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Reconstructive

Lacrimal Plasty with Dacryocystorhinostomy-Anastomosis Using Microsurgery

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Background: Dacryocystorhinostomy (DCR) is the standard treatment for nasolacrimal duct obstruction, but it has the disadvantage of creating a raw surface, which may lead to reocclusion due to the development of postoperative granulation tissue. In this study, we developed and evaluated an ideal new surgical method, dacryocystorhinostomy-anastomosis (DCR-A), involving end-to-side anastomosis under microscopic visualization that does not result in raw surfaces.
Methods: In DCR, the lateral aspect of the dacryocyst and the nasal mucosa are incised, and the mucosal valves are sutured together. In DCR-A, the occluded section of the dacryocyst or nasolacrimal duct was trimmed and anastomosed by circumferential suturing through a hole in the nasal mucosa. The success rate and the requirement for postoperative therapy were compared between 21 sides of DCR patients and 11 sides of nasal DCR-A patients.
Results: DCR-A was significantly better than conventional DCR. No additional postoperative therapy was required for DCR-A.
Conclusion: DCR-A improves symptoms of nasolacrimal duct obstruction to a greater extent than conventional DCR and does not require additional postoperative treatment.
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INTRODUCTION

Blockage of the nasolacrimal duct causes epiphora and acute or chronic dacryocystitis.[1,2] The cause of nasolacrimal duct obstruction is multifactorial and has not yet been elucidated.[3] The middle nasal duct, ethmoid sinus, and maxillary sinus have been reported as possible drainage sites for lacrimal fluid in the treatment of patients with nasolacrimal duct obstruction.[4] The most common treatment for nasolacrimal duct obstruction is dacryocystorhinostomy (DCR),[5–7] which drains into the middle nasal duct. There are two types of DCR: endonasal DCR, which is performed using an endoscope, and external DCR, which is performed through a skin incision under direct vision.[8,9] In our department, we have been using the most common double-flap external DCR method.[10–12] In this method, the mucosal flaps of the lacrimal sac and nasal cavity are sutured to each other, but it is impossible to avoid leaving raw surfaces on the upper and lower edges of the flaps, which can cause reocclusion of the lacrimal canal because of excessive postoperative growth of granulation tissue on these areas. In addition, the physiological structure of the lacrimal canal is disrupted due to severe damage to the lacrimal sac. To resolve these issues, we have developed and are currently using dacryocystorhinostomy-anastomosis (DCR-A), a method of anastomosing the edge of the lacrimal sac to a hole in the lateral wall of the nasal mucosa as end-to-side anastomosis under a surgical microscope. This article describes DCR-A in detail and presents a comparison with conventional DCR.

MATERIALS AND METHODS

This study was approved by the Committee for Medical Ethics of Shinshu University School of Medicine institutional review board (IRB#: 5104). All patients provided informed written consent in the form of opting in on the hospital website.

A retrospective photography and chart review was performed for patients with epiphora who visited our hospital (Shinshu University Hospital) between January 1, 2015, and December 31, 2021. The clinical records, including operative reports and photographs of each patient, were studied. All patients complained of excessive shedding of tears. In all patients, lacrimal duct obstruction was diagnosed preoperatively with lacrimal

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duct contrast-enhanced computed tomography. Patients with tumors, lacrimal canalicular obstruction, or lacrimal punctum obstruction were excluded. All operations were performed by one surgeon (D.Y.). Cases were divided into two groups according to the type of surgical procedure (Table 1).

DCR Group

Seventeen patients (six men and 11 women) who visited our hospital during the 3-year period from January 2015 to December 2017 underwent conventional DCR. Age at the time of surgery ranged from 45 to 82 (mean 68.0) years. Four patients had bilateral obstruction. A total of 21 sides were treated by conventional DCR. No patient had a history of radiation or surgery to the face.

DCR-A Group

Nine patients who visited our hospital during the 4-year period from January 2018 to December 2021, consisting of four men and five women, underwent DCR-A. Age at the time of surgery ranged from 6 to 85 (mean 63.0) years. Two patients had bilateral obstruction. A total of 11 sides in nine patients were treated by DCR-A. No patient had a history of radiation or surgery to the face.

Evaluation

Postoperative Recurrence Rate

The postoperative recurrence rate was calculated by confirming the presence or absence of flowing tears and passage of water through the new nasolacrimal duct opening by injecting colored water endoscopically through the lacrimal punctum in the first 6 months after surgery in each group. The rates were compared between the two groups.

