The Nasolacrimal System

Nora Siegal and Christopher B. Chambers

Contents

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6.1 Introduction

6.1.1 Development of the Nasolacrimal System

The nasolacrimal system begins to develop in utero at approximately 6 weeks. At this time, an epithelial layer of ectodermal tissue is entrapped as a core between the (medial) maxillary process and (lateral) frontonasal process. Fusion of the lateral nasal prominence with the maxillary prominence entraps a double layer of epithelial cells which later canalizes to form the lacrimal outflow system. Over the next several months, this horizontally oriented cord of cells assumes its final, mature vertical position (Fig. 6.1). Improper or incomplete development of this system can be associated with epiphora, discharge, dacryocystitis, or cellulitis.

The upper portions of the nasolacrimal system include the puncta, canaliculi, and common canaliculus [1]. Atresia or agenesis of the puncta is not uncommon. Typically, there is a veil or membrane consisting of the conjunctiva that occludes the punctal orifice. Although this may present as a small dimple in the eyelid margin, it is often difficult to appreciate. Gentle pressure along the mucocutaneous junction of the medial eyelid may aid in the discovery of a hidden punctum. A cutdown of this region can also be performed but is not recommended in the hands of an inexperienced lacrimal surgeon. Congenital absence of the punctum is rare and usually seen in syndromes such as ectrodactyly-ectodermal dysplasia-clefting (EEC) syndrome and lacrimo-dento-digital syndrome (Levy Hollister) [2, 3] (Fig. 6.2). Gross examination of the puncta through gentle eversion of the eyelids will reveal whether punctal atresia is present.

Abnormalities of the lower portions of the nasolacrimal system (the lacrimal sac and nasolacrimal duct) typically result from abnormal canalization of the epithelial core. Canalization begins at approximately 16 weeks, and abnormal separation of epithelial cells can result in fistulae between the lacrimal sac and either the nasal cavity (internally) or the skin (externally). External fistulae can often manifest in a pediatric patient as a secondary punctum located inferior and medial to the normal punctum (Fig. 6.3). If an internal fistula is present, fluid can get trapped in the nasolacrimal system. The entrapped fluid (which can be mucous, causing a mucocele, or amniotic fluid causing an amniotocele) may present in a neonate as a cystic distention

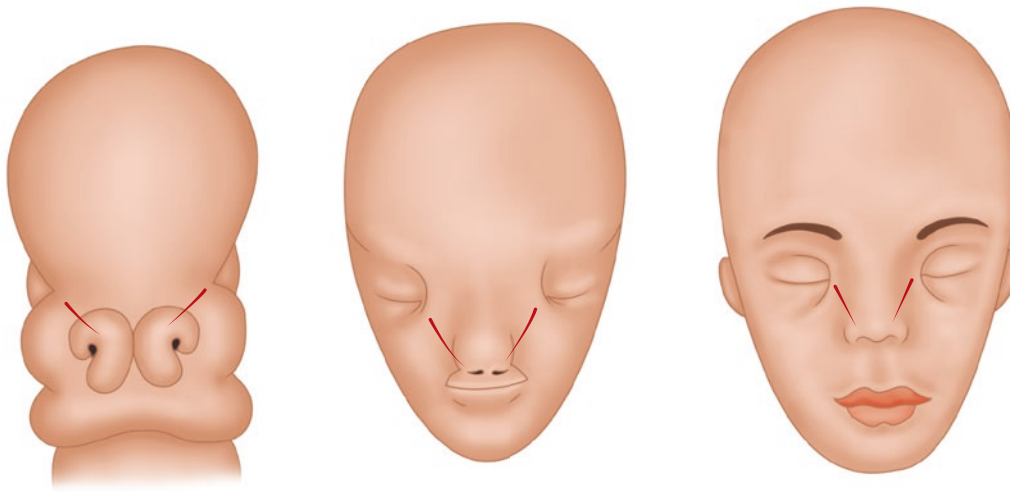


Fig. 6.1 Nasolacrimal duct formation. Fusion of the lateral nasal prominence with the maxillary prominence entraps a double layer of epithelial cells which later canalizes to form the lacrimal outflow system. As the face develops, this cord of cells (red) shifts from a horizontal orientation to vertical position. (Illustration credit: Christopher B Chambers)

