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Postoncological lacrimal duct reconstruction: A practical classification system for reconstructive planning and short-term results of a case series

M.V. van Burink, H.A. Rakhorst, G.M. van Couwelaar, U. Schmidbauer*

Department of Plastic, Reconstructive and Hand Surgery, Ziekenhuisgroep Twente, Geerdinksweg 141, 7555 DL Hengelo, The Netherlands

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KEYWORDS
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Summary *Background:* Surgical resection of skin tumors in the medial canthal area may damage the lacrimal duct and can result in chronic epiphora. Postoncologic reconstruction of the lacrimal duct has not been studied extensively. The current study discusses the anatomical and functional features of the lacrimal duct. It describes short-term functional outcomes after monocanalicular reconstruction of the lacrimal duct in a case series of 10 patients.
Methods: From February 2015 to October 2017, all patients with a postoncological lacrimal duct defect were analyzed to make an anatomical classification. The functional outcomes of patients after monocanalicular reconstruction were measured with the Munk scale up to 3 months after stent removal.
Results: Twelve patients had lacrimal duct defects after Mohs resection. Anatomical characteristics were used to create a clinical classification for lacrimal duct defects. This classification divides the upper (U) and lower (L) proximal lacrimal duct into two sections which can be damaged: the punctum and pars verticalis (1), the canaliculus horizontalis (2), or combined (3). The Common lacrimal duct (C) is the distal part of the lacrimal duct and can also be affected. Ten patients were analyzed after lacrimal duct reconstruction. Three months after stent removal, none of the patients suffered from epiphora.

* Corresponding author.
E-mail addresses: maxvanburink@gmail.com (M.V. van Burink), u.schmidbauer@zgt.nl (U. Schmidbauer).

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Conclusions: This article proposes an anatomical classification for lacrimal duct defects in the proximal lacrimal drainage system. The classification can be applied in comparing cases and determining reconstructive strategies after oncologic skin tumor resection. Short-term results are promising for future efforts to reconstruct the lacrimal duct.

Introduction

The incidence of skin cancer is growing to epidemic proportions in modern healthcare. With a mean age of 60–80 years, the elderly, sun-exposed patients are at risk.[1] Dated incidence reports specify that 5–10% of all skin tumors are located in the periorbital area, of which 86% to 96% are basal cell carcinoma, followed by squamous cell carcinoma, sebaceous cell carcinoma, and melanoma.[2-5] The medial canthal area in particular is at risk with an apparent increase in the prevalence of skin tumors.[2] Medial canthal tumors rarely involve the lacrimal duct.[6-9]

The current treatment standard is surgical excision until tumor-free margins are achieved using various modalities.[4,5,10-12] Irradical resections lead to recurrence rates up to 25.4%.[13,14] Mohs surgery is particularly useful in resection of basal cell carcinomas in the medial canthal area, where underlying structures such as the lacrimal duct, canthal ligaments, and the posterior lamella are susceptible to damage.[15,16] Radiotherapy is considered to be contraindicated for skin tumors in the medial canthal area because of the possibility of lacrimal duct obliteration and eyelid eversion.[15]

Defects in the lacrimal system are associated with intermittent or constant epiphora.[17] Failure to recognize and properly reconstruct lacrimal duct defects after skin tumor resection in the medial canthal area can hinder the tear-flow mechanism and lead to epiphora.[16,18,19] Patients experience this as disabling and often require revision surgery.

This study aims to create a clinical classification for lacrimal duct defects by analyzing cases and anatomical characteristics of the lacrimal duct. The classification was found to be useful in comparing cases and determining reconstructive strategies. Further, short-term functional results of lacrimal duct reconstructions are described.

Anatomy

The lacrimal duct lies beneath the anterior and posterior medial canthal tendons. The proximal segment of the lacrimal drainage system consists of superior and inferior punctum lacrimalis, canaliculus lacrimalis, and the common canaliculus[17] Figure 1.