Follow-up Therapies Required to Maintain Postoperative Lacrimal Canal Patency

Corticosteroid was injected through the lacrimal punctum, or a lacrimal silicone tube inserted into the canal if the flowing tears recurred within 6 months after surgery, which was thought to be due to obstruction because of postoperative granulation tissue overgrowth. The requirement of the two follow-up therapies was investigated and compared between the two groups.

Frequency of Tears

The frequency of tears in the first 6 months after surgery was evaluated with reference to the Munk scale.[13] The degree of improvement, defined as the difference between pre- and postoperative grade, was compared between the two groups.

Table 1. DCR and DCR-A Cases

DCR Cases	DCR-A Cases
Three-year period from January 2015 to December 2017	Four-year period from January 2018 to December 2021
17 patients (6 men, 11 women)	9 cases (4 men, 5 women)
Age: 45–82 (mean 68.0) years	Age: 6–85 (mean 63.0) years
21 sides (bilateral in 4 cases)	11 sides (bilateral in 2 cases)

Takeaways

Question: Is dacryocystorhinostomy-anastomosis (DCR-A), which we have developed as a treatment for nasolacrimal duct obstruction, more effective than conventional DCR?

Findings: The success rate and the requirement for postoperative therapy were compared between DCR-A patients and DCR patients. DCR-A was significantly better than conventional DCR. No additional postoperative therapy was required for DCR-A.

Meaning: DCR-A improves symptoms of nasolacrimal duct obstruction to a greater extent than conventional DCR.

Statistical Analysis

Fisher exact test was used to analyze the postoperative recurrence rate and the requirement for follow-up therapies. The frequency of tears was analyzed using the Mann–Whitney U test. SPSS Statistics 24 was used in all analyses, and a P value less than < 0.05 was taken to indicate statistical significance.

Surgical Procedures

DCR

All operations were performed under general anesthesia. A 2-cm arc-shaped skin incision line was designed just above the lacrimal sac of the lower eyelid. Following injection of 1% lidocaine and 1/100,000 epinephrine solution, a skin incision was made using a #15 scalpel. The orbicularis oculi muscle fibers were separated with blunt dissection until the surface of the periosteum was reached. The periosteum was incised along a line slightly medial from the anterior lacrimal ridge. From this incision, the periosteum was elevated from the bone, and the lacrimal sac was completely exposed at the lacrimal fossa (Fig. 1A).

The lacrimal sac fossa was carefully perforated. The bony septum of the fossa was removed in the following area. The superior level was at the caudal edge of the medial canthal tendon, the inferior level was 2 mm caudal to the lacrimal fossa, the anterior limit was the nasomaxillary suture, and the posterior limit was the posterior lacrimal ridge. The nasal mucosa was exposed when the frontal process of the maxillary bone, including the anterior lacrimal ridge was shaved thin with a diamond burr over an area of about 1 cm^2. The nasal mucosa was carefully detached from the bone, and the bony window was created without damaging the nasal mucosa by further shaving or removing the bone using osteotomy forceps (Fig. 1B).

After injection of 1% lidocaine and 1/100,000 epinephrine solution into the nasal mucosa, the nasal mucosal flap was elevated anteriorly by making a U-shaped cut using a crescent knife. The medial wall of the lacrimal sac