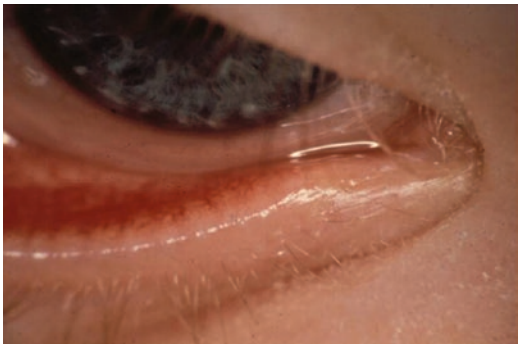


Fig. 6.2 Congenital absence of the punctum of the lower eyelid. (Courtesy of William Katowitz, MD)

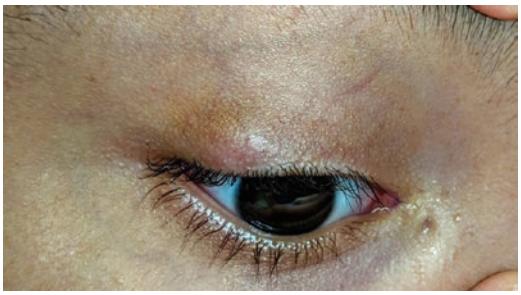


Fig. 6.3 External nasolacrimal fistula can manifest as a secondary punctum located inferior and medial to the normal punctum (arrow)

below the medial canthus. These entities can be evaluated in the emergency room through the use of ultrasonography or simple nasal endoscopy. Importantly, dacryocystoceles have been reported to extend into the nasal cavity and may cause respiratory distress [4].

Infection or inflammation of the nasolacrimal system can occur in the setting of non-patency. The most common etiology is the presence of a membrane covering the distal nasolacrimal ostium at the valve of Hasner. On exam, this manifests as a resistance to probing in the lower portion of the system. Pediatric patients typically present with tearing and mucopurulent discharge, which is followed by the appearance of an inflamed mass below the medial canthus (Fig. 6.4). Stagnant tears within a non-patent system allow bacteria, which typically get drained through the lacrimal system into the nose, to proliferate within the lacrimal system and cause infection. The most common organisms are Gram-positive cocci such as *Streptococcus*

Fig. 6.4 Acute dacryocystitis revealing erythema and induration of the lacrimal sac with early abscess formation. Note mattering of the lashes with mucous discharge lining the eyelid margins

Pneumoniae, *Staphylococcus*, and Gram-negative *Enterobacteriaceae* [5]. Nasolacrimal probing should not be performed in the setting of active infection or inflammation due to the friability of the tissues and the risk of creating a false passage within the system and thus the spread of the infection. Children presenting with evidence of dacryocystitis should receive broad-spectrum antibiotics and should undergo thorough imaging of the orbits if orbital cellulitis is suspected.

Congenital nasolacrimal duct obstructions must be distinguished from other, nonobstructive functional abnormalities in the evaluation of a pediatric patient with tearing. Eyelid malpositions that can also result in tearing include entropion/ectropion, colobomas, masses, or telecanthus/hypertelorism can result in poor punctum-to-globe apposition. Eyelash abnormalities such as trichiasis (inversion of normally located lashes) and distichiasis (accessory row of lashes) can irritate the cornea and conjunctiva resulting in discomfort, redness, and tearing. These conditions are best evaluated with the use of a slit lamp microscope.