The circular entrance in the upper (canaliculus lacrimalis superior) and lower (canaliculus lacrimalis inferior) lacrimal duct is the punctum lacrimalis superior and inferior, respectively. The upper and lower punctum lacrimalis are positioned at approximately 6.0 and 6.5 mm, respectively, from the medial canthus in the pars ciliaris from the tendo pars lacrimalis musculus orbicularis oculi lateral to the caruncula lacrimalis. The opening is parallel to the border of the eyelid on the edge of the nonepithelialized conjunctiva and pointed slightly dorsal, for optimal drainage of tears. The diameters of the upper and lower punctum are approximately 0.25 and 0.3 mm, respectively. Because the lower punctum is positioned 0.5 mm more lateral, the upper and lower punctum will not be in contact when the eyes are closed.[20]

The canaliculus lacrimalis continues in the ampulla, a 1.8–2.25 mm long pars verticalis, with a 0.08–0.1 mm diameter. It curves dorsal from the ligamentum palpebrale mediale in the medial direction as the pars horizontalis. The pars horizontalis has a length of 7–9 mm, in which the pars horizontalis superior is 0.5 mm shorter than the pars horizontalis inferior and has a diameter of 0.3–0.6 mm. It continues in little wider canaliculus communis (present in more than 95% cases).[20]

The canaliculus communis bends dorsal along with the curvature of the eye, with approximately 118°, after which it enters the distal segment of the lacrimal drainage system consisting of the saccus lacrimalis and the ductus nasolacrimalis. The canaliculus communis inserts into the saccus lacrimalis anteriorly in the lateral wall of the sac with an average angle of 58°[17,21]

The saccus lacrimalis, with vertical measurements of approximately 12 mm and a diameter of 4–6 mm, lies in the fossa lacrimalis of the os lacrimalis. Caudally, the saccus lacrimalis continues in the ductus nasolacrimalis with the upper part in a canal between the maxilla and os lacrimalis, which is approximately 12.4 mm in length, and the lower part, approximately 10 mm, anchored within the concha nasalis inferior. It ends in the meatus nasi inferior.[20]

Physiology

If the eyelid is open, the ampulla is dilated. Because of the slightly dorsal pointed punctum, tears are drawn into it. The lacrimal duct lies within the muscle fibers of the tendo pars lacrimalis musculus orbicularis oculi. Movement of the eyelid activates the pump action by contraction of the deep heads of muscle.

When the eyelid closes, compression on the ampulla and canaliculus causes tears to be propelled toward the canaliculus communis. The resulting lateral pull and traction on the tear sac from pars lacrimalis musculus orbicularis on the lacrimal diaphragm creates a negative pressure in the lacrimal sac, resulting in the drainage of tears, through the saccus lacrimalis, into the meatus nasi inferior.[17,22,19] The specific epithelium and elastic structure of the ductus lacrimalis allows for a dilation of three times the diameter.[17]

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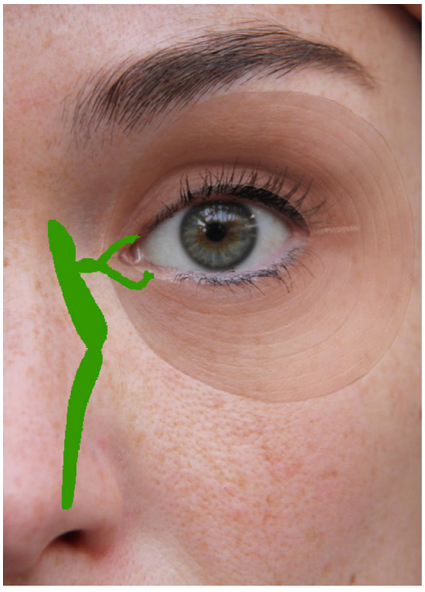

