Is the distance from punctum a factor in the anatomical and functional success of canalicular laceration repairs?

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Purpose: The aim is to analyze the influence of the location of lacrimal canalicular laceration over the eventual anatomical and functional success after surgery. **Methods:** Retrospective, observational study of proximal canalicular laceration (PCL) and distal canalicular laceration (DCL) repairs by a single surgeon (MS). The distance between lacrimal punctum and the lateral canalicular lacerated end was defined as proximal (<6 mm) and distal (≥6 mm). The operation theater setup, microscopic magnified view, local adrenaline, and pigtail probe were used to locate the medial canalicular lacerated end. All patients underwent lacrimal stenting and the stents were removed after 3 months (12th week visit). After stent removal, a fluorescein dye disappearance test and lacrimal irrigation were performed to assess the anatomical and functional success of the operation. **Results:** Of 36 canalicular lacerations, 30 (83.33%) were monocanalicular lacerations which were repaired using monocanalicular stents. Of 6 (16.67%) bicanalicular lacerations, three were repaired using bicanalicular stents while in the remaining three, one monocanalicular stent was placed in each lacerated canaliculi. The medial cut end was identified by magnified visualization in 27 (75%), with adjunctive local adrenaline in four (11.11%) and pigtail probe in five (13.89%) patients. The mean post stent removal follow-up was 44 weeks. The DCL ($n = 24$, 66.67%) showed better functional and complete success as compared to PCL (75% vs. 33.33%, $P = 0.03$). Eight (22.22%) had spontaneous stent extrusion, two (5.56%) had loop prolapse, four (11.11%) had punctum granuloma, and three (8.33%) had medial canthus dystopia. **Conclusion:** The location of canalicular laceration may help to prognosticate the functional and qualified success rate. We experienced better-qualified success in the distal canalicular laceration group.

Key words: Anatomical success, distal lacrimal canaliculus, functional success, lacrimal canalicular laceration, proximal lacrimal canaliculus

According to an epidemiological study of eyelid injuries, the canalicular lacerations are present in approximately 16% of all eyelid lacerations.[1] The damage to lacrimal drainage system can occur after a direct or indirect injury to the eyelid, orbit, or periorbital region. In monocanalicular lacerations, higher incidence of inferior or lower (72%) canaliculus is reported, whereas the bicanalicular lacerations occur in 6%–24% of all canalicular injuries.[2,3]

Wulc and Arterberry categorized canalicular lacerations into direct and indirect, depending on the mechanism of injury. The direct canalicular lacerations occur mostly with sharp objects, for example, glass, iron nail, hanger, hooks, tree branches, etc., while blunt tangential forces or blows lead to indirect canalicular lacerations. Of their 24 patients, 21 (84%) had an indirect impact leading to canalicular lacerations.[4] On the contrary, Jordan *et al*. in their series of 236 patients of canalicular lacerations, reported 128 (54.2%) direct canalicular injuries.[5]

Over the past two decades, the vital role of temporary intracanalicular stent placement during the canalicular

laceration repair has been established. It helps to restore the continuity and maintain the patency of lacerated canalicular system during the healing process.[1-5] Meticulous eyelid and medial canthal tendon repair accounts for the best cosmetic and functional outcomes.[5] In literature, various modifications in the techniques of canalicular repair have been attempted by different authors. Chu *et al*. found higher success in patients managed with direct canalicular wall suturing (98%) as compared to pericanalicular tissue suturing (81%).[6] Kersten and Kulwin described a simplified "one-stitch" canalicular repair with 95.5% success.[7] Tint *et al*. also found success in 97.3% of patients using bicanalicular stents.[8]

Overall, the disparate success rate in the published literature (64.86%–100%) instigates an argument for determining the predictors of anatomical and functional surgical success.[1-10] This query led us to find a correlation between the distance of canalicular laceration form the respective punctum and the anatomical, functional, and qualified success rate of the lacrimal canalicular repair.

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Methods

In this retrospective observational study, medical records of 110 patients with eyelid lacerations presenting from July 2013 to June 2015 were reviewed. Of 110 eyelid lacerations, 36 (32.73%) had co-existing canalicular lacerations. Our study strictly adhered to the tenets of Declaration of Helsinki and the clinical review and documentation was performed by a single surgeon (MS). The details of clinical history, laterality, time of presentation, type of canalicular injury, method of repair, type of stent, and the outcome was analyzed [Fig. 1]. The distance between the respective lacrimal punctum and the lateral end of canalicular laceration was measured during each surgical procedure.