The mechanism of tear drainage is facilitated by a combination of positive pressure created by blinking and negative pressure induced by both capillary action and suction within the drainage apparatus. The secretory portion of the lacrimal system is composed of the main and accessory lacrimal glands, located superotemporally to the globe within the lacri-

mal fossa of the frontal bone and within the palpebral conjunctival stroma, respectively. These glands provide lubrication for the cornea by secreting tears which ultimately accumulate as a tear lake along the margin of each eyelid [6]. The excretory portion of the lacrimal system, which includes the puncta, canaliculi, lacrimal sac, and nasolacrimal duct, allows for drainage of excess tears (Fig. 16.1). The puncta are 0.3 mm concavities located at the medial aspect of both the superior and inferior lid margins. They are continuous with the superior and inferior ampullae, respectively, which are 2 mm in length and oriented perpendicular to the eyelid margin. These ampullae drain tears into the superior and inferior canaliculi (8 mm in length) which usually come together as a common canaliculus. The common canaliculus opens into the lacrimal sac (10–12 mm in length) which is located in the lacrimal sac fossa, comprised anteriorly by the frontal process of the maxillary bone and posteriorly by the lacrimal bone. The sac is continuous with the nasolacrimal duct (12–18 mm) and empties below the inferior turbinate at the inferior meatus within the nasal cavity (Fig. 6.5) (Table 6.1).

Table 6.1 Nasolacrimal Anatomy

Lacrimal outflow pathway	Length (mm)	Anatomical pathway
Superior and inferior ampullae	2	Continuous with the puncta and drain tears into the superior and inferior canaliculi
Superior and inferior canaliculi	8	Usually come together as the common canaliculus which opens into the lacrimal sac
Lacrimal sac	10–12	Located in the lacrimal sac fossa (maxillary and lacrimal bones) and is continuous with the nasolacrimal duct
Nasolacrimal duct	12–18	Empties below the inferior turbinate at the inferior meatus within the nasal cavity

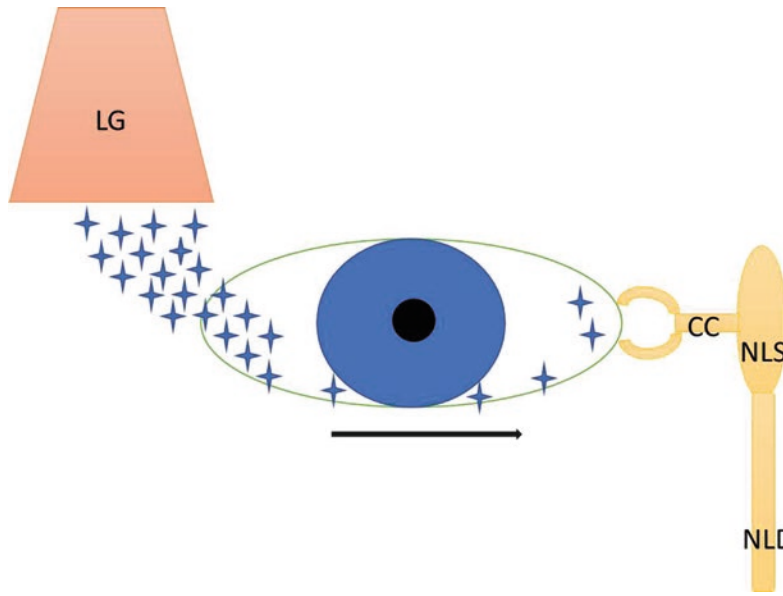


Fig. 6.5 Schematic representation of the lacrimal apparatus of the right eye. Tears produced in the lacrimal gland (LG) are released onto the surface of the globe and accumulate as a tear lake along the eyelid margin. These tears are drawn into the superior and inferior canaliculi through negative pressure and then travel through the common canaliculus (CC). Tears collect in the lacrimal sac (NLS) where they remain in between each blink. Tears are then forced down the nasolacrimal duct (NLD) and empty into the nose

Normal tear drainage requires proper functioning of the entire nasolacrimal system. At the beginning of a blink, the tear drainage system contains tears that have been provided by the lacrimal gland and accessory glands. Eyelid closure, achieved by contraction of the pretarsal orbicularis oculi muscle, moves the puncta medially and posteriorly and compresses the canaliculi. This action forces tears within the system to move down the nasolacrimal duct into the nasal cavity [6]. After orbicularis relaxation, the components of the lacrimal pump reopen to create a negative pressure in the lacrimal sac which draws tears down into the drainage system (◘ Fig. 16.2). Obstruction at any level can result in epiphora, with proximal obstruction leading to clear tear discharge and distal obstruction leading to mucoid discharge.

