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Prognosis and Cost Effectiveness of the Monocanalicular Intubation with Re-Sterilized Silicone Tubes in Canalicular Lacerations: Observational Case Series

Kanalikül Laserasyonlarında Tekrar Sterilize Edilmiş Silikon Tüpler ile Yapılan Monokanaliküler Entübasyonun Prognozu ve Maliyet Etkinliği: Gözlemsel Olgu Serisi

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ABSTRACT Objective: Canalicular lacerations are the most common type of trauma in the lacrimal system. Monocanalicular or bicanalicular silicon stent intubation is usually used to treat canalicular lacerations. This study aimed to report on the prognosis and cost-effectiveness of monocanalicular intubation using re-sterilized silicone tubes for the treatment of canalicular lacerations. **Material and Methods:** Demographic characteristics of the patients, timing of the surgery from the initial injury, surgical time, postoperative treatment, follow-up time, timing of the silicon tube removal, postoperative patency in lacrimal irrigation (anatomical success) and subjective epiphora (functional success) were investigated. Approximately 5 centimeters silicone tubes remaining from dacryocystorhinostomy surgery and re-sterilized with ethylene oxide were used to treat lacerated canaliculus. To prevent corneal contact, the silicone tube was left approximately one and a half centimeters beyond the lacrimal punctum. Initially, a polypropylene suture was passed through the silicone tube and the free end of the silicone tube was positioned downward, approximately 5 millimeters lateral to the lacrimal punctum, and about 1-2 millimeters below the gray line of the eyelid by suturing to the skin and orbicularis muscle. Anatomical success was determined with the lacrimal irrigation test conducted at the time of silicone tube removal. Functional success was assessed using the Munk score. **Results:** The study included 27 patients, with an average age of 47.5 years and a mean follow-up time of 7.6 months. Canalicular reconstruction was performed within 24 hours of the injury in all patients, with an average surgical time of 24.7 minutes. Intraoperative complications, ocular surface irritation, stent migration, or spontaneous loss of the stent prior to removal, as well as signs of infection were not observed. Granuloma formation was observed in one (3.70%) patient, and medial ectropion of the lower eyelid was observed in one (3.70%) patient. The anatomical success rate was found to be 100% and functional success rate was found to be 96.2% after the silicon tube removal. **Conclusion:** Repairing lacerated canaliculi with re-sterilized silicon tubes was found to be both successful and cost-effective. Our technique avoids manipulation of the uninjured canaliculus, allowing for a relatively quick and straightforward tube insertion and removal process, like other monocanalicular intubation tubes. However, monocanalicular intubation tubes are expensive and may not be readily available at all clinics at all times. The most significant advantage of our technique was that it did not require additional costs or instruments, making it particularly valuable during periods of limited instrument production and transportation, such as during the coronavirus disease-2019 pandemic.

Keywords: Monocanalicular intubation; re-sterilized silicon tube; epiphora; lacrimal irrigation; Munk score

