Evaluation of the Canalicular Entrance Into the Lacrimal Sac: An Anatomical Study

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Purpose: The purpose of this study was to investigate the prevalence of a common canalicular entrance in the lacrimal sac and to investigate the anatomy of the canalicular/lacrimal sac junction with direct visualization using a novel cadaveric dissection technique.

Methods: Preserved cadavers were dissected to allow direct visualization of the canalicular entrance(s) to the lumen of the lacrimal sac. The prevalence of a common canaliculus and the anatomical variations of the canalicular/lacrimal sac mucosal fold of tissue were recorded.

Results: One hundred twenty-four lacrimal systems (95 cadavers; 43 female, 52 male) were included in the study analysis. Overall, 123 lacrimal systems demonstrated a common canaliculus entering the lacrimal sac. Only one demonstrated 2 separate orifices (right orbit; male) in the sac (0.08%; 95% confidence interval, 0.1%–4.4%). Seventy-four lacrimal systems had some variation of a canalicular/lacrimal sac mucosal fold (59.7%). The remaining 50 (40.3%) had no visible canalicular/lacrimal sac mucosal fold.

Conclusions: This study provides direct anatomical evidence that the prevalence of separate canalicular orifices in the lacrimal sac is lower than previously reported (<1%). Additionally, the presence of a valve-like structure at the canalicular/lacrimal sac junction is common. These observations can potentially play a role in evaluating and treating lacrimal system pathology.

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Lester Jones[1–4] was the first to report that approximately 90% of individuals have a common canaliculus, while the remaining 10% have upper and lower canaliculi that enter the lacrimal sac separately.[1–6] However, the method by which the data were obtained was never detailed.[1–4] Interestingly, a recent study evaluated the prevalence of a common canaliculus using digital macrodacryocystography (DMD) and found it closer to 98%.[7]

On a similar note, there has been much debate about the existence of a valve at the canalicular/lacrimal sac junction and whether it serves a functional role. Prior studies suggested a valve-like tuft of tissue at the canalicular/lacrimal sac junction. In 1908, Aubaret[8] accredited Rosenmüller as the first to describe an irregular mucosal fold located around the superior portion of the canalicular/lacrimal sac junction in 1797. Since Aubaret's work, there have been few published studies that describe the canalicular/lacrimal sac mucosal folds (CLS-MFs) and their functional role.

The purpose of our study is to investigate the prevalence of the common canaliculus and to investigate the anatomy around the canalicular/lacrimal sac junction via direct anatomical observation in cadaveric dissections.

METHODS

Cadavers previously dissected by medical students during their anatomy courses at New York University Langone Medical School, Columbia University College of Physicians and Surgeons, and Weill Cornell Medical College were used for the study. Permission for the study was granted by each medical school. Cadavers were excluded from the study if there was prior direct dissection and anatomical disruption around eyelid structures medial to the puncta and canaliculi, osteotomy evidence of prior dacryocystorhinostomy, or canalicular obstruction noted on punctal dilation or through the injection of surgical lubricant. Surgical loupes (×2.5 magnification) and adequate illumination were used to aid in the dissection.

Dissection Technique. The upper and lower puncta were dilated with a punctal dilator. A lacrimal cannula was used to inject surgical lubricant to reinflate the lacrimal sac, which was routinely found to be collapsed secondary to postmortem changes and the preservation process. The dissection was achieved with exposure of the lacrimal sac via a standard external dacryocystorhinostomy incision followed by blunt dissection to expose the sac in the lacrimal fossa. The anterior crus of the medial canthal tendon was incised, allowing better exposure. The lacrimal sac was incised posteriorly with a curved blade and opened to expose its lumen. An egress of surgical lubricant after the lacrimal sac confirmed entry in the lacrimal sac. Surgical lubricant was reinjected through each canaliculus separately (superior and inferior) to directly observe the location within the sac where the lubricant first appeared, corresponding to a canalicular/lacrimal sac orifice. All dissections were performed by an oculoplastic surgeon (CIZ) and an assistant. The

