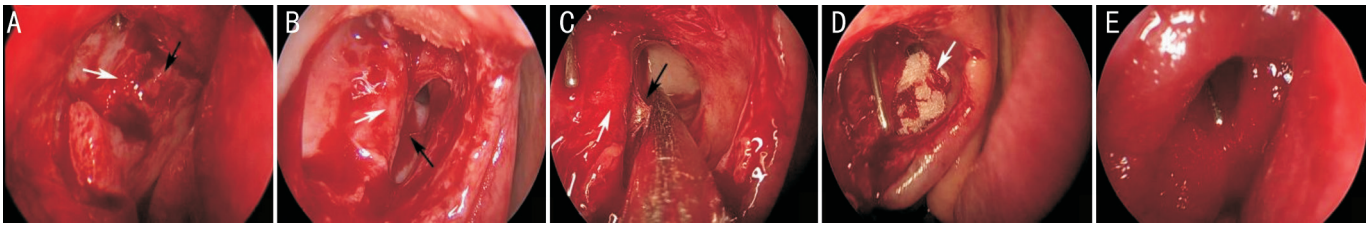

Figure 2 Clinical photographs of mucosal management during En-DCR A: A clinical photograph of the lacrimal sac flap (white arrow), which was posteriorly flattened to appose to the nasal mucosa (black arrow) in a C1 patient; B: A clinical photograph of the lacrimal sac flap (white arrow), which was apposed to the anterior ethmoid sinus mucosa (black arrow) in a C2 patient; C: A clinical photograph of the lacrimal sac flap (white arrow), which was apposed to the anterior ethmoid sinus mucosa (black arrow) in a C3 patient; D: A clinical photograph of Merogel (white arrow) used to connect 2 mucosa in a C3 patient; E: A clinical photograph of the Merogel covering the ostial surface. En-DCR: Endoscopic dacryocystorhinostomy.

The patients included in this study were assigned into three groups, based on the CT-DCG. During surgery, C1 patients retained intact anterior ethmoid cells, whereas in C2 and C3 patients, the anterior ethmoid region was routinely entered and enlarged. Moreover, in the last step of the surgery, the dacryocyst and nasal mucosa were anastomosed in C1, whereas the dacryocyst mucosa and anterior ethmoid sinus were anastomosed in C2 and C3.

Surgical Procedures All patients received non-laser En-DCR, conducted by the same surgeon (Yu B). The surgery followed guidelines established previously[13,15]. Patients were provided with either local or general anesthesia, according to personal choice, and the need for other ancillary endoscopic procedures, along with En-DCR. Using a 0° 4.0-mm endoscopic endoscope (Karl Storz, Tuttlingen, Germany), the En-DCR was initiated by incising the nasal mucosal flap and separating posteriorly, using a stripper. Then, the ethmoid sinuses were entered, using a detacher, and enlarged with a straight cut (XPS3000; Medtronic Xomed, MN, USA). In C2 and C3 cases, the underlying maxilla and frontal process of the maxilla were thinned with a power burr (XPS3000; Medtronic Xomed, MN, USA) and removed with a Kerrison rongeur. Moreover, the lacrimal sac was tented using a probe through the superior canaliculus and incised vertically with a sickle knife to create a large C-shaped posterior lacrimal sac flap. In C1, the lacrimal sac flap was rolled out and flattened posterior of the lateral nasal wall to oppose to the nasal mucosa (Figure 2A). In C2 and C3, the lacrimal sac flap was opposed to the anterior ethmoid sinus mucosa (Figure 2B, 2C). One piece of Merogel (Medtronic Xomed, Jacksonville, FL, USA) was then used to connect the nasal mucosa to the ethmoid sinus mucosa (Figure 2D) and three pieces of Merogel were stretched to cover the wound surface around the ostium (Figure 2E).

After the surgery, the patients were administered with methylprednisolone (20 mg/kg·d) and ceftriaxone (2.0 g/d) for 2d. Additionally, lacrimal injections of dexamethasone and tobramycin were provided once a day for the first 3 postoperative days. Intranasal Rhinocort Aqua Nasal Spray (Astra Zeneca, Wilmington, DE, USA) was administered twice daily for 8wk. Finally, follow ups were scheduled at 1, 2, and 4wk, as well as 3, 6, and 12mo post surgery. Wound healing and presence of granulation tissue and scars within the ostium were evaluated at each follow up. Any reports of epiphora and purulent discharge were documented and nasolacrimal irrigation was done by an independent staff member.