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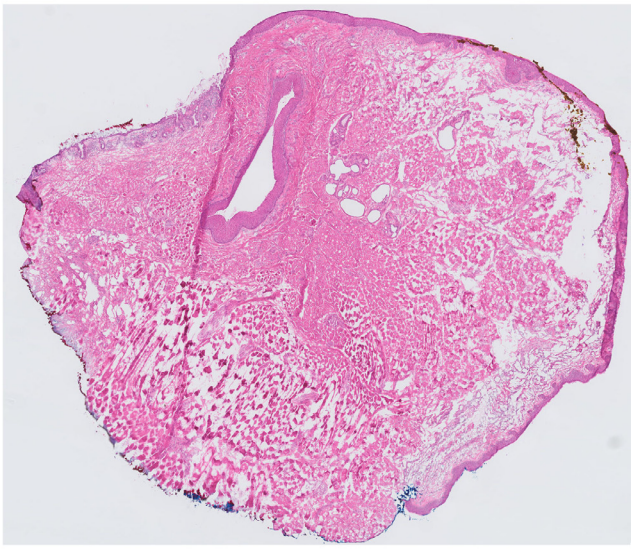

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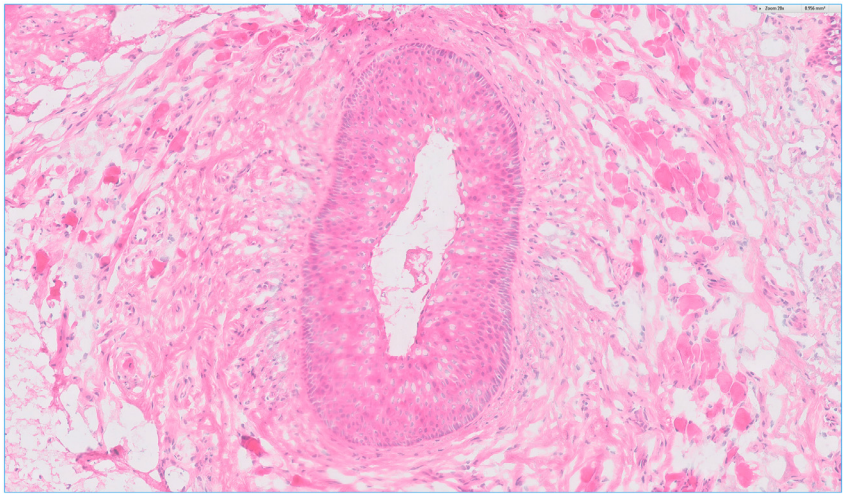

c

Figure 1 The anatomy of the lacrimal duct of the left eye (green), musculus orbicularis oculi (transparent) (a). Histology of a resected basal cell carcinoma located in the medial lower eyelid; within the lesion, a transection of the lacrimal duct is visible (haematoxylin and eosin stain) (b). Magnification of lacrimal duct (c). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Patients and methods

All patients who had a lacrimal duct defect following oncological Mohs resection of a basal cell carcinoma in the medial canthus area from February 2015 to October 2017 were included. Retrospective patient analysis and anatomical characteristics were used to create a new clinical classification for lacrimal duct defects. Because there was no standardized follow-up for patients who were treated before 2017, patients who received a lacrimal duct reconstruction before 2017 were excluded for functional analysis.

Patients provided written consent for participation and the use of their photos. Medical Ethical Review Committee approval was obtained for this study, and data collection was compliant with the principles of the Declaration of Helsinki.

Surgical technique

Following Mohs surgery with negative tumor margins, patients were operated in supine position under general anesthesia, with preoperative administration of intravenous antibiotics. After sterile exposition, the lacrimal duct, or remnant of the lacrimal duct, was identified under microscopic magnification and classified according to the classification of ductus lacrimalis defects after oncologic skin tumor resection (Table 2, Figure 4).

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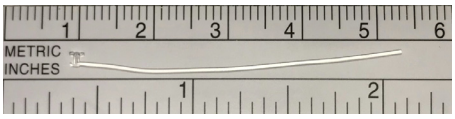

Figure 2 Mini Monoka stent® with a cuff length of 2 mm and a diameter of 0.64 mm.

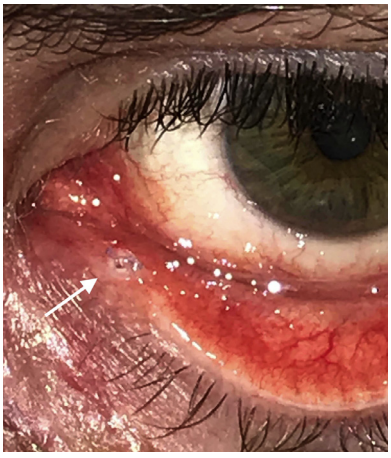

Figure 3 Mini Monoka stent® in situ 3 months postoperative (arrow), before stent removal.