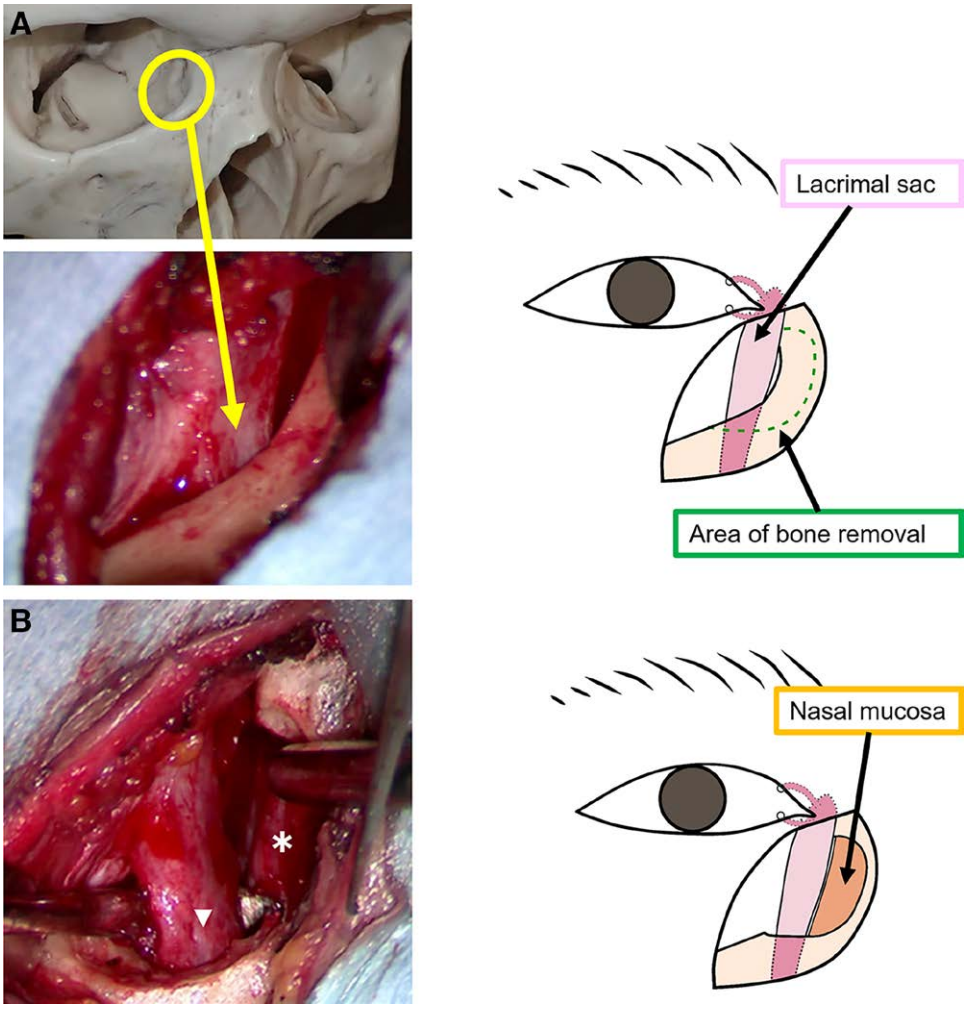

Fig. 1. A, Exposed lacrimal sac. B, Exposed nasolacrimal duct (▼) and nasal mucosa (*).

was incised, and a lacrimal sac mucosal flap was elevated posteriorly (Fig. 2A). Silicone tubes (N-ST; Zeiss) were used as indwelling stents, and the mucosal flaps were sutured to each other with 6-0 monofilament polydioxanone sutures (PDS-II; Ethicon) (Fig. 2B). The lumen remained open on both superior and inferior sides, and raw wounds remained at these two orifices. After wound cleaning, the orbicularis muscle and skin were closed in a layered manner. The tubes were removed from 4 weeks to several months after surgery.

DCR-A

The same procedure as the conventional method was performed until creation of the bony window (Figure 1A, B). The exposed lacrimal duct was cut transversely, leaving as much as possible. If the nasolacrimal duct fragment was obstructed, it was gradually separated using delicate scissors to reopen and expose the nasolacrimal duct lumen. If the lacrimal sac and duct were tightly attached to the surrounding supporting tissue, including the orbicularis oculi muscle, the periosteum around them and the orbicularis oculi muscle were separated to allow the nasolacrimal duct to reach the nasal mucosa with room to spare. The nasal mucosa was circularly excised after intramucosal injection of local anesthetic according to the diameter of the nasolacrimal duct cut-off stump (Fig. 3A). At this time, the diameter of the tear duct break was measured and a dermal trephine (Derma Punch; Maruho) of similar size was used. Holes greater than or equal to 5 mm in diameter were usually drilled. When using the trephine, the nasal cavity was loaded with gauze to avoid injuring the nasal turbinates by punching with the trephine.

