4 Paradigm Shifts in the Lacrimal Anatomy

Hirohiko Kakizaki

Introduction

Anatomical knowledge in the lacrimal drainage system is rapidly advancing year by year. This topic would need a separate update, hence I picked up two representative topics which have been believed to be gold standard, but now needs to be revised based on the recent evidence and hence the need for a paradigm shift here! The first part of this chapter deals with valvular system and second with the medical canthal tendon.

The Valvular Structures in the Lacrimal Passage

The lacrimal excretory passage has been believed to have several valves such as Rosenmüller, Hasner, Bochdalek, Folta, Krause, spiral valve of Hyrtl, and Taillefer (Fig. 4.1) [1, 2]. These have been thought to play an important role in the lacrimal drainage [1, 2]. However, a perfect one-way valve structure like one in the heart or vein has not been convincingly demonstrated in the lacrimal excretory passage [3]. The lacrimal valves are only mucosal folds or protuberances [1, 2]. In spite of these understandings, the true entities and functional values of the so-called valves of Rosenmüller and Hasner have not been correctly understood so far.

H. Kakizaki, MD, PhD
Department of Ophthalmology,
Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

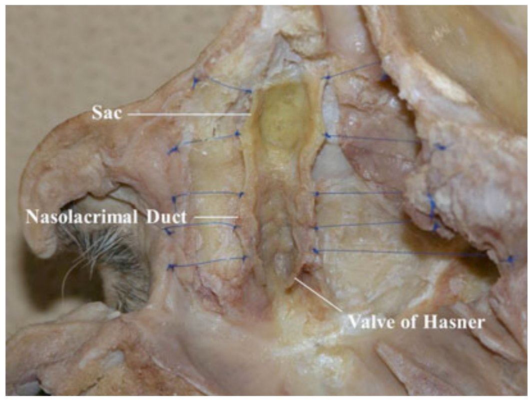

Fig. 4.1 The lacrimal drainage system has numerous mucosal folds or valves across its length

The Valve of Rosenmüller

The so-called valve of Rosenmüller [4, 5] is situated, although only in a half of cases [6], at the junction between the common canaliculus and the sac [7]. This structure is not a valve, in truth, but only a mucosal fold. A valve-like mechanism here is contributed and functionally structured by movement of the common lacrimal canaliculus in blinking, which originates from contraction and relaxation by Horner's muscle [8]. The internal canalicular orifice largely opens by a temporal traction of Horner's muscle during eye closing but moves nasally during an eye opening [8].

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*,
DOI 10.1007/978-81-322-2020-6_4, © Springer India 2015

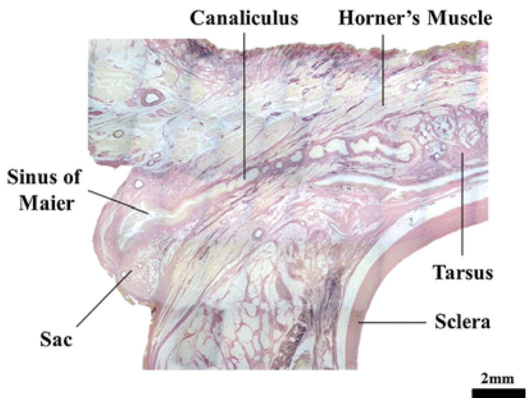

Fig. 4.2 A sinus of Maier is shown here, into which the canalicular part is expanded (Elastica van Gieson stain)

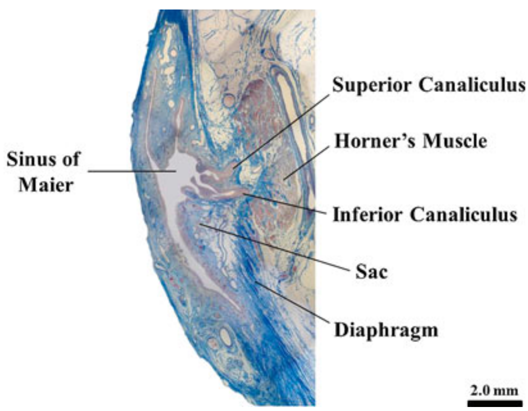

Fig. 4.3 A sinus of Maier, in which a part of sac is expanded. The superior and inferior canaliculi separately empty into the sinus of Maier (Masson's trichrome stain)

The diverticulum, called the sinus of Maier [1, 2], is obvious, especially during eyelid closure, in which folds or membranes are not shown (Figs. 4.2 and 4.3). These folds or membranes only reflect a mucosal spare in the closed state of the internal canalicular orifice, allowing for expansion of the diverticulum. As the lacrimal sac comprises a cavernous structure [9, 10] and may not withstand dynamic movements during repetitive blinking, such a buffering structure may be necessary. Therefore, the movement of the internal canalicular orifice may not directly contribute to lacrimal drainage or antiregurgitation, but protects the sac against repetitive blinking.