ÖZET Amaç: Kanalikül laserasyonları, lakrimal sistemdeki en yaygın travma türüdür. Kanalikül laserasyonlarının tedavisinde genellikle monokanaliküler veya bikanaliküler silikon stent entübasyonu kullanılır. Bu çalışmada, kanalikül laserasyonlarında tekrar sterilize edilmiş silikon tüplerle yapılan monokanaliküler entübasyonun prognozu ve maliyet etkinliğinin araştırılması amaçlandı. **Gereç ve Yöntemler:** Hastaların demografik özellikleri, ilk yaralanmadan ameliyatın başlangıcına kadar geçen süre, ameliyatın süresi, ameliyat sonrası tedavi, takip süresi, silikon tüp çıkarılma zamanı, ameliyat sonrası lakrimal irrigasyonda geçiş (anatomik başarı) ve subjektif epifora (fonksiyonel başarı) incelendi. Kanalikül laserasyon onarımında gözyaşı kanalı cerrahisinden artan yaklaşık 5 cm'lik silikon tüpler etilen oksit ile tekrar sterilize edilerek kullanıldı. Korneal teması önlemek için silikon tüp lakrimal punktumdan itibaren yaklaşık 1,5 cm uzun bırakıldı. Başlangıçta polipropilen sütür silikon tüpün içinden geçirildi ve silikon tüpün serbest ucu, lakrimal punktumun yaklaşık olarak 5 mm lateralinde ve göz kapağı gri çizgisinin yaklaşık 1-2 mm altında cilt ve orbiküler kasa sütüre edilerek aşağı yönde konumlandırıldı. Anatomik başarı, silikon tüp çıkarıldıktan sonra gözyaşı kanalı irrigasyon testi ile belirlendi. Fonksiyonel başarı ise Munk skoru ile değerlendirildi. **Bulgular:** Çalışmaya dâhil edilen 27 hastanın yaş ortalaması 47,5 idi. Ortalama takip süresi 7,6 aydı. Tüm hastalarda, 24 saat içinde kanalikül laserasyonu sonrası rekonstrüksiyon gerçekleştirildi. Ortalama cerrahi süre 24,7 dakika idi. Ameliyat sırasında komplikasyon, ameliyat sonrası oküler yüzey irritasyonu, stent migrasyonu veya stentin spontan kaybı ve enfeksiyon görülmedi. Bir hastada (%3,70) granülom formasyonu ve bir hastada (%3,70) alt göz kapağının mediyal ektropiyonu gözlendi. Silikon tüp çıkarıldıktan sonra anatomik başarı %100 ve fonksiyonel başarı %96,2 olarak bulundu. **Sonuç:** Bu çalışmada, kanalikül laserasyonlarının tedavisinde tekrar sterilize edilmiş silikon tüplerle onarım başarılı ve maliyet etkin olarak bulundu. Tekniğimizde, diğer monokanaliküler entübasyon tüplerinde olduğu gibi sağlam kanalikülün manipülasyonu gerekmemektedir ve silikon tüpün yerleştirilmesi ve çıkarılması nispeten hızlı ve basittir. Ancak monokanaliküler entübasyon tüpleri pahalıdır ve her klinikte her zaman mevcut olmayabilir. Tekniğimizin en önemli avantajı, ek maliyet ve donanım gerektirmemesidir, bu da özellikle koronavirüs hastalığı-2019 pandemisi gibi enstrüman üretimi ve taşımasının sınırlı olduğunda dönemlerde önemli bir avantaj sağlayabilir.

Anahtar Kelimeler: Monokanaliküler entübasyon; tekrar sterilize edilmiş silikon tüp; epifora; lakrimal irrigasyon; Munk skoru

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Canalicular lacerations are the most common type of trauma in the lacrimal system due to the vulnerability of the medial side of the eyelids.[1-3] Canalicular lacerations may results both penetrating and non-penetrating trauma.[4] They tent to occur more frequently in young adults, with the inferior canaliculus being the most commonly affected.[5] Monocanalicular or bicanalicular silicon stent intubation is usually used to treat canalicular lacerations.[6] While there is no consensus on the superior technique for repairing the canaliculus, there is a general consensus among all techniques that lacerated canaliculi must be repaired immediately to avoid canalicular stenosis or obstruction.[7-9]

The aim of the study was to report on the prognosis and cost effectiveness of the monocanalicular intubation with re-sterilized silicon tubes in the management of canalicular lacerations.

MATERIAL AND METHODS

The study retrospectively analyzed data from 60 patients who underwent repair for canalicular lacerations at Sakarya University Training and Research Hospital from January 2015 to January 2022. The study was confirmed by the Ethics Committee of Sakarya University Faculty of Medicine (date: February 27, 2023; no: 69) following the Declaration of Helsinki. Prior to their participation in the study, all patients or their parents provided informed consent, which included details about the procedure's associated risks.