The lacrimal duct was dilated and probed with a Mini Monoka stent® (Figure 2).

In case of a grade 1 or 3 defect, the punctum lacrimalis is absent and must be reconstructed. The proximal end of the stent cuff is fixated in the remnant of the skin of the conjunctiva and the transposition flap with Vicryl 9-0®. Hereby, the cuff is fixated pointing slightly dorsal to reconstruct the anatomical position of the punctum lacrimalis.

In case of a grade 2 defect of the canaliculus horizontalis, the Mini Monoka stent® is first inserted in the punctum lacrimalis. The stent bridges the lacrimal defect and is inserted in the remnant of the pars horizontalis. The proximal end of the stent cuff is fixated at the punctum with Vicryl 9-0®.

After the stent is fixated, the eyelid can be reconstructed using conventional methods (Figures 5, 6). When reconstructing the medial canthus, the alignment of the eyelid to the eyeball should be handled with care. The punctum lacrimalis should point slightly dorsal, to secure a proper tear-flood mechanism. A protective lens is left in place for 1 week to protect the cornea from irritation.

Postoperative

Postoperative patients attended the outpatient clinic after 1 week.

The stent was removed postoperative 8-12 weeks (Figure 3).

Lacrimal duct function was measured using the noninvasive Munk scale with the stent in situ, and 2 and 12 weeks after stent removal[23] (Table 4). Additionally, complications and the need for additional surgery were noted.

Table 1 Patient characteristics.

Patient characteristics		
Number of patients (n)	12	
Mean age (years)		73 (47-91)
Sex (*n* (%))	Male	2 (17%)
	Female	83%
Etiology (%)	BCC	100
Affected eyelid (*n* (%))	Upper	1 (8%)
	Lower	11 (92%)
Smoking (*n* (%))		0
Diabetes Mellitus (*n* (%))		0
Anticoagulants (*n* (%))		1 (8%)

Results

Between February 2015 and October 2017, 12 patients had a lacrimal duct defect after oncological Mohs resection. The mean age was 73 years (47-91). Nine patients had a nodular basal cell carcinoma, and three patients had an infiltrative basal cell carcinoma (Table 1).

One patient had a defect of the upper eyelid in which the punctum, pars verticalis, and the pars horizontalis were resected. Eleven patients had a defect of the lower eyelid; three patients had a partial or total resection of the punctum and pars verticalis; four patients had a partial or total resection of the pars horizontalis; and four patients had a partial or total resection including the pars verticalis and pars horizontalis (in all cases with total punctum resection). None of the patients had a lacrimal duct defect of the common duct or more distal from the common duct (Table 2, Figure 4).

Anatomical classification

An anatomical classification to aid in planning of lacrimal duct reconstruction was developed (Table 1, Figure 2). It divides the proximal lacrimal duct of the upper (U) and lower (L) eyelid into two sections; the first section consists of the punctum and pars verticalis (U1-L1), and the second section is the canaliculus horizontalis (U2-L2). The common lacrimal duct (C) is the distal part of the lacrimal duct.

If a proximal lacrimal duct defect exceeds the border between sections 1 and 2, this can be referred as (U3-L3). Defects in the distal lacrimal duct (C) are combined with either upper lacrimal duct (CU 2-3) or lower lacrimal duct (CL 2-3) defects. In the rare occasion of defect consisting of upper, lower, and common lacrimal duct defects, this can be referred as (CUL 2-3).

Lacrimal duct reconstruction

In 2017, 10 patients received a lacrimal duct reconstruction with a monocanalicular Mini Monoka stent®. After lacrimal duct reconstruction, the eyelid was reconstructed (Table 3).

In 10 patients, the stent was surgically removed after 8-12 weeks. During this procedure, in one patient, the local flap was revised and excess fat and skin were removed.