Studies for the valve of Rosenmüller have been mostly performed using cadavers. Although cadavers usually have closed eyelids, their Horner's muscle tone was completely lost [11], which is similar to an eyelid in the opening state with closing of the internal canalicular orifice. This situation may show folds or membranes at the internal canalicular orifice. Cadaveric studies would evaluate only one aspect of the above process. Live patients enable us to observe opening and closing of the internal canalicular orifice. The valve of Rosenmüller may thus be a phantom anatomy.

The Valve of Hasner

The so-called valve of Hasner is only the terminal soft tissue component of the lacrimal excretory passage [12]. An imperforate valve will result in epiphora and signs of congenital nasolacrimal duct obstruction [12]. This soft tissue is situated at the meatal opening of the nasolacrimal duct (NLD), several millimeters inferiorly after NLD's exit from the bony lacrimal canal [13, 14]. This soft tissue has been thought to prevent air current or fluid from within the nose being drawn up into the lacrimal duct.

The shape of this terminal soft tissue shows four types: wide-open type (12 %), valve-like type (8 %), sleeve-like type (14 %), and adhesive type (66 %) [14]. Judging from these variations, the wide open type at least should demonstrate regurgitation of air current or fluid [12]. Bert (quoted by Aubaret) [1, 2] found that colored fluids injected in the nose escaped from the lacrimal puncta only 3 times in 18 experiments, whereas direct injections into the duct invariably appeared at these points, showing that the terminal soft tissue of the lacrimal excretory passage usually shows valve-like mechanism but not always. Although Bert's study has been reported more than 100 years ago, it has been under surgeons' recognition.

Anatomy of the Medial Canthal Tendon (MCT)

History of the MCT Anatomy

The medial canthus is a complex anatomical region and the most striking entity here is the medial canthal tendon (MCT) [15–19]. The MCT was earlier known as the "medial canthal ligament" [20]. In view of inadequate information, some considered it to be a ligament, but others saw it simply as a large adhesion to the periosteum of the frontal process of maxilla [20].

A different opinion about the medial canthal region was published in 1970s by Lester T. Jones, who was the first to reconsider this classical anatomy. Jones and his colleague reported that the medial canthal ligament was not a ligament, but rather a tendon of the orbicularis oculi muscle (OOM) [17].

The classical teaching about MCT is its two limbs, i.e., the anterior and posterior [18, 21]. The anterior limb, which is stronger than the posterior limb [22], was thought to be situated in front of the lacrimal sac and connected to the anterior lacrimal crest and the medial aspect of the tarsal plate [18]. Ritleng et al. also stated that the anterior part of the medial canthal ligament was actually the tendon of the pretarsal OOM [3] and suggested to call it as the "medial palpebral tendon" [18]. Yamamoto et al. proposed that the MCT comprised an aggregate of muscle fibers from the orbital area of the OOM, as well as the tendon from the tarsal area [16].

Many anatomists worked on the anatomy of the MCT, however we revisited the anterior limb to include two lamellae, i.e., the anterior and posterior [23]. The anterior lamella is the tendon of the pretarsal part of the OOM [23]. The posterior lamella is the musculotendinous junction of the preseptal and orbital parts of the OOM [23]. The anterior limb continues to the pretarsal OOM without insertion into the tarsal plate [24].

The classical teaching with regards to the posterior limb is its attachment to the posterior lacrimal crest and tarsal plate and Horner's being related to its posterior surface (Fig. 4.4) [18]. However, true fixation of the nasal aspect of the tarsal plate is performed by Horner's muscle and the medial rectus capsulopalpebral fascia (mrCPF) [24] and not by the posterior limb of the MCT. Most researchers considered this posterior limb as a relative subsidiary structure, compared with the anterior limb [22, 25, 26], although some thought the posterior limb to have the same tough fibrous consistency as the anterior limb [27].