The study investigated various aspects, including the demographic characteristics of the patients, the timing of surgery following the initial injury, the duration of the surgical procedure, postoperative treatments, follow-up duration, the timing of silicon tube removal, postoperative patency in lacrimal irrigation (anatomical success), and subjective assessment of epiphora (functional success). Canalicular laceration was diagnosed with biomicroscopic examination and lacrimal probing. Patients with combined bicanalicular lacerations and those whose surgery was performed more than 24 hours after the initial injury were excluded from the study. Each patient underwent a complete ophthalmic evaluation.

Anatomical success was determined during the lacrimal irrigation test, conducted at the time of silicon tube removal. It was considered achieved when the patient reported the sensation of liquid passing through the nasopharynx while irrigating with balanced saline solution through the repaired canaliculus. Functional success was assessed with the Munk score; where success was defined when the patient reported values within the first two values (0-1).[10]

STATISTICAL ANALYSIS

The data underwent analysis using Microsoft Excel (Microsoft Corp., Redmond, WA, USA), and numerical values were presented in the form of mean±standard deviation.

SURGICAL TECHNIQUE

Approximately 5 centimeters silicone tubes left over from the dacryocystorhinostomy surgery were cleaned with a sterile water solution. Afterward, they were packed and sterilized using ethylene oxide. All surgeries were performed under general anesthesia with an operation microscope. The procedure began by identifying the proximal and distal cut ends of the canalicular laceration using a lacrimal cannula. The punctum was dilated with a lacrimal dilator. An approximately 5 centimeters re-sterilized silicon tube was inserted into the punctum, pushed forward and externalized through the distal cut end of the canalicular laceration. The silicon tube was then threaded through to the proximal cut end of the canalicular laceration and pushed forward until it reached the lacrimal sac. The process was concluded when the silicone tube could not be advanced any further. After the canalicular intubation, the pericanalicular tissue and eyelid lacerations were repaired using 6-0 absorbable suture, ensuring that the eyelid's contour and the position of the lacrimal punctum within the lacrimal lake were maintained. To prevent corneal contact, the silicone tube was left approximately one and a half centimeters beyond the lacrimal punctum. Initially, a 6/0 polypropylene suture was passed through the silicone tube completely and the free end of the silicone tube was positioned downward, approximately 5 millimeters lateral to the lacrimal punctum, and about 1-2 millimeters below the gray line of the eyelid by suturing to the skin and orbicularis muscle (Figure 1).