The cut-off nasolacrimal duct was anastomosed to the hole in the nasal mucosa. The posterior wall of the duct was sutured first, and then the anastomosis was completed with suturing of the anterior wall in a manner similar to the back wall-first technique for vascular anastomosis.[14,15] All sutures between the duct wall and the wall of the nasal cavity were done using 6-0 monofilament polydioxanone (PDS-II; Ethicon) or 7-0 coated braided polyglactin 910 (coated Vicryl; Ethicon). It was easier to use a small needle to suture (Fig. 3B). The gauze was placed in the nasal cavity, and the staining solution was injected through the lacrimal punctum again. The gauze was confirmed to be

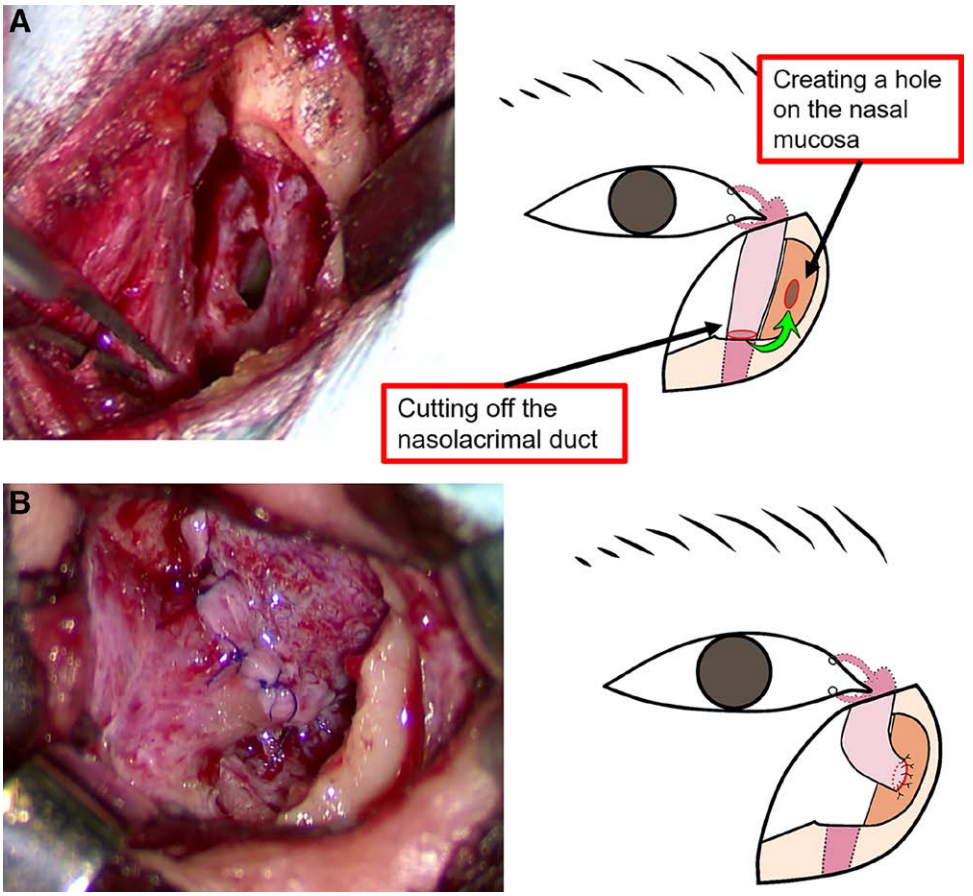

Fig. 2. A, Creating a nasal mucosal flap with an anterior base and a lachrymal sac mucosal flap with a posterior base. B, Suturing the two mucosal flaps to each other. The lumen continues to be open on both superior and inferior sides. Additionally, raw wounds remain at those two orifices.

stained, and intrawound cleaning and skin suturing were performed.

RESULTS

Surgical outcomes are summarized in Table 2. The proportions of patients with no recurrence of tears at 6 months after surgery were 76.2% (16 of 21 sides) for the DCR group and 100% (0 of 11 sides) for the DCR-A group. The proportions of patients in whom water could pass through the new nasolacrimal duct opening were 85.7% (18 of 21 sides) for the DCR group and 100% (11 of 11 sides) for the DCR-A group. The rates of both outcomes were higher in the DCR-A group, but neither difference was significant ($P = 0.101$ and 0.268, respectively, Fisher exact test).

Steroids were injected into the lacrimal canal by 6 months after surgery in 33.3% and 0% of cases in the DCR and DCR-A groups (7 of 21 sides and 0 of 11 sides), respectively. The difference between the two groups was significant ($P = 0.035$, Fisher exact test).

The median (IQR) differences between the pre- and postoperative values of the Munk scale were 3 (2–4) for the DCR group and 4 (4–4) for the DCR-A group, indicating significantly greater improvement in the DCR-A group ($P = 0.025$, Mann–Whitney U test).