6.2 Canalicular Trauma

Eyelid lacerations are very common in both blunt and penetrating trauma to the face due to the delicate nature of eyelid tissues. Penetrating injuries due to sharp objects such as knives, broken glass, or metallic tools require a careful evaluation of both the globe and soft tissues. The presence of foreign bodies and the extent of orbital injury must be evaluated through the use of CT imaging. Dog bites, a common cause of eyelid lacerations in children, are reported to involve canalicular damage in 66% of cases [7]. In a study by Savar et al. [7], the majority of these injuries involved damage to the inferior canaliculus [7]. Canalicular lacerations are common with medial canthal tendon avulsion, which is often the result of shearing forces [8]. If the medial canthal tendon is disinserted, it should be reattached to the posterior lacrimal crest if possible. Normally, the medial canthal tendon has two limbs that surround the lacrimal sac within the lacrimal sac fossa (◘ Fig. 16.2). The anterior limb attaches to the frontal process of the maxilla (anterior lacrimal crest), while the posterior limb attaches to the lacrimal bone (posterior lacrimal crest). Appropriate repositioning of the medial canthal tendon establishes normal, anatomic tone of the lower lid around the globe and decreases the likelihood of post-traumatic epiphora.

In the emergency department, physicians should determine the tetanus status of the patient and administer broad-spectrum antibiotics and pain control prior to wound exploration [9]. Soft tissue lacerations can be irrigated with saline via a high-pressure syringe and cleaned with hydrogen peroxide to ensure that all foreign bodies and dried blood are removed. Canalicular injuries can be missed upon gross inspection, and it should be presumed that the canaliculus has been violated if an eyelid margin laceration is full thickness and medial to the punctum [8, 10]. Magnification using a slit lamp or surgical loupes can aid in the assessment of canalicular trauma. Damage to the canalicular system is diagnosed through punctal probing. A topical anesthetic is instilled into the fornix, and a punctal dilator can be used to dilate the punctum. A series of lacrimal probes are then introduced into the nasolacrimal system in the following fashion: perpendicular to the eyelid margin for 2 mm and then turned at a sharp 90° angle to be parallel to the lid margin toward the medial canthus. Providing slight lateral tension on the eyelid facilitates the easier movement of the probe through the canaliculus. If the end of the lacrimal probe can be visualized during this procedure, a canalicular laceration is confirmed. Another method of evaluating canalicular trauma is through the use of lacrimal irrigation. A 1 or 3 mL syringe filled with normal saline can be attached to a blunt irrigation cannula. This can be inserted into the punctum and proximal canaliculus so that saline is instilled slowly. If the canalicular system is lacerated, the saline will efflux out of the system instead of traveling down into the nasopharynx. Simple probing is the preferred method as it may be difficult to differentiate reflux from true efflux in a lacerated canalicular system.

6.3 Canalicular Laceration Repair

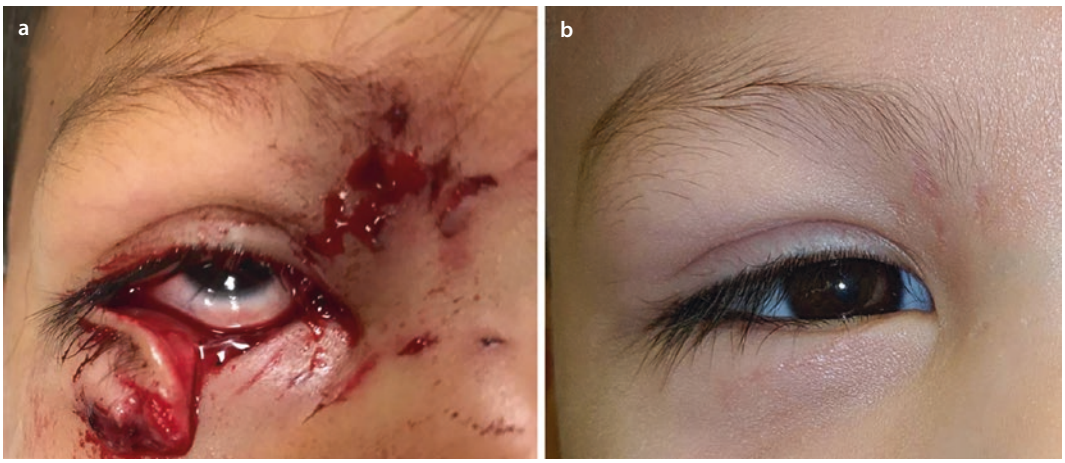
Many studies have revealed that canalicular injuries are more common in young, male patients. Reports cite between 54% and 83% of canalicular lacerations being in this patient