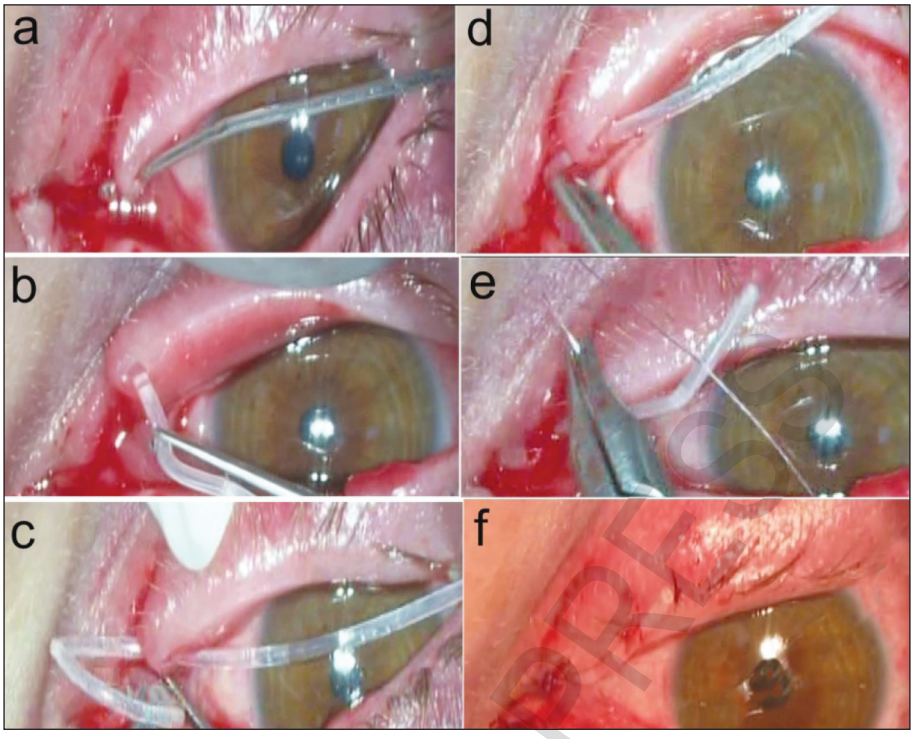

FIGURE 1: Surgical technique of the monocanalicular intubation with re-sterilized silicon tube. **a)** The proximal and distal cut ends of the canalicular laceration were identified with a lacrimal canula. **b-c)** An approximately 5 centimeters sterilized silicon tube was embedded in the punctum and pushed forward and externalized of the distal cut end. **d)** The silicon tube was intubated to the proximal cut end of the canalicular laceration and pushed forward to the lacrimal sac. **e)** A 6/0 polypropylene suture was passed completely through the silicon tube. **f)** The free end of the silicone tube was positioned downward, approximately 5 millimeters lateral to the lacrimal punctum, and about 1-2 millimeters below the gray line of the eyelid by suturing to the skin and orbicularis muscle. The integrity of the canaliculi and pericanalicular tissues was achieved.

Approximately 3 months later, the silicone tube was removed by cutting the sutures and using forceps externally through the punctum. Postoperatively, all patients were treated with topical antibiotic drops and ointments for 2 weeks. The patients were examined postoperatively at week 1, month 1 and 3, and one-month following stent removal. During these postoperative follow-ups, subjective symptoms of epiphora and lacrimal irrigation were assessed.

RESULTS

Out of a total of 60 patients who had canalicular lacerations resulting from trauma, 27 patients were included in the study, comprising 24 males and 3 females. Among these 27 patients, 26 (96.3%) had lower canalicular lacerations. The mean age of the patients was 47.50 years, ranging from 15 to 79 years. The mean follow-up period lasted 7.6 months, with a range of 6 to 12 months. In all patients, canalicular reconstruction was performed within 24 hours, with the duration ranging from 5 to 24 hours. The mean surgical time was 24.7 minutes, and no intraoperative complications were observed in any of the cases. Additionally, there were no instances of ocular surface irritation, stent migration, spontaneous stent loss prior to removal, or infection. Two patients exhibited postoperative complications, with one (3.70%) developing granuloma formation and another (3.70%) experiencing medial ectropion of the lower eyelid. In these patients, granuloma excision and medial ectropion repair surgeries were performed after silicon tube removal. Silicon tubes were successfully explanted in all patients at months 3 postoperatively. The anatomical success rate following tube removal was found to be 100%. According to the Munk score, functional success was achieved in 96.2% of the patients, with 25 patients scoring 0, one patient scoring 1, and one patient scoring 3. The demographic data and clinical characteristics of the patients are presented in Table 1.

TABLE 1: Demographic and clinical characteristics of the patients.

Mean age (years)	47.50±17.6
Gender	Male 24 (88.9%)
	Female 3 (11.1%)
Injury type	Penetrating-13 (48.1%)
	Non-penetrating-14 (51.9%)
Laterality (eye)	Right 14 (51.9%)
	Left 13 (48.1%)
Involved canaliculus	Upper 1 (3.7%)
	Lower 26 (96.3%)
Mean surgical time from initial injury (hours)	10.44±6.22
Mean surgical time (minutes)	24.7±4.45
Functional success (Munk score)	0 point-25 patients
	1 point-1 patient
	3 point-1 patient
Anatomical success (%)	100

DISCUSSION

Canalicular lacerations are observed in 16% to 37% of eyelid trauma cases, particularly in middle-aged males.[6] Both blunt and penetrating traumas are equally prevalent, with lower canaliculi injuries being more common.[6,11-13] In our study, consistent with literature, we observed nearly equal occurrences of blunt and penetrating traumas, with a majority of our patients being male (88.9%) and having an average age of 47 years. Moreover, 96.3% of the injuries affected the lower canaliculus.