REPRESENTATIVE CASE

At the first visit to our department, a 33-year-old woman who had become aware of increased tear secretion about one and a half years prior to presentation reported having to wipe tears from her eyes more than 10 times a day (Munk scale: 4; Fig. 4). At a visit to a local doctor, purulent fluid flowed back when the tear duct was washed. Computed tomography showed complete obstruction of the nasolacrimal duct. DCR-A was performed under general anesthesia. No silicone tube stents were used, and postoperative intracanal steroid injection was not needed. Colored water injected endoscopically through the lacrimal punctum was confirmed to pass through the new nasolacrimal duct opening formed in the middle nasal canal 6 months after surgery.

DISCUSSION

DCR is the standard treatment for nasolacrimal duct obstruction.[2] There are two types of DCR: intranasal and extranasal. The intranasal method has the advantage that it does not require an incisional wound to the facial skin, and the extranasal method has the advantage that the mucosal flap can be sutured under direct vision, so the re-obstruction rate is low.[10] However, with several recent technical

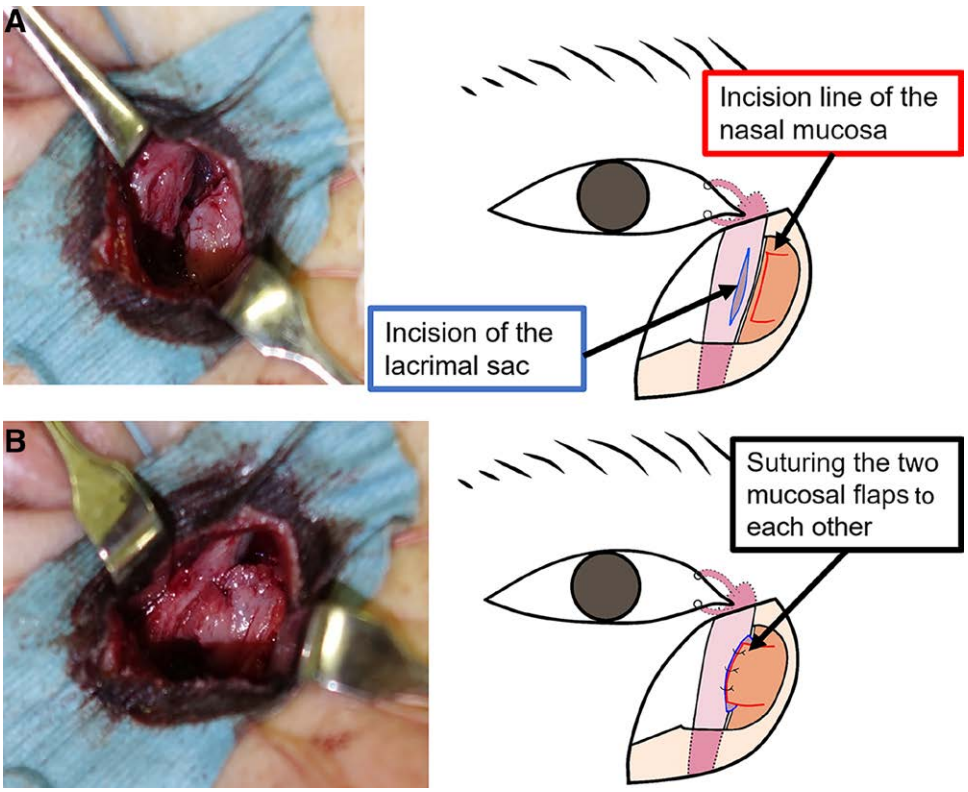

Fig. 3. A, A circular lateral hole is created in the nasal mucosa and the nasolacrimal duct is cut off. B, The cut nasolacrimal duct is anastomosed to the lateral hole of the nasal mucosa.

Table 2. Results

	DCR	DCR-A	Statistical Method	*P*
The total numbers	21 sides	11 sides		
Percentage of patients with no recurrence of tears	76.2% (16/21)	100% (11/11)	Fisher exact probability test	0.101
Percentage of patients with passage of water	85.7% (18/21)	100% (11/11)	Fisher exact probability test	0.268
Percentage of cases requiring silicone tube stents	100% (21/21)	0% (0/11)	Fisher exact probability test	0
Percentage of cases requiring steroid injection into the lacrimal canal	33.3% (7/21)	0% (0/11)	Fisher exact probability test	0.035
The median (IQR) in the Munk scale before and after surgery	3 (2–4)	4 (4–4)	Mann–Whitney U test	0.025