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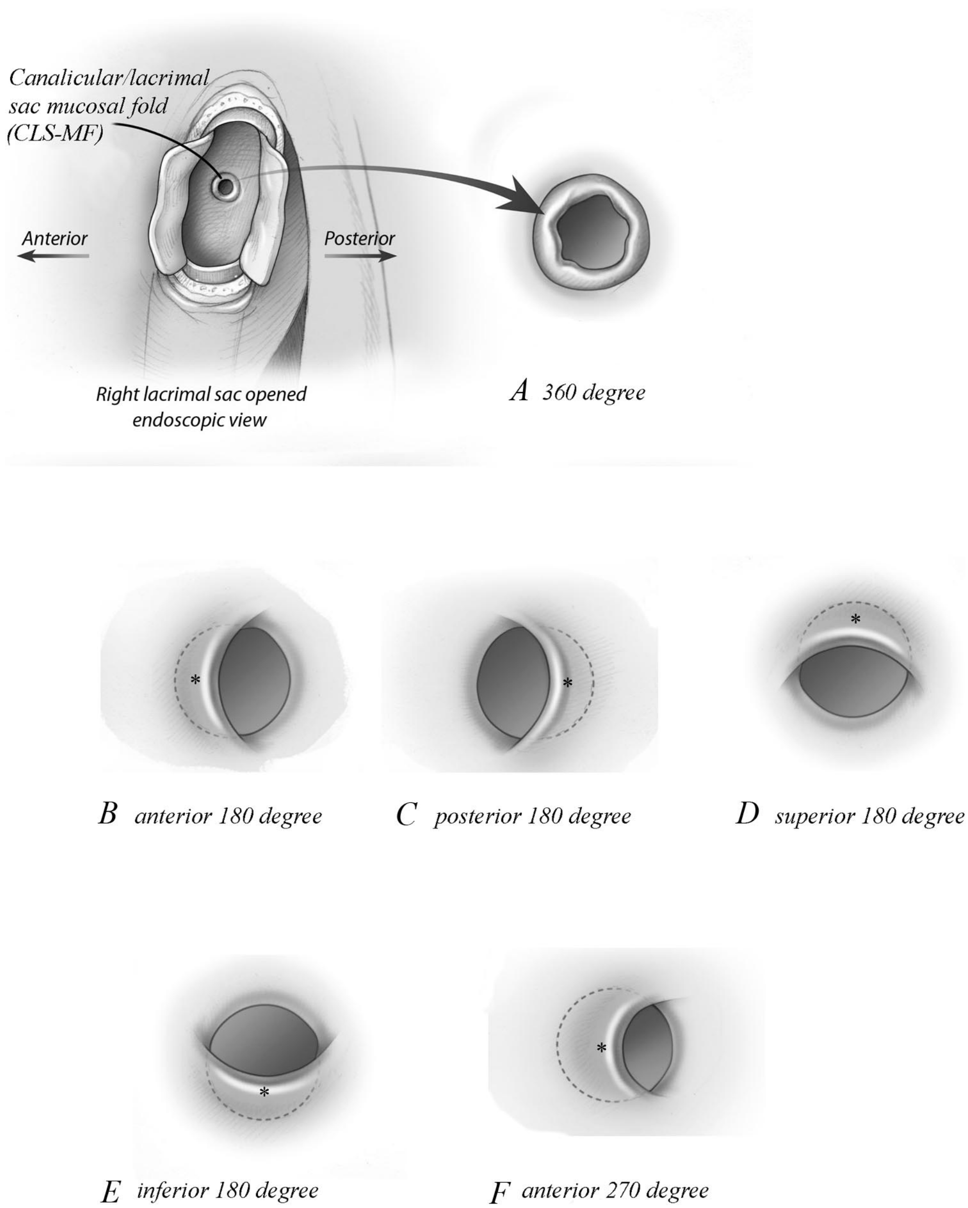