The canalicular lacerations were classified into proximal canalicular laceration (PCL) and distal canalicular laceration (DCL) depending on the distance between the lacrimal punctum and lateral canalicular lacerated end. We defined PCL as the distance of <6 mm and DCL as ≥6 mm from the lacrimal punctum. The monocanalicular laceration means either superior or inferior isolated canalicular laceration, whereas bicanalicular laceration means both superior and inferior canalicular laceration of one side (In latter situation, if the injury to any canaliculus was ≥6 mm, the patient was included in DCL group). The measurement was performed with a Vernier's calipers after inserting a Bowman's probe from the respective punctum.

All surgeries were performed by a single ophthalmic plastic surgeon (MS) under desired anesthesia. The punctum was dilated with Nettleship's punctum dilator, and a probe was

Figure 1: (a) Left inferior proximal canalicular laceration with medial canthal tendon injury (arrow showing punctum). (b) Right inferior proximal canalicular laceration with medial canthal tendon injury after an iron-rod trauma. The arrow points at the classical "calamari ring sign." (c) Right complex bicanalicular laceration with both tarsal plates avulsion and orbital fat prolapse after an iron-rod trauma. (d) Massive tissue necrosis, crusting and scab formation suggest a delayed presentation of right inferior canalicular injury. Needful tissue debridement and pigtail probe assisted monocanalicular repair was performed

passed to measure the exact distance of lateral canalicular cut end and to identify occult injuries [Fig. 2a-c]. Medial lacerated end of the canaliculus was located using direct visualization under an operating microscope with or without the help of local adrenaline as a decongestant [Fig. 2d]. In case of nonvisualization of the medial cut end, the exit point of fluorescein stained 2% methylcellulose was used to locate the probable vicinity of the medial end. For this method, the lacrimal sac was pressure occluded with the tip of the little finger, and stained viscoelastic was injected from the opposite canaliculus. The pigtail probe was used as the last option for identification of medial end and the stent was passed in retrograde fashion. All canaliculi were repaired using intracanalicular stents and pericanalicular tissue suturing with or without the repair of associated medial canthal tendon injury [Fig. 2e and f]. The pericanalicular tissue was repaired with 8-0 vicryl interrupted sutures in anterior, superior and posterior part of the canaliculus, followed by closure of muscle, conjunctiva, and skin. The Aurostent (Aurolab, Madurai, Tamil Nadu, India) was used as monocanalicular stent while lacrimal intubation set with olive tips (Madhu Instruments, New Delhi, India) was used for bicanalicular lacrimal stenting. Adequate instructions were given to the patients about the medications, stent care, and postoperative visits.

After examination on the 1st postoperative day, all patients were reviewed at 1st, 2nd, 4th, 8th, 12th, and 24th week. Oral antibiotics (Cefixime 100–200 mg BD) were prescribed to all patients for 5–7 days while topical moxifloxacin 0.5% (4–6 times/day) and hydroxyl-propyl-methylcellulose 0.3% (4–6 times/day) eyedrops were continued for first 4 weeks. At each follow-up visits, the lacrimal punctum, position of the stent and ocular surface were evaluated, and any interventions related to stent replacement were noted. In all patients, lacrimal stents were removed at 3 months (12th week visit). Monocanalicular stents were removed during slit-lamp office examination while the bicanalicular stent removal required nasal endoscopy and was performed in operation theater (under mucosal-surface anesthesia).

After stent removal, all patients underwent a standard fluorescein dye disappearance test (FDDT) to access the functional patency of repaired lacrimal system. A single drop of 2% fluorescein dye was instilled in conjunctival cul-de-sac and the eye was examined with cobalt blue filter light. FDDT was considered positive if the fluorescein dye persisted in the tear-film at the end of 5 min. The negative test meant complete washout of dye within 5 min of instillation. After FDDT, a gentle lacrimal irrigation was performed to check the anatomical patency using a 27-gauge straight lacrimal irrigation cannula. The irrigation findings were categorized as patent (no fluid regurgitation), stenosis (patency confirmed by the patient but >50% of fluid regurgitation), and blocked (complete fluid regurgitation). No attempt was made to probe the canaliculus to avoid any iatrogenic injury. The qualified success was defined as:
- Complete-patent lacrimal irrigation + negative FDDT
- Partial-patent irrigation or stenosis + positive FDDT
- Failure-blocked irrigation + positive FDDT.