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Table 2 Classification of *ductus lacrimalis* defects after oncologic skin tumor resection.

Lacrimal duct defects			N
Upper lacrimal duct (U)	1	*Punctum+pars verticalis*	0
	2	*Canaliculus horizontalis*	0
	3	*Punctum - Canaliculus lacrimalis*	1
Lower lacrimal duct (L)	1	*Punctum+pars verticalis*	3
	2	*Canaliculus horizontalis*	4
	3	*Punctum-Canaliculus lacrimalis*	4
Common lacrimal duct (C)	U2	*Canaliculus horizontalis*	0
	U3	*Punctum-Canaliculus lacrimalis*	0
	L2	*Canaliculus horizontalis*	0
	L3	*Punctum-Canaliculus lacrimalis*	0
	UL2	*Canaliculus horizontalis*	0
	UL3	*Punctum-Canaliculus lacrimalis*	0

Two patients had early protrusion of the stent, after 16-21 days, with no functional loss. No other complications were encountered, and no other additional procedures were performed (Table 4).

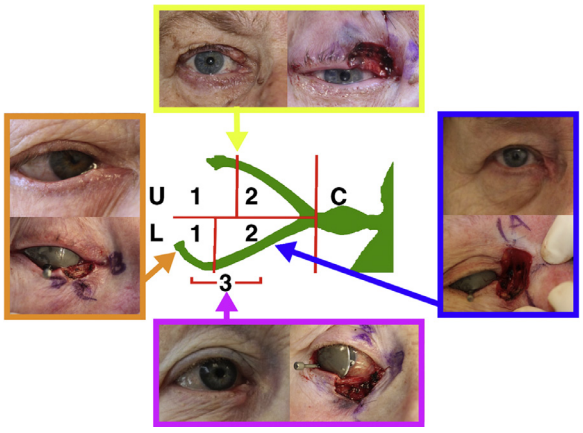

Figure 4 Classification of ductus lacrimalis defects after oncologic skin tumor resection. *(Upper-yellow)*, A 67-year-old woman with a nodular basal cell carcinoma (BCC) in the medial part of the upper eyelid. No relevant comorbidity **(a)**. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect. Anatomical classification; U3 **(b)**. (*Left-orange*), A 72-year-old woman with an infiltrative BCC in the medial part of the right lower eyelid. No relevant comorbidity **(c)**. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect. Anatomical classification; L1 **(d)**. (*Right-blue*), A 72-year-old woman with a nodular BCC in medial part of the lower eyelid. No relevant comorbidity **(e)**. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect, Anatomical classification; L2 **(f)**. (*Lower-purple*), A 78-year-old woman with a nodular BCC in the medial part of the right lower eyelid. No relevant comorbidity **(g)**. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect. Anatomical classification; L3 **(h)**. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

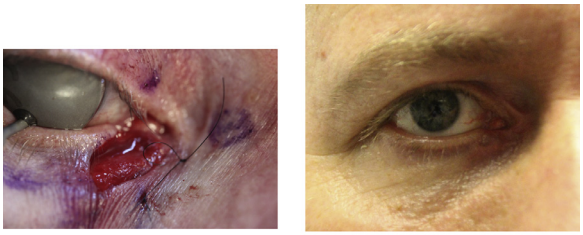

Figure 5 A 48-year-old male with a nodular BCC in the medial part of the lower eyelid. No relevant comorbidity. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect. Anatomical classification; L2 **(a)**. The lacrimal duct was reconstructed accompanied by a Tripier flap reconstruction of the lower eyelid. Three months postoperative (**b**).