population [11–13]. Common mechanisms of injury include physical altercations, accidents in high-speed vehicles, dog bites, and sport-related injuries. Most oculoplastic surgeons agree that canalicular repair should occur within 72 hours of trauma to prevent granulation tissue from obscuring anatomy and leading to stenosis of the nasolacrimal system and possible fistula formation [14, 15]. There are several factors that determine whether repair at the bedside or in the operating room is undertaken, including the patient's age, health status, level of comfort, other associated injuries, and the experience and preference of the surgeon. Studies have suggested that the success of canalicular repair is highly dependent upon the surgeon's training level, and when possible, oculoplastic surgeons should be consulted for such repairs [13].

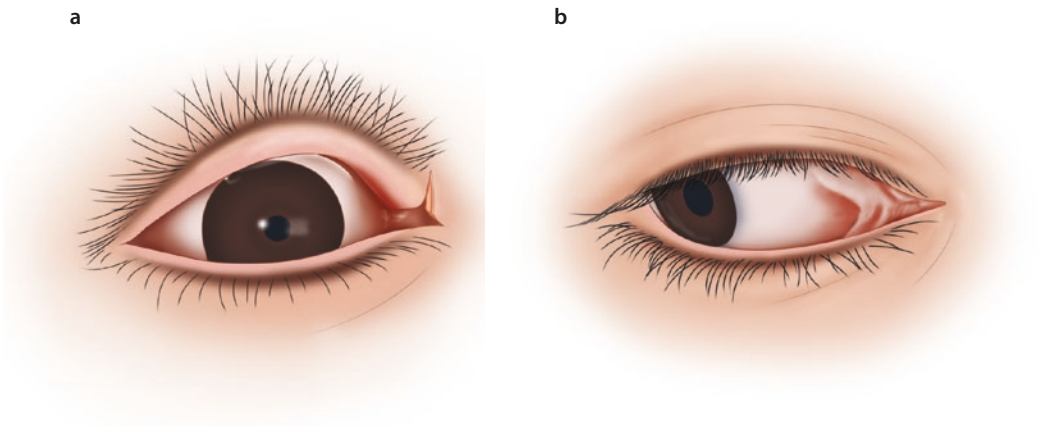
The debate regarding mono- vs bicanalicular stenting for canalicular repair is ongoing with no clear difference in outcome. Repair using a monocanalicular stent (Mini Monoka stent, FCI Ophthalmics Inc., Pembroke, MA) involves only the injured canaliculus. Bicanalicular stenting through the use of a Crawford tube (FCI Ophthalmics Inc., Pembroke, MA) requires that the stent be passed through the uninjured canaliculus and thus puts it at risk for injury [15]. When a Mini Monoka stent is used, it gets seated in place at the level of the punctum. Although monocanalicular stents have the advantage of easy removal with only forceps in the office, their placement at the level of the punctum prevents tear drainage while they are in place. Patients who receive a monocanalicular stent should be counseled that tearing will likely occur while the tube is in place and the tissues are healing. Bicanalicular stents are typically secured endonasally during canalicular repair, and removal in the office can be more complex, sometimes requiring the use of an endoscope and/or endonasal anesthesia. In young children, there may be a need to return to the operating room for sedation in order to safely remove a bicanalicular stent.