The surgery was deemed successful when there was a lack of epiphora, irrigation flowed freely through the lacrimal system, and normal mucosal layer covered the intranasal ostium. Conversely, tear drainage reconstruction (TDR) failure was considered in the presence of any of the following: 1) persistent postoperative epiphora or dacryocystitis; 2) obstruction in the lacrimal irrigation system; 3) endoscopy-verified granuloma and/or scarring that obstructs the lacrimal sac ostium or the absence of dye in the abnormal functional endoscopic dye test.

Statistical Analysis SPSS v.17.0 was used for all statistical testing. Demographic data was compared *via* independent *t*-tests and Chi-squared tests, while success rates were compared *via* Pearson Chi-squared tests. $P<0.05$ served as the significance threshold for this study.

RESULTS

A total of 1439 patients, providing us with 1623 affected eyes, were initially recruited for this study. Among them, 23 patients (28 affected eyes) exhibited upper or lower canaliculus stenosis, during surgery; silicone tube intubation were used in 53 patients (61 affected eyes) due to small or cicatrized lacrimal sacs; and 39 patients (45 affected eyes) failed to complete postoperative follow-up. These patients were excluded from the study and the remaining 1324 patients, with affected 1489 eyes, were included in the final analysis. Among them, 179 affected eyes from 156 patients were C1, 878 affected eyes from 785 patients were C2, and 432 affected eyes from 383 patients were C3.

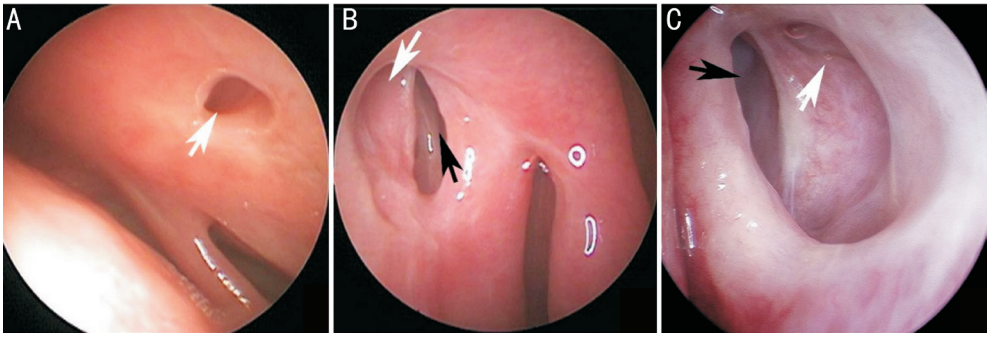

Figure 3 Examples of ostial patency success, as evidenced by endoscopic examination A: A clinical photograph illustrating a patent ostium lined by healthy epithelium (white arrow) at 12mo in a C1 patient; B: A clinical photograph depicting a patent ostium (white arrow) and anterior ethmoid sinus ostial (black arrow) lined by healthy epithelium at 12mo in a C2 patient; C: A clinical photograph showing a patent ostium (white arrow) and anterior ethmoid sinus ostial (black arrow) lined by healthy epithelium at 12mo in a C3 patient.

Table 1 Characteristics of patients belonging to the 3 ethmoid categories

Parameters	C1	C2	C3	Statistic	*P*
Age	53.96±15.06	53.75±15.17	53.67±15.28	0.02	0.98
Gender (M/F)	69/110	325/553	162/270	0.16	0.93
Eye (OD/OS)	92/87	454/424	220/212	0.07	0.97
Symptom duration	15.24±15.27	16.31±16.61	15.35±14.94	0.71	0.70

Patient clinical characteristics of the 3 ethmoid categories are compiled in Table 1. There were no significant differences in patient age (F=0.02, P=0.98), gender (χ^2=0.16, P=0.93), eye laterality (χ^2=0.07, P=0.97), or symptom duration (χ^2=0.71, P=0.70) among 3 groups.

The overall success rate of En-DCR was 93.0 % (1385/1489) at the 12mo follow up, based on the setting criteria (Figure 3). Additionally, the success rates were comparable among the 3 categories (C1: 91.1%, 163/179; C2: 94.0%, 825/878; and C3: 91.9%, 397/432; χ^2=3.097, P=0.213).

Granuloma formation, scar synechia at the site of the rhinostomy, and canalicular obstruction were the major causes of post-operative lacrimal system obstruction (Figure 4). TDR failure occurred in a few patients as described below: In 16 C1 eyes, due to intranasal ostial occlusion brought on by granuloma formation or scar synechia. In 50 C2 eyes, due to intranasal ostial occlusion, similar to C1, and in 3 C2 eyes, due to common canalicular obstruction. Lastly, in 32 C3 eyes, due to intranasal ostial occlusion, similar to C1 and C2, and in 2 C3 eyes due to common canalicular obstruction, and 1 C3 eye, due to lower canaliculi obstruction.