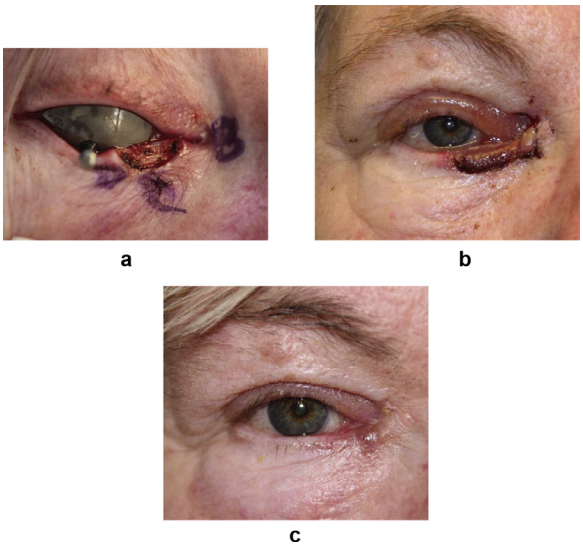

Figure 6 A 78-year-old woman with a nodular BCC in the medial part of the right lower eyelid. No relevant comorbidity. Direct after Mohs surgery with negative tumor margins a lacrimal duct defect. Anatomical classification; L3 **(a)**. The lacrimal duct was reconstructed accompanied by a Tripier flap reconstruction of the lower eyelid. Two weeks postoperative **(b)**. Three months postoperative (**3**).

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Table 3 Surgical technique of eyelid reconstruction.

Technique	*n*	%
Tripier flap	6	50
Glabellar flap	2	17
Full-thickness graft	2	17
Bilobed flap	1	8
Cranial orbicularis flap	1	8

Table 4 Complications.

Complications	*n*	%
Premature loss of stent	2	17
Flap loss	0	0
Infection	0	0
Ectropion	0	0

Epiphora

With the monocanalicular stent in situ, nine patients suffered from epiphora (Table 5). After stent removal, the epiphora diminished in all patients.

Three months after stent removal, no epiphora was reported in nine patients (grade 0). One patients reported minor epiphora and required dabbing less than twice a day (grade 1). None of the patients endured constant epiphora.

Discussion

This article proposes an anatomical classification for lacrimal duct defects in the proximal lacrimal drainage system, and presents the functional outcomes after lacrimal duct reconstruction, with monocanalicular silicone stenting. This procedure is accompanied with an eyelid reconstruction. In 2017, 10 patients were treated with no functional loss of tear-flood drainage 3 months after stent removal.

With an increasing incidence of lower eyelid and medial canthal tumors, an increase in lacrimal duct defects after oncologic resection can be expected.[2] Because of the high recurrence rates after primary resection in the medial canthal area, Mohs surgery is the standard treatment.[13] If a lacrimal duct defect is not properly recognized, a reconstructed eyelid with an insufficient lacrimal duct can lead to constant epiphora.[17,18] Early recognition and repair of lacrimal duct and additional surgery such as conjunctivodacryocystorhinostomy (Jones tube)[24] can prevent epiphora.

This anatomical classification can be applied in comparing cases and determining reconstructive strategies after oncologic skin tumor resection of the eyelid and lacrimal duct. The small diameter of the lacrimal duct (0.3–0.6 mm) can make it difficult to identify a lacrimal duct defect. The pathology report after Mohs surgery may report the lacrimal duct in the resected tissue. Overall, we recommend the use of a surgical microscope for the identification and repair of lacrimal duct defects. Inserting the silicone tube under microscopic magnification will be easier and will decrease the chance of making a false lumen when mistaking a recess in the musculus orbicularis oculi for the lacrimal duct. This can result in complications after reconstruction. A well-vascularized pedicle flap (if possible, we prefer to use a Tripier or Glabellar flap) covers the silicone stent. Theoretically, this results in the formation of a neolacrimal duct either by neoepithelialization or, more likely, fibrosis.

There is no consensus with regard to the postoperative duration in which it is safe to remove the stent and have the best long-term patency, without lacrimal duct obliteration. In the literature, durations between 6 weeks and 12 months are mentioned.[25-30] This is mostly after traumatic lacerations of the lacrimal duct. We believe it is safe to remove the tube after 8–12 weeks, because a well vascularized transposition flap is placed to cover the silicone stent. By this time, neoepithelialization or fibrosis will be complete, and it is safe to remove the tube, with minimal chance of lacrimal duct obliteration.