Monocanalicular and bicanalicular stent intubation techniques are available for the repair of monocanalicular lacerations. Silicone tubes serve as intubation stents to safeguard canaliculi function during healing and aid in the proper layered reconstruction of surgical tissue.[12,14] Using pigtail probes in bicanalicular intubation for canalicular repair is a procedure that lacks direct visualization and carries the potential risk of damaging intact canaliculi and creating false passages.[15] The advancement of microsurgery techniques has significantly improved the ability to locate the cut end of the damaged canaliculus, making monocanalicular intubation a preferred choice for direct visualization of the epithelial lining of the lacerated canaliculus and ensuring the protection of intact canaliculi. Some monocanalicular tubes, like Crawford, and bicanalicular silicon tubes require retrieval from the nasal cavity, which could lead to nasal mucosa damage and bleeding.[3,15] To mitigate these risks, pushed monocanalicular stents (Mini-Monoka and Masterka) have been introduced which do not require additional fixation.[16,17] However, Masterka has a metal rod that could potentially cause accidental lacrimal system injury and creation of a false passage during insertion by an inexperienced surgeon.[3,17] The Mini-Monoka tube, although lacking a metal rod, may occasionally bend upon insertion, potentially extending the surgical time.[3,17] Similar to the Mini-Monoka tube, our method also involves a silicone tube that can bend however there is no risk of harming the lacrimal system. The surgical time may be extended due to the bending of the tube or its fixation in the peripunctal area in our technique, however the mean surgical reconstruction time was found to be relatively fast, at 24.7 minutes (ranging from 20 to 30 minutes). This technique was found to be easily performed with an operation microscope. When the tube was correctly inserted into the true passage, it advanced with minimal resistance.

The significance of the upper canaliculus for tear drainage has been a topic of debate. Even after a blockage of the lower canaliculus, there are patients who do not experience epiphora. This issue supports the equal importance of the upper canaliculus in tear drainage function. Both upper and lower canaliculi contribute almost equally to tear drainage, thus emphasizing the necessity to repair each canalicular laceration.[18] In our study, only one patient had an upper canaliculus laceration which was surgically repaired. Suturing the silicone tube in the upper canaliculus may be more challenging due to the increased mobility of the eyelid. However in our patient no complications or epiphora symptoms were observed.

The timing of canalicular repair has been considered a crucial factor in predicting surgical success. Generally, intervention within 48 hours has been recommended to improve outcomes.[6,13,19] In our hospital, when patients arrived, they underwent surgery on the same day or within 24 hours, resulting in a 100% anatomical success rate.

Previous studies have reported varying anatomical and functional success rates ranging from 25%

to 100% for monocanalicular stents and from 40% to 100% for bicanalicular stents.[4,19-23] The Munk score as 0 or 1 was reported 76,9% in the previous study.[15] In this study, the anatomical and functional success rates were comparable to those reported in previous studies, with a 100% anatomical success rate and a 96.2% functional success rate according to the Munk score. While anatomical success can be achieved in most patients, postoperative complaints such as epiphora, blurred vision, and foreign body sensation have been described.[4] In this study, these complaints were not observed in patients who achieved anatomical success.

The removal time of the silicon tube is an important factor for success rates. Animal models have suggested that 12 weeks is enough for reepithelization, but the exact timing for removal remains a topic of debate.[24] In our patients, we removed the silicon tubes three months after surgery, resulting in a 100% anatomical success rate.