developments in intranasal procedures and devices, some ENT surgeons have suggested that re-obstruction rates are comparable between the two procedures,[16] and it is still controversial which of the techniques is superior.[9,10] The extranasal approach has been used as the first alternative in our department because of the inconspicuous operative scar when incisions are made along the relaxed skin tension line and atraumatic manipulations are performed. The luminal continuity between the lacrimal sac and the nasal cavity are conserved because the lacrimal sac mucosa and the nasal cavity mucosa can be reliably sutured to each other on the anterior and posterior sides using the double-flap procedure under an open operative field using this method. On the other hand, as the lumen remains open on both superior and inferior edges of these flaps and raw wounds remain at these two sites, they are prone to proliferation of granulation tissue.[17] However, it is difficult to completely close a large bony or mucosal hole once opened even after proliferation of granulation tissue. Therefore, we believe that obvious epiphora is unlikely to recur after treatment using conventional DCR. In fact, the success rate of DCR has been reported to be between 73% and 100%.[18–20] In this study, the success rate of DCR over 6 months after surgery was 76.2% based on tear flow and 85.7% based on water flow. Although the success rate was 70%–80%, tears continued to flow for 1–3 months postoperatively, probably because of luminal coarctation caused by proliferation of granulation tissue on the raw wounds until the scar had matured completely. In such cases, steroids were injected through the lacrimal punctum to decrease the proliferation of granulation tissue, as it was thought that there was a risk of reocclusion because of granulation. It was also necessary to place indwelling silicone tubes as stents to prevent reocclusion. Therefore, the conventional DCR method required not only surgery but also postoperative therapy to prevent reocclusion after discharge from the hospital. Even with these efforts, some patients complained of constant tears to varying degrees. Therefore, it was difficult to definitively conclude whether conventional surgery was