After stent removal, we asked patients for the amount of tear flood or epiphora. It is valuable to grade the severity of epiphora using a uniform grading system such as the Munk scale.[23] This is a noninvasive and easy method, which indirectly indicates the lacrimal duct function, as an insufficient lacrimal duct is associated with intermittent or constant epiphora.[17] The contribution of the inferior canaliculus in tear drainage is believed to be 55–64% and for the superior canaliculus to be 35–56%.[30] It has not been researched if one lacrimal duct (upper or lower) can take over the full function of tear flood.

Postoperative complications associated with monocanalicular stenting include early tube protrusion, which is associated with epiphora. In addition, punctal slits and punctal granuloma formation have been reported.[25] A previous study reported a higher complication rate when reconstructing the eyelid combined with a lacrimal duct reconstruction. But no surgical technique of reconstructing

Table 5 Munk scale for epiphora grading for patients with a Mini Monoka stent® *in situ*, 2 weeks after stent removal and 3 months after stent removal.

Grade	Munk Scale	Stent	2 weeks	3 months
0	No epiphora	1	5	9
1	Epiphora requiring dabbing less than twice a day	0	4	1
2	Epiphora requiring dabbing 2–4 times a day	0	1	0
3	Epiphora requiring dabbing 5–10 times a day	2	0	0
4	Epiphora requiring dabbing more than 10 times a day	4	0	0
5	Constant epiphora	3	0	0

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the lacrimal duct is described.[34] In this case series, no major complications occurred. There were two patients with a patent function after early tube protrusion at 16 and 21 days, respectively. We encountered no patients with functional loss of tear flood and no patients with constant epiphora. Some patients even reported less epiphora compared to the healthy eye.

The surgeon's choice when reconstructing the lacrimal duct in the first anatomical section may be either marsupialization of the lacrimal duct or lacrimal stenting. Marsupialization is a technique in which the lumen of lacrimal duct is fixated using everting stitches, creating a funnel. A lacrimal duct defect in the second section cannot be reconstructed by only marsupialization.

Lacrimal stenting is known for the treatment of epiphora in patients with (congenital) lacrimal duct obstruction.[31,32] It is also widely used for lacrimal duct reconstruction after periorbital trauma. In a traumatic laceration of the lacrimal duct, there is often a linear tear, which can be repaired with stitches and intubation with a monocanalicular silicone stent.[26,28-30]

After periocular trauma, lacrimal stenting is a widely used method for lacrimal duct reconstruction, and many techniques, including a wide range of materials, have been described.[30] Lacerations are often repaired by monocanalicular stenting to prevent canalicular obstruction and can be covered with a vascularized peddicle flap.[33] This technique is the less invasive than bicanalicular intubation and can avert injury to the uninvolved canaliculus. Silicone is the most popular tube material because of the technical ease associated with its insertion and the low degree of reactivity it induces in surrounding tissues.[25]

Little is known about the long-term functional outcomes when stenting partial lacrimal duct defects after oncologic resection, combined with eyelid reconstruction. We believe the lacrimal duct reconstruction with a monocanalicular stent, such as Mini Monoka stent®, is a safe and easy to learn procedure with good functional results and minimal complications.

Further research will clarify the role of lacrimal duct reconstruction after tumor resection. This classification can be used for the study of the lacrimal duct. It is not suitable for defects in the distal lacrimal drainage system, consisting of the saccus lacrimalis and ductus nasolacrimalis.

Limitations

The current study describes a small patient series and short-term outcomes of lacrimal duct reconstruction. Furthermore, future studies might include control groups or could randomize groups with and without lacrimal reconstruction.

Conclusion

In this study, an anatomical analysis of lacrimal duct defects after oncologic skin tumor resection is conducted to develop an anatomical classification for lacrimal duct defects in the proximal lacrimal drainage system. The classification was found to be useful in comparing cases and determining reconstructive strategies. Short-term results are promising for future efforts to reconstruct the lacrimal duct.

Patient consent

Patients provided written consent for the use of their photos.

Conflict of interest statement

The authors have the following to disclose: the authors have no financial/personal interest in monocanalicular stents.

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Pathology was performed in Ziekenhuisgroep Twente, Department of Pathology, Hengelo, the Netherlands. Contributor: E. Eijken

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