Complications and prognosis of canalicular laceration depend on various factors, such as anatomical variability of the canaliculus, proximity of the injury to the punctum, and the timing of surgery following the initial injury.[25] The presence of granulomas or cicatricial ectropion can contribute to the presence of epiphora symptoms, irrespective of lacrimal passage patency. Rates of granuloma formation (6.7%) and cicatricial ectropion (8.1%) have been reported with bicanalicular intubation.[15] In this study, rates of the granulomas and ectropion were found to be 3.7%. Granulomas may result from the use of a suture and may not be directly related to the surgical technique or the use of a silicon tube. Suturing the silicone tube to the skin below the gray line of the eyelid may increase the risk of ectropion. However, suturing the silicone tube while the eyelid is in its normal anatomical position, without being everted, reduces this risk. Ectropion was already observed in one patient, and it was surgically corrected. The fixation of silicone tube to the skin below the gray line of the eyelid with polypropylene suture could potentially increase the risk of corneal contact and abrasion. However, to prevent corneal contact the silicone tube was left long, and the free end of the silicone tube was positioned downward. The point to be careful about was to ensure that the suture was tight enough and that the silicone tube did not move. In our study, by paying attention to the above-mentioned points, no corneal abrasion was observed.

The premature extrusion of a tube can be attributed to various factors, such as the length of the tube leading to bending and upward force, false passage creation during intubation, which may produce an upward force and dislodge the stent, and patient manipulation of the plug.[26] However, extrusion rates with Monoka 11.1% to 29% have been reported, with most cases occurring within the first month.[27,28] Previous studies have reported the incidence of premature stent loss ranging widely from 3% to 43.7%.[17,26,29-33] None of the patients in our study experienced premature stent loss, or stent migration. We fixed the silicon tube with sutures, and no tube extrusion was observed. In our method, to prevent premature loss or migration of the silicone tube, it should be left under sufficient tension, and the suture should pass completely through the tube. If instability was observed, a second suture should be applied for the fixation when necessary. Additionally, surrounding tissues should be closed properly.

The main strength of this study lies in the utilization of silicone tubes remaining from dacryocystorhinostomy surgeries, which were re-sterilized with ethylene oxide, eliminating the need for special materials. These silicone tubes, lacking lumens, eliminate the potential for infection from any residual blood or materials within the tubes. The technique avoids manipulation of the uninjured canaliculus, enabling a relatively quick and straightforward process for tube insertion and removal, similar to other monocanalicular intubation tubes such as Mini-Monoka and Masterka. However, monocanalicular intubation tubes, like a Mini-Monoka and Masterka are expensive and may not be readily available at all clinics at all times. In our technique, there is no additional cost required, and currently, DSR tubes are used in every clinic. It is important to note that our technique may not be suitable for patients with combined upper and lower canalicular lacerations.

The main limitations of the study include its retrospective design and the absence of a control group. Future prospective, comparative studies involving a larger patient cohort and extended follow-up periods are

needed to further evaluate the success of monocanalicular stent intubation using re-sterilized silicone tubes.

CONCLUSION

Repairing lacerated canaliculi with re-sterilized silicone tubes was found to be both successful and cost-effective in this study. Monocanalicular intubation tubes could not be readily available in every clinic due to their high cost. Consequently, this presents a challenge in the surgical management of cases involving canalicular lacerations. The most significant advantage of our technique was that it did not require additional costs or instruments, making it particularly valuable during periods of limited instrument production and transportation, such as during the coronavirus disease-2019 pandemic.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Ali Altan Ertan Boz;* ***Design:*** *Ali Altan Ertan Boz, Kadriye Demir Boncukçu;* ***Control/Supervision:*** *Nilgün Özkan Aksoy;* ***Data Collection and/or Processing:*** *Ali Altan Ertan Boz, Eda Gümrükçüoğlu;* ***Analysis and/or Interpretation:*** *Ali Altan Ertan Boz, Nilgün Özkan Aksoy;* ***Literature Review:*** *Eda Gümrükçüoğlu, Kadriye Demir Boncukçu;* ***Writing the Article:*** *Ali Altan Ertan Boz, Kadriye Demir Boncukçu;* ***Critical Review:*** *Nilgün Özkan Aksoy;* ***References and Fundings:*** *Ali Altan Ertan Boz;* ***Materials:*** *Ali Altan Ertan Boz, Eda Gümrükçüoğlu.*

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