Both lacrimal irrigation and FDDT were repeated after 1 month of stent removal. Minimum post stent removal follow-up of 24 weeks (6 months) was ensured.

Statistical analysis was performed using SPSS software (version 20, IBM, New York, USA). Chi-square test was applied for statistically comparing the success rates in PCL and DCL groups.

Results

All patients ($n = 36$, 100%) had unilateral canalicular lacerations, right 22 (61.11%) and left 14 (38.89%). There were 27 (75%) males and 9 (25%) females with a mean age at presentation of 28.47 ± 11.31 years. The average duration of the presentation was 2.1 days after injury (range - 3 h to 9 days). There were 30 monocanalicular (inferior - 23; 63.89% and superior - 7; 19.44%) and 6 (16.67%) bicanalicular lacerations. Etiologically, 17 patients had road traffic accidents, 5 each had iron rod injury and fist blows, 4 had cloth hanger hook injuries, 3 had buffalo horn injuries and 2 had dog bites.

All 30 (83.33%) monocanalicular lacerations were repaired using the monocanalicular stent while in 3 (8.33%) bicanalicular lacerations; Crawford's bicanalicular stents were used. Other 3 patients with bicanalicular lacerations were repaired using monocanalicular stent in each lacerated canaliculi, as described by Naik et al.[10] Other associated injuries included tearing of medial canthal tendon in 8 (22.22%), orbital wall fractures in 6 (16.67%) and globe perforation, eyelid tissue loss and abrasions in 1 each.

General anesthesia was required in 8 (22.22%) patients only. All surgeries were performed in the main operation theater by the ophthalmic plastic surgeon. In all cases, the identification of the medial lacerated end of canaliculus was first tried by direct visualization under an operating microscope employing high magnification. In 27 patients (75%), the classical "calamari ring sign" (whitish ring of rolled epithelium at the lacerated canalicular end) was elicited without any adjunctive support, whereas in 4 (11.11%), the topical or local tissue infiltration with adrenaline (1:100,000) was used to decongest the surrounding hyperemic soft tissue/muscles. A modified pigtail probe was used in 5 (13.89%) patients in whom both the above maneuvers failed to localize the medial cut end of the canaliculus.

In monocanalicular lacerations, the mean distance between the respective punctum and lateral lacerated
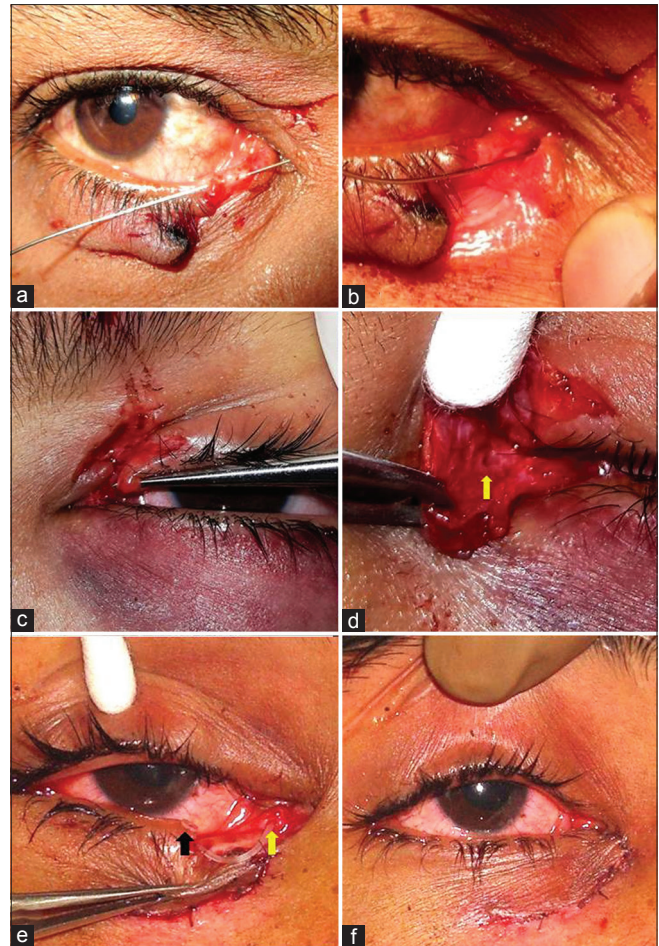