Postoperative complications like orbital fat prolapse, cerebrospinal fluid leak, and sinusitis or visual dysfunction did not occur in the patients in this study. In 9 patients, frontal maxillary process removal resulted in some bleeding, which was remedied using either electric coagulation or bone wax. Additionally, 5 patients experienced postoperative epistaxis the day of or the day after surgery. This was resolved with cotton packing soaked in a vasoconstrictive solution during outpatient care.

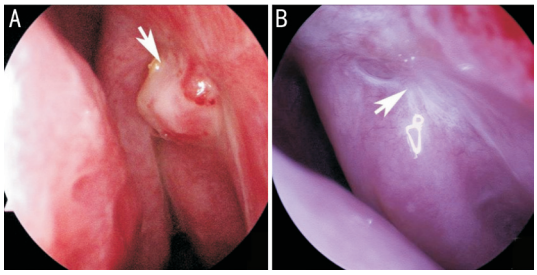

Figure 4 Examples of TDR failure, due to ostial closure, as evidenced by endoscopic examination A: A clinical photograph depicting a large granuloma (arrow) obstructing the ostium in a C1 patient; B: A clinical photograph of extensive scarring (arrow) that resulted in ostial closure in a C2 patient. TDR: Tear drainage reconstruction.

DISCUSSION

The ethmoid sinuses develop early in a child's life. During infancy, they begin to occupy neighboring bone, by 2y of age, they pack the space between the nasal cavity and the orbit, and by 12y of age, the adult configuration is reached. These sinuses often project past the ethmoid bone suture and into the lacrimal and maxillary bones of the lacrimal sac fossa.

Therefore, understanding the physical interaction between the anterior ethmoid air cells and the lacrimal sac fossa is essential for DCR[7-9,11]. Unfortunately, an ethmoid-cell entry may present a blind cul-de-sac and can lead to surgical failure. Similarly, Welham and Wulc[16] found that neighboring ethmoid air cells can increase chances of scarring and, therefore, increase chances of complications and DCR failure. However, these obstacles are not seen with En-DCR, since, with this procedure, the nasal mucosa is repaired first and

ethmoid structures and its mucosa are easily identified under the endoscopic[17]. This provides En-DCR with an added advantage in treating nasal abnormalities that are normally associated with an increased risk of surgical failures.

Using CT imaging, we can visualize the anatomical structure of the bone frame, ethmoid air cells, lacrimal bone, and lacrimal sac. Performing CT prior to DCR, followed by endoscopy during DCR, increases the chance of identifying intervening ethmoids[11]. CT-DCG is, therefore, an effective tool for the precise assessment of ethmoidal cells and lacrimal sac before En-DCR[18]. To perform CT-DCG, a contrast media, containing iopromide, iohexol, and omnipaque, is injected into the inferior or superior canaliculus before axial and coronal images of 1–2 mm varying slice thickness are taken[19]. The high-resolution CT-DCG allowed for the clear visualization of the lacrimal sac and the surrounding bone and soft tissues, and was essential in the determination of the relative relationship between the lacrimal sac and the ethmoid sinus cells.

The close relationship of the ethmoidal sinuses to the lacrimal sac fossa has long been recognized. In 1955, Romanes[20] described anterior ethmoid sinus cells lying medial to the lacrimal sac fossa. Likewise, Blaylock *et al*[8] examined 190 CT scans, with normal ethmoid anatomy, and established the 3 categories of ethmoids we know today. In another study, Jiang *et al*[21] examined 16 adult Chinese cadavers and found C2 and C3 incidences at 50% and 31.2%, respectively. Interestingly, an interracial study showed that the ethmoid cell was located further anterior to the lacrimal sac in Asians, relative to whites[22]. In this study, 1324 affected eyes were examined for the clinical outcomes of En-DCR, with respect to different category ethmoids. We demonstrated that the use of CT-DCG provided better visualization of the anterior ethmoid sinus and the dacryocyst, making it easy to classify the ethmoid. We found that 12.0% (179/1489) of the affected eyes have C1 ethmoid, 59.0% (878/1489) have C2, and 29.0% (432/1489) have C3. Our findings were in accordance with other published reports[7-9,17,20-21].