Canalicular repair can be performed under local anesthesia at the bedside or on under general anesthesia in the operating room. The ideal setting is determined by the patient's age, level of cooperation, and the surgeon's comfort level. All young children must be taken to the operating room for optimal repair. Once the eyelids have been cleaned and infiltrated with a local anesthetic, the distal end of the canalicular laceration must be found. This step is best achieved in good lighting with the use of a headlight and an assistant who can help with retraction and hemostasis. The lacerated ends of the canaliculus look like blood vessels cut in the coronal plane or small holes lined by mucosa [16]. If the distal cut end cannot be found by examination with surgical loupes or a microscope, injection of saline or fluorescein solution can be performed into the uninjured canaliculus. Efflux of fluid can be seen coming from the distal cut end. Another technique is to instill a few drops of 2.5% phenylephrine into the laceration, which may cause the pouting of the cut canaliculus [15–17]. After the distal end is found, a lacrimal probe should be passed through the cut end to ensure a hard-stop on the lacrimal bone. The monocanalicular stent can then be cut to size and threaded through the proximal end of the laceration and through the distal end. Trimming of the stent should be minimal to allow proper bridging of the distance between the cut ends. The trimmed edge of the stent is then threaded into the nasolacrimal system using either non-toothed forceps to prevent stent trauma or a needle driver in a hand-over-hand technique. This step can be challenging and requires patience as the stent has a tendency to prolapse back especially if the stent is left overly long. Once the stent is partially threaded into the nasolacrimal system, the pericanalicular soft tissues can be reapproximated. This step is best achieved through the use of an assis-

tant who can help realign the tissues and prevent stent prolapse. A 5-0 polyglactin suture on a small, half-circle needle can help facilitate suture passes in the pericanalicular tissue and also in the medial canthal region in the setting of an avulsed medial canthus. Proper alignment of the two ends of the laceration reestablishes the eyelid anatomy and increases the likelihood of nasolacrimal system patency after healing has taken place. Once the repair is complete, the lower eyelid should be well approximated to the globe. Antibiotic ointment is applied to the wounds for 1–2 weeks. The monocanalicular stent can be removed in the office 3 months following repair (■ Figs. 6.6 and 6.7).



■ **Fig. 6.6** Five-year-old boy who suffered a dog bite with resultant right lower eyelid canaliculus-involving laceration and medial canthal avulsion **a**. Postoperative month 3 status post-repair of the lower eyelid **b**



■ **Fig. 6.7** A 17-year-old male who suffered a basketball injury resulting in a laceration of the upper canaliculus and medial conjunctiva **a**. Postoperative week 1.5 status post-repair of upper eyelid laceration and conjunctiva **b**

Case Presentation

A 4-year-old boy presented to the emergency room after running into a wire fence during recess at school. Exam was notable for a left lower eyelid laceration involving the inferior canaliculus (Fig. 6.8a). Lacrimal probing revealed the distal cut end of the canalicular laceration (Fig. 6.8b). CT of the orbits did not reveal any fractures. The patient underwent immediate surgical repair with placement of a Mini Monoka stent. At postoperative month 3, the monocanalicular stent was removed. The lower lid was nicely apposed to the globe, and there was a normal tear lake, suggesting proper alignment of the nasolacrimal system (Fig. 6.8c).