Figure 2: (a) Use of a Bowman probe for determining the distance of canalicular laceration from punctum. (b) The medial canalicular end identified under microscope and Bowman probe confirms the medial canaliculus patency and a hard stop. (c) Left superior proximal canalicular laceration with tip of punctum dilator visible through medial cut end. (d) Local adrenaline assisted identification of classical "calamari ring sign" (arrow). (e) A monocanalicular stent with properly placed collarette (black arrow) and inside the medial canaliculus (yellow arrow). (f) Desired cosmesis at the end of canalicular laceration repair

Table 1: Comparison of various factors and outcomes in proximal and distal canalicular lacerations

Distance of canalicular laceration from punctum	n (%)	Etiology	Type of stent	Complications	Anatomical outcome (irrigation)	Functional outcome (FDDT)	Success
PCL (<6 mm)	12 (33.33)	Direct - 8 (66.67%) RTA - 4 (33.33%)	Mono - 12 (100%)	SSE - 4 (33.33%)	Patent - 10 (83.33%) Stenosis - 2 (16.67%) Blocked - 0	Negative - 4 (33.33%) Positive - 8 (66.67%)	Complete - 4 (33.33%) Partial - 8 (66.67%) Failure - 0
DCL (≥6 mm)	24 (66.67)	Direct - 6 (25%) RTA - 13 (54.17%) Fist injuries - 5 (20.83%)	Mono - 18 (75%) Bi - 6 (25%)	SSE - 4 (16.67%) Granuloma - 4 (16.67%)	Patent - 19 (79.17%) Stenosis - 2 (8.33%) Blocked - 3 (12.5%)	Negative - 18 (75%) Positive - 6 (25%)	Complete - 18 (75%) Partial - 3 (12.5%) Failure - 3 (12.5%)

RTA: Road traffic accident, Mono: Monocanalicular, Bi: Bicanalicular, SSE: Spontaneous stent extrusion, FDDT: Fluorescein dye disappearance test, PCL: Proximal canalicular laceration, DCL: Distal canalicular laceration

end of canaliculus was 6.37 mm, whereas in bicanalicular injuries, it was 5.5 mm and 6.67 mm for superior and inferior lacerations, respectively. Overall, the PCL and DCL group had a mean distance of 4.58 mm and 7.55 mm from the punctum, respectively. The details of PCL and DCL subgroups are described in Table 1.

The stents were kept *in situ* for an average of 3.5 months or 14 weeks (range 8–18 weeks). After stent removal, first the functional success was elicited with FDDT, and then the anatomical patency was checked with lacrimal irrigation. The mean post stent removal follow-up was 44 weeks or 11 months (range 7–16 months). The 5 min FDDT revealed functional lacrimal drainage system in 22 (61.11%), whereas in 14 (38.89%), it was positive. Of 14 patients with positive FDDT, 10 (27.78%) had an intermittent epiphora while 4 (11.11%) complained of constant watering. After FDDT, the lacrimal irrigation was performed which revealed a patent canalicular system in 28 (77.78%), stenosis of canaliculi in 4 (11.11%), blocked canaliculi in 3 (8.33%), and only superior canalicular patency in 1 patient having bicanalicular laceration.

Complete success was seen in 22 (61.11%), partial success in 11 (30.55%) while failure was noted in 3 (8.33%) patients. Four of 12 patients in PCL group and 18 of 24 patients in distal canalicular laceration had complete success. This difference in complete success was found to be statistically significant (P = 0.03) on Chi-square test. Overall, 8 (22.22%) patients had spontaneous monocanalicular stent extrusion while bicanalicular stent prolapse was seen in two (5.56%) Punctum granuloma was present in 4 (11.11%, 3 - monocanalicular), whereas three (8.33%) had medial canthus dystopia.