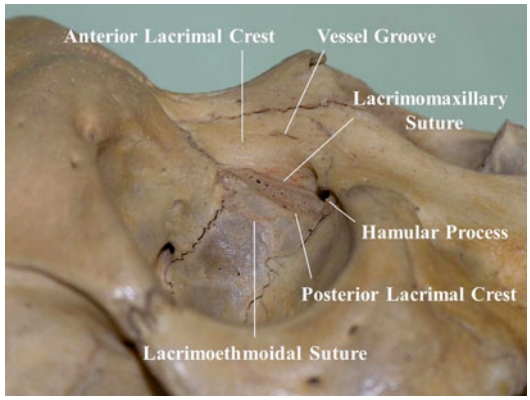

Fig. 4.4 Important bony landmarks in medial canthal anatomy

The Truth of the Posterior Limb of the MCT

The classical anatomical teaching has been that the medial canthus is supported by the anterior and posterior limbs of the MCT and the Horner's muscle. The posterior limb of the medial canthal ligament, as a deep or reflected part arising from the main ligament [18, 25], was thought to be merely a thin fascial expansion [28] or simply a thin and weak structure to assist the anterior limb [26]. The posterior limb of the MCT was thought to be attached behind the lacrimal sac and contiguous with the lacrimal fascia, and thus helped to support the upper part of the lacrimal sac [25].

Some anatomist regarded the posterior limb of the MCT as Horner's muscle [22]. Ritleng et al. stated that Horner's muscle was a separate structure from the posterior limb of the MCT, and that the structure corresponding to the posterior limb was not a tendon, but Horner's muscle [18]. Adenis et al. reported that the posterior component of the MCT was more delicate and had more of a dynamic structure than the anterior portion, and Horner's muscle comprised the posterior portion of the MCT [22]. Shinohara et al. reported that the posterior connective tissue fibers of the MCT were interwoven with fibers of the lacrimal fascia and extended to the common lacrimal canaliculus and to the bifurcation of Horner's muscle [29].

Our group revisited the anatomy of the posterior limb of the MCT as recently as 2012 but failed to detect it in any of the studied specimens, irrespective of race [30, 31]. Instead, a thick fibrous lacrimal diaphragm [32], namely, the common fascia between the lacrimal sac and Horner's muscle, was noted around the posterior lacrimal crest, which appeared to be continuous with Horner's muscle fascia and was indistinguishable from the muscle's tendon [30, 31]. This thick, fibrous diaphragm, similar to Horner's muscle tendon, may have been regarded mistakenly as the posterior limb of the MCT [30].

Way Forward: The Modified Tarsal Fixation Model

To better study, understand, and standardize the anatomical exploration of medical canthus, we believe the modified tarsal fixation model is the way forward. Horner's muscle and the mrCPF are key to understand the modified tarsal fixation model of the medial canthus [24]. Horner's muscle, the lacrimal part of the OOM, originates from the posterior lacrimal crest and inserts to the medial aspect of the tarsal plate in the eyelid margin and to the pretarsal OOM in others [18, 21, 24, 31]. The mrCPF is a fibrous structure, which originates from the pulley of the medial rectus muscle around the globe equator, and inserts to the medial tarsal aspect, the lacrimal caruncle, and the medial orbital wall via the medial check ligament [24, 33]. The mrCPF contains many smooth muscle fibers as well [24]. The main function of the mrCPF is connecting the medial rectus muscle and the medial aspect of the tarsal plate as the "medial eyelid retractor" during eye movement [24, 33].

Horner's muscle supports the medial side of the tarsal plate, in the area close to the eyelid margins and not by the mrCPF as was earlier believed [24]. At this level, no tendon or ligament supports the tarsal plate [24]. In the area away from the eyelid margin, the tarsal plate is supported by the mrCPF. The tarsal plate is not supported here by a tendon or a ligament [24]. The medial aspect of the tarsal plate is not, therefore, supported by the anterior or posterior limb of the MCT, but rather by Horner's muscle and the mrCPF. The anterior limb of the MCT only influences medial canthal fixation via the pretarsal OOM located on the tarsal plate [24].

Conclusion

Anatomy in the lacrimal drainage system is fast showing a "paradigm shift" on many aspects. This has led to many concepts being revisited and anatomical dogmas being questioned. Since most of these paradigm shifts have clinical implications, we therefore need to update our anatomical knowledge to catch up and be at the forefront!