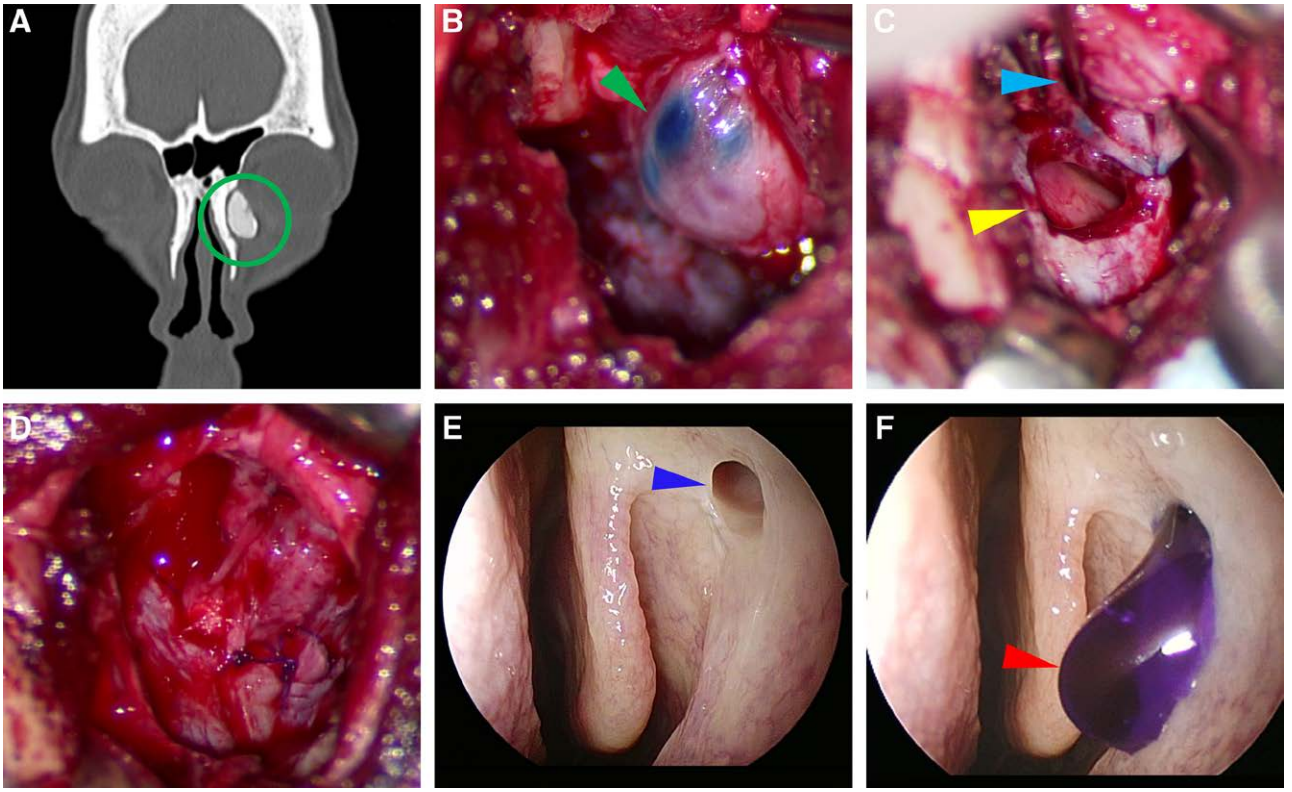

Fig. 4. Representative case. A, Contrast staining of the cephalic side of the left lacrimal passage. Obstruction was observed on computed tomography (green circle). B, Site of occlusion of the left lacrimal sac after dissection of the left nasolacrimal duct obstruction and before release of the lacrimal sac lumen. The blue pigment staining the inside of the lacrimal sac can be seen through it (green arrowhead). C, Site of occlusion of the left lacrimal sac after release of the lacrimal sac lumen (light blue arrowhead) and transverse hole in the nasal mucosa (yellow arrowhead). D, The lacrimal sac was anastomosed to the nasal mucosa. E, Nasal endoscopic findings at 8 months postoperatively. The hole of the lacrimal sac nasal anastomosis (blue arrowhead) is clearly visible. F, Purple water was observed flowing into the nasal cavity (red arrowhead).

successful postoperatively. This was probably because the tear fluid does not flow through a simple ductal structure into the nasal cavity, but through a complex slit-like space, due to the size and shape of the postoperative granulation growth and subsequent scarring of the mucosal sutures. Therefore, to improve the tear flow, it was necessary to devise a surgical procedure that would prevent the formation of a raw surface to prevent granulation.

The eight-flap method[21] and the three-flap method[22] have been reported as ways to prevent raw surface formation. The eight-flap method involves the creation of detailed mucosal flaps, which are pieced together like a puzzle to minimize the raw areas between each suture holding the lacrimal sac to the nasal mucosa. However, this procedure can only be applied in cases where the lacrimal sac is dilated, enlarged, and obstructed at the lower part of the nasolacrimal duct, and is difficult to apply in cases where the lacrimal sac mucosa is vulnerable due to localized inflammation. In the three-flap method, although a mucosal flap is not created on the posterior surface, flaps are created on the cephalad and caudal sides to prevent the formation of raw areas other than the posterior surface. This is based on the fact that the posterior surface of the bony window has less marrow and is less prone to granulation growth even if the mucosae are not sutured together.[23] These methods seem to compensate for the shortcomings of the double-flap method. However, neither of these methods completely eliminates the raw surface. In addition, the morphology of the lacrimal sac is severely disrupted because a large incision is made in the mucosa of the lateral wall of the sac to create mucosal flaps. These issues can lead to a breakdown of the pumping action by the lacrimal sac and Horner muscle,[24] and the physiological mechanism will deteriorate.

Therefore, we felt that it was necessary to develop a method that would avoid the formation of raw areas and would not cause significant damage to the lacrimal sac. We developed the DCR-A method involving cutting the nasolacrimal duct at the obstructed site without cutting the lateral wall of the lacrimal sac and making a hole on the nasal mucosa to perform an end-to-side anastomosis. As this method forms no raw wound, granulation tissue proliferation should not occur, and re-obstruction should be rare.

In 1961, Burn[25] successfully directly anastomosed the mucosa of the lacrimal sac with the mucosa of the nasal cavity in 11 of 12 cases and reported it as end-to-side anastomosis. Although this was an ideal method, the

procedure was very difficult because surgical microscopes had yet to be developed and fine needles and threads were not available.

In addition, the nasolacrimal duct cannot reach the mucosa of the nasal cavity unless the obstruction is in the lower part of the nasolacrimal duct because the distance between the upper part including the lacrimal sac and the mucosa of the nasal cavity is too long for direct anastomosis. Because it was difficult to anastomose the nasolacrimal duct and the nasal mucosa by suturing circumferentially, no techniques for completely anastomosing the nasolacrimal duct and the nasal mucosa have been reported since Burn, with the exception of one report of an ingenious method of end-to-side anastomosis by Honda[26] in 1997.