Discussion

We found a long-term qualified success rate of 91.66% in patients who underwent lacrimal canalicular laceration repair. As per our knowledge, this is the first study in literature to correlate the distance of canalicular laceration with the clinical outcome. Complete success in terms of "no epiphora" was observed in 33.33% for PCL and 75% for DCL group, whereas on the contrary, partial success was better in PCL (66.67%) than DCL (12.5%). This functional failure in PCL might be secondary to the compromised lacrimal pump function due to fibrosis and altered contraction of pericanalicular orbicularis oculi or Horner's muscle. The lacrimal pump has a more prominent action over the proximal portion of canaliculus than distal.[11,12]

A lacrimal portion of the eyelid is a highly specialized zone; both anatomically and physiologically. Anatomically, Jordan *et al.* in 2008 described the mechanism behind canalicular lacerations in detail and postulated that the supero-medial bony orbital rim and side of the nose act as a funnel with the canalicular system lying at its base. This funnel directionally facilitates any approaching slender object in providing the access to the canalicular region of the eyelid.[5] Moreover, the medial lacrimal portion of the eyelid, containing canaliculus and Horner's muscle, is devoid of tarsus and lacks surrounding connective tissue. Hence, it becomes a vulnerable and the weakest portion for indirect canalicular lacerations secondary to blunt tangential eyelid or cheek blows.[4,8,10]

The predominance of male gender (75%) and lower canalicular injury (63.89%) was observed in the study which is similar to the previous studies.[9,10] We found bicanalicular lacerations in 16.67% of patients as compared to 11.84%, 12.5%,

Table 2: A comparative table of various published studies highlighting the outcomes of canalicular laceration repairs using variety of stents

Serial number	Study (year)	Number of patients	Etiology	Stent used	Followup (after stent removal)	Outcome	Complications
1	Kennedy *et al.* (1990)[14]	222	Body contact injuries - 35.6% Dog bite - 14%	Johnson wire, silicon tubes, veirs rod, suture, Teflon stent	≥1 month - 69.8% ≥6 months - 58.1%	Functional success - 76.8%	-
2	Kersten and Kulwin (1996)[7]	67	-	Bi stents	>6 months - 67.2%	Anatomical success - 100% Functional success - 96%	-
3	Mauriello and Abdelsalam (1996)[15]	33	-	Mono+Bi stents	-	Functional success - 100%	Premature stent extrusion - 1 Eroded anterior eyelid margin- 1
4	Naik *et al.* (2008)[10]	24	Blouse-hook fastener - 20.8% Metal rod injury - 20.8%	Mini-monoka	18.5 months	Anatomical success - 90% Functional success - 100%	Spontaneous stent extrusion - 3
5	Jordan *et al.* (2008)[9]	228	Blunt trauma - 98 Penetrating trauma - 54	Pigtail probe used Silicone stents	18 months	Anatomical success - 83.8% Functional success - 79.6%	-

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Table 2: Contd...

Serial number	Study (year)	Number of patients	Etiology	Stent used	Followup (after stent removal)	Outcome	Complications
6	Lee *et al.* (2009)[16]	36	-	Monoka	7.8 months	Functional success - 92%	Spontaneous stent extrusion - 2 Punctal slits - 2
7	Eo *et al.* (2010)[17]	17	-	Monostent Mini-Monoka stent	7 months	Anatomical success - 94.12% Functional success - 82.35%	Stent extrusion - 1
8	Wu *et al.* (2010)[13]	98	Motor vehicle accidents - 42.86% Stick injury - 23.47%	Bi stents	-	Anatomical success - 79.6% Functional success - 84.7%	Punctum erosion - 6 Cicatricial ectropion - 2
9	Tint *et al.* (2011)[8]	40	Blunt indirect trauma - 55% Dog bites - 10%	Crawford Bi stents	6 months	Functional success - 64.86%	Premature stent loss - 8 Medial ectropion - 2
10	Liang *et al.* (2012)[18]	35	-	Bi stents	13.8 months	Functional success - 91.2%	Lower punctum splitting - 1
11	Chowdhury *et al.* (2014)[19]	61	Punch - 28% Fall - 12% Broken glass - 10%	Mini-Monoka stent	23 months (median)	Functional success - 92%	Stent loss - 5
12	Murchison and Bilyk (2014)[20]	137	Altercations - 31.4% Accidents - 21.9% Dog bite - 16.1%	Mini-Monoka - (86.1%) Crawford Bi stent - (12.4%)	6 months (poststent removal)	Complete functional success - 72.3%	-
13	Singh *et al.* (2017)[24]	39	Blunt trauma - 51.2% RTA - 30.7% Animal injury - 15.4%	Mono - 19 20-gauge silicone rod - 14 Bi - 6	4.97 months	Anatomical success - 74.4% Functional success - 89.7%	Stent extrusion -28.2% Punctum granuloma - 5.1% Stent exposure - 2.5%
14	Our study	36	RTA - 47.22% Fist injuries - 13.89% Animal attacks - 13.89%	Mono - 91.67% Bi - 8.33%	11 months	Anatomical success - 77.78% Functional success - 61.11%	Spontaneous stent extrusion - 8 (22.22%) Punctum granuloma - 4 (11.11%) Medial canthus dystopia - 3 (8.33%) Loop prolapse - 2 (5.56%)