During routine En-DCR, osteotomy is initiated at the lacrimomaxillary suture and then carried forward into the nasal fossa until the lacrimal sac is exposed[1-2,11,15]. However, this technique may not suitable in cases of C2 and C3 ethmoid. In such cases, the developed ethmoid cells partly or completely covers the lacrimal sac. Therefore, these cells would first need to be entered and enlarged in order to expose the suture and initiate osteotomy. In our experience, it was not necessary to remove the anterior ethmoid sinus completely. In fact, doing so damaged the mucosal layer of the frontal sinus-outflow pathways and caused frontal sinusitis. In such cases, we recommend incision and enlargement of the anterior part of the sinus before conducting either partial or the entire surgical intervention within the ethmoid sinus.

Conventionally, it was essential to form a single nasal sac flap and a single lacrimal sac flap and oppose them during En-DCR[2,11-12,15,23]. In this study, however, we generated a large C-shaped lacrimal sac flap. In C1, the lacrimal sac flap was rolled out and flattened posterior to the lateral nasal wall to oppose it to the nasal mucosa, as previously described[15]. In C2 and C3, however, the ethmoid cell was entered and the anterior part of the ethmoid was enlarged with a straight cut while avoiding tear to the nasal mucosa. The ethmoidal mucosa was preserved to perform a mucosa–mucosa approximation with the marsupialized lacrimal sac flaps, which laid flat posteriorly to the ethmoid sinuses. This technique was beneficial in that it allowed access to the large stomal space and reduced synechiae of the nasal cavity.

To prevent damage to the intranasal lacrimal sac ostium, some surgeons introduced a bi- or monocanalicular silicone tube to stent the rhinostoma. However, many avoid using silicone tube intubation, in chronic dacryocystitis patients, since the tubes are inorganic and may, therefore, facilitate the development of persistent intranasal granulation tissue, punctual adhesions, canalicular laceration, or postoperative infections. This type of intubation is generally recommended in patients with a small lacrimal sac, a narrow upper nasal cavity, or canalicular stenosis/obstruction[24-27]. Given these complications, silicone tubes were not implanted in any of the patients examined in this study.

Merogel, an esterified hyaluronan derivative, lasts longer than hyaluronan and can easily be used in a non-woven sponge preparation. In the past, merogel has been successfully used as an anti-adhesive packing agent to stimulate mucosal epithelial healing in functional endoscopic sinus surgery[28]. Moreover, in earlier studies, we demonstrated that supplementary use of Merogel enhances the success of En-DCR surgery for primary chronic dacryocystitis *via* promotion of early osteium re-epithelialization, suppression of fibrotic tissue development at the ostium, and prevention of the lacrimal sac apposition to the nasal mucosa flaps[15,29-30].

Based on literature, En-DCR has a success rate of 82.2%-95.6%[4,10-13,24-26]. In this study, En-DCR was performed with a success rate of 93.0%, with complete attenuation of clinical symptoms post-surgery, and with an unobstructed lacrimal system, as evidenced by free-flowing irrigation of the system and nasal cavity. We also reported comparable success across different ethmoid categories. In fact, the success rate evaluation at the 12-month follow up showed 91.1% (163/179) success in C1, 94.0% (825/878) in C2, and 91.9% (397/432) in C3. Therefore, we successfully demonstrated that the degree of ethmoid sinus development does not affect the surgical

outcome, especially when the ethmoid sinus is well managed, and the mucosal anastomosis of ethmoid sinus and nasal canal is possible.

Furthermore, we also demonstrated a low incidence of complications. Nine patients experienced bleeding during frontal maxillary process removal and electric coagulation, or bone wax was used to remedy it. Five patients experienced epistaxis after operation, which was remedied using cotton soaked in a vasoconstrictive solution. Serious complications like orbital fat prolapse, cerebrospinal fluid leak, sinusitis or visual impairment did not occur in any of our patients.

Despite efforts to improve operative success rates and consistent with prior studies, our surgical patients experienced granulation and ostial scar tissue formation[3-5,11,15,25]. There was 16 cases of C1 TDR failure, due to granuloma formation or scar synechia, leading to intranasal ostial closure; 50 cases of C2 TDR failure, due to granuloma formation or scar synechia, leading to intranasal ostial closure, and 3 cases of C2 TDR failure, due to common canalicular obstruction; lastly, 32 case of C3 TDR failure, due to granuloma formation or scar synechia, 2 cases due to common canalicular obstruction and 1 cases of lower canaliculi obstruction.

In summary, En-DCR with mucosal anastomosing has a high success rate (93.0%) with low complication risk, making it an optimal choice for En-DCR in patients with chronic dacryocystitis. The categories of ethmoid cells, if well managed, do not affect surgical outcomes.

ACKNOWLEDGEMENTS

Conflicts of Interest: Wang YH, None; **Jiang WH,** None; **Tu YH,** None; **Zhou GM,** None; **Wu WC,** None; **Yu B,** None.

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