The ability to completely anastomose the nasolacrimal duct to the nasal mucosa in a circumferential manner in this series was mainly due to the development of microsurgical techniques and devices. Even without a microscope, it is possible to suture the anterior half of the anastomosis using a surgical loupe. However, it is particularly difficult to suture the posterior wall because the nasal mucosa cannot be inverted as when performing vascular end-to-end anastomosis. Although we initially felt that there would be no problem regarding positioning knots of the posterior wall sutures in the lumen, in contrast to vascular anastomosis, we found that the knots facing the lumen interfered with the field of view and made the anastomosis difficult in actual practice. To resolve this issue, we used the back wall-first technique,[14,15] which is a microsurgical technique used to suture the posterior wall when the vessels cannot be inverted during anastomosis. This maneuver made it somewhat easier to suture the posterior wall. Moreover, by keeping a few threads sewing the posterior wall untied and grasping them with small bulldog clips, the posterior wall could be sutured more safely and securely.[27] The anterior wall could be sutured without any difficulty.

In cases with nasolacrimal duct obstruction at a high position, it is necessary to consider how to make the nasolacrimal duct fragment reach the nasolacrimal mucosa. Before creating the bony window, the area around the lacrimal sac is detached by separating beneath the periosteum. The periosteum and part of the orbicularis oculi muscle fibers attached to the lacrimal sac interfere with the mobility of the lacrimal sac. Therefore, additional incisions of the periosteum around the lacrimal sac and part of the orbicularis oculi muscle fibers allow the lacrimal sac to be moved to the nasal cavity. In fact, there was a case where the blockage was in the upper part of the nasolacrimal duct, but by making an incision in this way, the lacrimal sac was able to reach the nasal cavity with room to spare and could be anastomosed. It is necessary to grasp the lacrimal sac with forceps and gently move it around to determine the boundary between the sac and the surrounding area under the microscope and to minimize the amount of dissection necessary. If this is done unintentionally, it may tear the lacrimal canal, perforate the orbital septa and result in protrusion of orbital fat, hinder the surgical view, make anastomosis more difficult, or damage the Horner muscle and prevent preservation of the pumping action, which is one of the advantages of this technique. By taking care of these pitfalls and increasing the mobility of the lacrimal sac, anastomosis is possible even in cases with obstruction at a high position, and the surgical indication of DCR-A can be extended to obstruction sites equivalent to the indication range of conventional DCR.

DCR-A is characterized by two points: the microsurgical technique (which is used to anastomose the lacrimal canal into the nasal cavity in a reliable and circumferential manner) and the surgical procedures of the perilacrimal sac (which enables treatment even of cases with nasolacrimal duct obstruction at a high position). With the development of operating microscopes, the number of facilities that can perform head and neck reconstruction using free flaps, breast reconstruction, etc, and the availability of a wide variety of fine sutures and needles, it is not difficult for microsurgeons to perform circumferential anastomosis between the nasolacrimal duct transection and a fistula in the nasal mucosa under the microscope, as long as the nasolacrimal duct transection reaches the nasal mucosa. It is not difficult for a microsurgeon to anastomose the nasolacrimal duct and the fistula under the nasal cavity. To date, we have applied this method in only eight sides in seven patients, but there has been no recurrence of tears in any of these eight sides. It was confirmed that water flowed smoothly through the new nasolacrimal duct opening formed in the middle nasal canal by injecting colored water endoscopically through the lacrimal punctum. We have experienced no cases of recurrent lacrimal duct obstruction due to contracture of the anastomosis. However, if recurrence due to contracture should occur in the future, we can modify this technique such that the anastomosis is of the tongue-in-groove type. In addition, there have been some reports on the use of W-shaped incisions for facial scars, which is considered to be a disadvantage of the extranasal approach.[28] However, if the incision is made just above the lacrimal canal along the relaxed skin tension line and the wound edges are protected, the wound will not be noticeable in a normal plastic surgery closed wound.

LIMITATIONS

All patients were Japanese, and all procedures were performed by the same surgeon. Although we were able to anastomose close to the lower end of the lacrimal sac, anastomosis may not be possible at a level close to the common lacrimal duct in the lacrimal sac, and this has not been verified. Further studies are required to verify the extent to which anastomosis is possible.

CONCLUSIONS

Nasolacrimal duct end-to-side anastomosis was performed. Unlike conventional DCR, the nasolacrimal duct or lacrimal sac could be anastomosed with the nasal cavity without the formation of raw surfaces, and the

procedure could also be applied in patients with nasolacrimal duct obstruction at a high level.

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