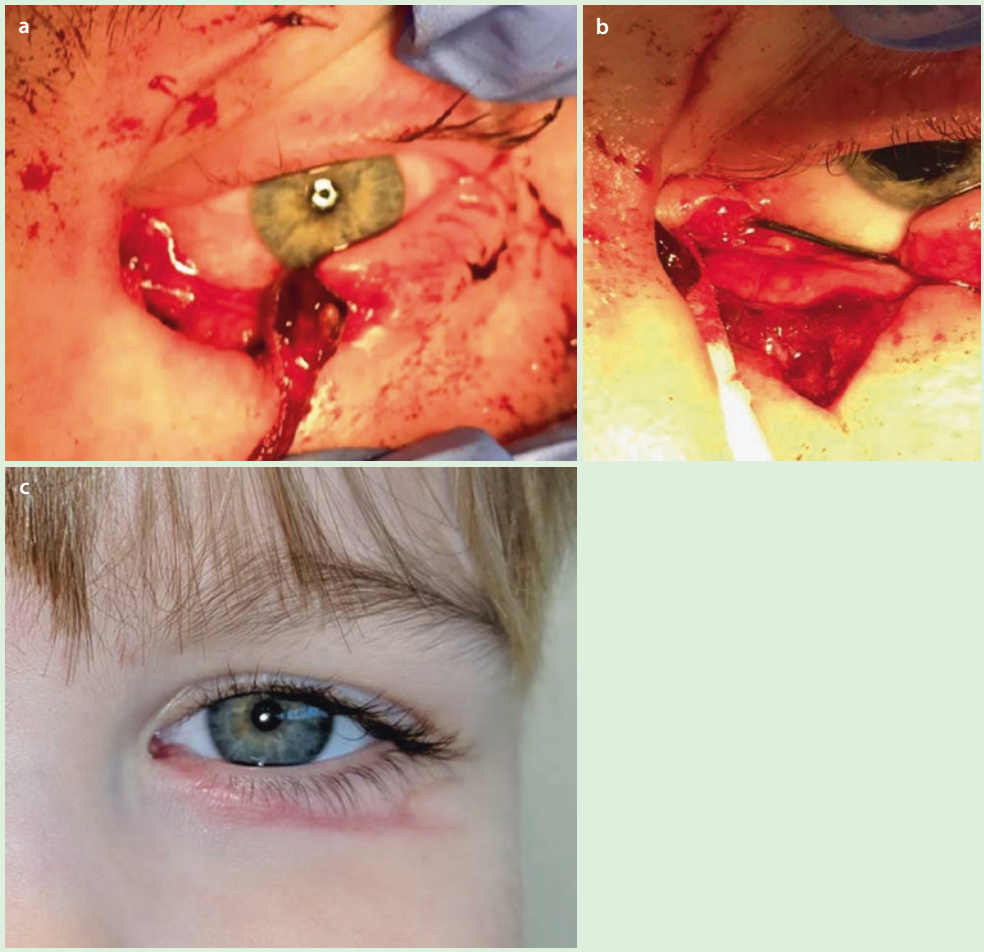


Fig. 6.8 Clinical photograph showing full-thickness medial left lower eyelid laceration including canalicular laceration **a**. Intraoperative photograph showing a lacrimal probe placed within the distal cut end of the canaliculus **b**. Postoperative photograph showing good lid position **c**

Key Points

- The nasolacrimal system begins to develop in utero at 6 weeks. Improper or incomplete development of this system can be associated with epiphora, discharge, dacryocystitis, or cellulitis.
- The secretory portion of the lacrimal system is composed of the main and accessory lacrimal glands, located superotemporally to the globe within the lacrimal fossa of the frontal bone and within the palpebral conjunctival stroma, respectively. These glands provide lubrication for the cornea by secreting tears which ultimately accumulate as a tear lake along the margin of each eyelid.
- The excretory portion of the lacrimal system, which includes the puncta, canaliculi, lacrimal sac, and nasolacrimal duct, allows for drainage of excess tears.
- Canalicular trauma is common in children and can be the result of either blunt or penetrating injury.
- Evaluation of canalicular trauma should be performed urgently and referral to an oculoplastic surgeon for repair should be made.
- Canalicular repair can be performed under local anesthesia at the bedside or on under general anesthesia in the operating room within 72 hours of trauma.

Review Questions

1. The anatomic pathway of the nasolacrimal system is punctum → canaliculus → common canaliculus, then?
   (a) Semilunar fold → lacrimal sac → nasolacrimal duct → valve of Hasner
   (b) Valve of Rosenmüller → lacrimal sac → nasolacrimal duct → valve of Hasner
   (c) Valve of Hasner → lacrimal sac → nasolacrimal duct → valve of Rosenmüller
   (d) Semilunar fold → lacrimal sac → nasolacrimal duct → valve of Hasner

2. The nasolacrimal duct opens below the:
   (a) Inferior turbinate
   (b) Superior turbinate
   (c) Middle turbinate
   (d) Middle meatus

3. Which bones comprise the lacrimal sac fossa?
   (a) Maxillary and lacrimal
   (b) Maxillary and ethmoid
   (c) Ethmoid and lacrimal
   (d) Maxillary and zygoma

Answer

1. (b)
2. (a)
3. (a)

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