References

1. Aubaret E. The valves of the lacrymonasal passages. Arch Ophthalmol. 1908;28:211–36.
2. Whitnall SE. Anatomy of the human orbit and accessory organs of vision. 2nd ed. New York: Krieger Publishing Company; 1979. p. 241–3.
3. Kurihashi K. Ruido no kaibo. Ganka. 1996;38:301–13. Japanese.
4. Burkat CN, Lucarelli MJ. Anatomy of the lacrimal system. In: Cohen AJ, Brazzo B, editors. The lacrimal system: diagnosis, management, and surgery'. New York: Springer; 2006. p. 3–19.
5. Katowitz JA, Hollsten DA. Silicone intubation of the nasolacrimal drainage system. In: Linberg JV, editor. Lacrimal surgery. New York: Churchill-Livingstone; 1988. p. 109–23.
6. Zoumalan CI, Joseph JM, Lelli Jr GJ, et al. Evaluation of the canalicular entrance into the lacrimal sac: an anatomical study. Ophthal Plast Reconstr Surg. 2011;27:298–303.
7. Kurihashi K, Imada M, Yamashita A. Anatomical analysis of the human lacrimal drainage pathway under an operating microscope. Int Ophthalmol. 1991;15:411–6.
8. Kakizaki H, Zako M, Miyaishi O, et al. The lacrimal canaliculus and sac bordered by the Horner's muscle form the functional lacrimal drainage system. Ophthalmology. 2005;112:710–6.
9. Thale A, Paulsen F, Rochels R, et al. Functional anatomy of the human efferent tear ducts: a new theory of tear outflow mechanism. Graefes Arch Clin Exp Ophthalmol. 1998;236:674–8.
10. Paulsen FP, Thale A, Hallmann UJ, et al. The cavernous body of the human efferent tear ducts: function in tear outflow mechanism. Invest Ophthalmol Vis Sci. 2000;41:965–70.

11. Knight B. The pathophysiology of death. In: Knight B, editor. Forensic pathology. 2nd ed. London: Arnold Publisher; 1996. p. 52–4.
12. Cowen D, Hurwitz JJ. Anatomy of the lacrimal drainage system. In: Hurwitz JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 15–21.
13. Bailey JH. Surgical anatomy of the lacrimal sac. Am J Ophthalmol. 1923;6:665–71.
14. Onogi J. Nasal endoscopic findings of functional obstruction of nasolacrimal duct. Rinsho Ganka. 2012;55:650–4. Japanese.
15. Kang H, Takahashi Y, Nakano T, et al. Medial canthal support structures–the medial retinaculum: a review. Ann Plast Surg. 2014 (Epub, in press).
16. Yamamoto H, Motikawa K, Uchinuma E, Tamashita S. An anatomical study of the medial canthus using a three-dimensional model. Aesthetic Plast Surg. 2001; 25:189–93.
17. Jones LT, Wobig JL. Newer concepts of tear duct and eyelid anatomy and treatment. Trans Am Acad Ophthalmol Otolaryngol. 1977;83:603–16.
18. Ritleng P, Bourgeon A, Richelme H. New concepts of the anatomy of the lacrimal apparatus. Anat Clin. 1983;5:29–34.
19. Fernandez-Valencia R, Gomez Pellico L. Functional anatomy of the human saccus lacrimaris. Acta Anat. 1990;139:54–9.
20. Couly G, Hureau J, Tessier P. The anatomy of the external palpebral ligament in man. J Maxillofac Surg. 1976;4:195–7.
21. Jones LT. Epiphora. Its relation to the anatomic structures and surgery of the medial canthal region. Am J Ophthalmol. 1957;43:203–12.
22. Adenis JP, Longueville E. Horner's muscle placation using an anterior approach. Orbit. 1991;10:187–91.
23. Kakizaki H, Zako M, Mito H, et al. The medial canthal tendon is composed of anterior and posterior lobes in Japanese eyes and fixes the eyelid complementarily with Horner's muscle. Jpn J Ophthalmol. 2004;48:493–6.
24. Kakizaki H, Zako M, Nakano T, et al. Direct insertion of the medial rectus capsulopalpebral fascia to the tarsus. Ophthal Plast Reconstr Surg. 2008;24:126–30.
25. Wolff E. Wolff's anatomy of the eye and orbit. 7th ed. Philadelphia: Saunders; 1976. p. 190.
26. Anderson RL. Medial canthal tendon branches out. Arch Ophthalmol. 1977;95:2051–2.
27. Ahl NC, Hill JC. Horner's muscle and the lacrimal system. Arch Ophthalmol. 1982;100:488–93.
28. Zide BM. Anatomy of the eyelid. Clin Plast Surg. 1981;8:623–34.
29. Shinohara H, Taniguchi Y, Kominami R, et al. The lacrimal fascia redefined. Clin Anat. 2001;6:401–5.
30. Kakizaki H, Takahashi Y, Nakano T, et al. The posterior limb in the medial canthal tendon in Asians: dose it exist? Am J Ophthalmol. 2010;150:741–3.
31. Poh E, Kakizaki H, Selva D, et al. The anatomy of medial canthal tendon in Caucasians. Clin Experiment Ophthalmol. 2012;40:170–3.
32. Jones LT. The cure of epiphora due to canalicular disorders, trauma and surgical failures on the lacrimal passage. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:506–24.
33. Kakizaki H, Selva D, et al. Dynamic study of the medial and lateral recti capsulopalpebral fasciae using cine mode magnetic resonance imaging. Ophthalmology. 2010;117:388–91.