RTA: Road traffic accidents, Mono: Monocanalicular, Bi: Bicanalicular

and 17.35% by Jordan *et al.*, Naik *et al.*, and Wu *et al.*[9,10,13] The etiology of canalicular lacerations, type of lacrimal stent used for repair, anatomical and functional outcome, follow-up and complications of various studies is discussed in Table 2.[14-20,24]

We successfully located the medial lacerated canalicular end with direct magnified visualization in 31 (86.11%) patients. A standard pigtail probe with round tip having an oval eyelet was used in 5 (13.89%). Jordan *et al.* in their largest published review, used a pigtail probe for canalicular intubation and showed good anatomical (83.8%) and functional (79.6%) success.[9] However, Naik *et al.* did not use pigtail probe in any of their patients.[10] We believe that in an odd case scenario where the medial canalicular lacerated end is not identified after long, adjunct-aided and magnified search, the usage of pigtail probe may prove to be

a saving technique if performed diligently. The medial canthal tendon injuries associated with monocanalicular lacerations were repaired using a 4-0 prolene suture approximating the most medial tarsal or tendon edge to the lacrimal crest periosteum. In bicanalicular laceration repairs, Crawford's stent alone provided an adequate posterio-medial traction force on the eyelids-canalicular system for the desired wound healing.[8]

The average duration of intubation in our study was 14 weeks (3.5 months). At a mean follow-up of 30 weeks (7.5 months) after stent removal, we found that the anatomical success is better in PCL group, but they have compromised functional success in the form of intermittent epiphora. The DCL is difficult to repair but once done, they show good anatomical and functional success. The difference in the

complete success of PCL and DCL was statistically significant on applying a Chi-square test (*P* = 0.003).

Horner's muscle or pericanalicular orbicularis oculi surrounds the lateral 4/5th of the lacrimal canaliculus, which plays the major role in lacrimal pump mechanism.[20] We hypothesize that the direct injury and postoperative fibrosis of Horner's fibers, may lead to compromised lacrimal pump function, leading to functional epiphora. This anatomical and functional uniqueness may explain the variation in complete success, but it needs detailed discussion and more studies for its application.

In a prospective study, Rosser *et al.* checked the specific patency of repaired canaliculus by occluding the uninvolved punctum and found success (88%) suggesting a good prognosis of an adequately repaired lacrimal canaliculus.[21] In our scenario, this will confer additional financial burden (punctum plugs) and to counsel its placement in the opposite normal punctum/canalicular system with potential side effects, will be challenging. Latest literature advocates surgical repair of every lacerated lacrimal canaliculus by a speciality trained ophthalmic plastic surgeon for best clinical outcomes and predicts a poorer outcome in road-traffic accidents and in whom a 20-gauge silicone rod is used in place of monocanalicular stents.[22-24] Table 2 compares the anatomical and functional success of our and previous studies reported in literature. In complications, we found spontaneous stent extrusion in 8 patients who were managed with stent repositioning with or without a suture. Four patients suffered from punctum/proximal canalicular granuloma and were treated with topical steroids. The granuloma formation is a foreign body type of reaction by local mucosal epithelium against the silicone material.

Conclusion

Although our study is a retrospective review, had a small sample size, and lacks control arm, we do point at a newer concept of variation in success rates of PCL and DCL repairs. The need for lacrimal stenting and early repair of every lacerated canaliculus cannot be overemphasized and monocanalicular stents suffice in the majority.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflicts of interest
There are no conflicts of interest.

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