FIG. 1. Illustrated endoscopic view of the canalicular/lacrimal sac junction and the different types of canalicular/lacrimal sac mucosal folds (CLS-MF) that were observed, right orbit. The CLS-MFs were described according to their orientation and extent around the canalicular/lacrimal sac orifice. Their extent around the orifice was approximately measured in circumferential degrees: **A**, 360 degree; **B**, Anterior 180 degree; **C**, Posterior 180 degree; **D**, Superior 180 degree; **E**, Inferior 180 degree; **F**, Anterior 270 degree. Asterisks denote the location of the mucosal folds.

presence of a common orifice or of 2 separate orifices in the lacrimal sac was confirmed by the surgeon and assistant and recorded.

Additionally, the anatomical variations of a CLS-MF, if present, were recorded for all lacrimal systems. CLS-MFs were described according to their orientation and extent around the canalicular/lacrimal sac orifice. Their extent around the orifice was approximated in circumferential degrees. Chi-squared test was used to identify any significant differences in CLS-MF variations with regard to laterality (right and left orbits) and gender.

RESULTS

Two hundred fifty-four lacrimal systems (127 cadavers; 56 female, 68 male) were explored using the technique described. One hundred twenty-four lacrimal systems (95 cadavers; 43 female, 52 male) met the inclusion criteria and were included in the study for analysis. Overall, 123 lacrimal systems demonstrated a common canaliculus entering the lacrimal sac. Only one demonstrated 2 separate canalicular orifices in the sac (right orbit; male). This particular cadaver's corresponding left orbit could not be included in the study due to prior dissection around the lacrimal sac. The prevalence of 2 separate canalicular orifices in the sac was 0.08% (95% confidence interval, 0.1%–4.4%).

The anatomical variations of the CLS-MF, if present, were recorded for all 124 lacrimal systems. The configuration of the CLS-MFs identified were as follows: a complete 360° CLS-MF (360), anterior-based 180° CLS-MF (anterior 180), posterior-based 180°

TABLE 1. Prevalence of the different variations in canalicular/lacrimal sac mucosal folds (n = 124)

Valve type	Prevalence (no.)	Percentage (%)
Anterior 180	20	16.2
Posterior 180	13	10.5
360 valve	36	29
Inferior 180	1	0.81
Superior 180	1	0.81
Anterior 270	3	2.4
No valve	50	40.3
Total	124	100

For the definition of the different variations in canalicular/lacrimal sac mucosal folds (ie, Anterior 180, Posterior 180, and 360 valve) please see 'Results' section in text.

CLS-MF (posterior 180), superior-based 180° CLS-MF (superior 180), inferior-based 180° CLS-MF (inferior 180), anterior-based 270° CLS-MF (anterior 270), and those that had no discernible fold or tuft of tissue (no CLS-MF) (Fig. 1). Seventy-four lacrimal systems had some variation of a CLS-MF (59.7%). The remaining 50 (40.3%) had no visible CLS-MF. The most common CLS-MF observed was a 360° CLS-MF that surrounded the lumen (48.9%), followed by anterior 180 (27.0%) and posterior 180 (17.6%) CLS-MFs. Table 1 shows the prevalence of the variations that were identified. Of particular note, the sac with 2 separate canalicular orifices had no CLS-MF surrounding either lumen (Fig. 2). There was a significant difference between the right and left orbits such that there was a higher percentage of 360° CLS-MFs (38.3% versus 15.7%) and anterior 180 CLS-MFs (19.2% versus 11.7%) in the right orbit when compared with the left orbit ($p < 0.005$). There was also a significant difference such that the left orbit had a higher percentage of posterior 180 CLS-MF (17.6% versus 5.5%) and no CLS-MF (50.1% versus 32.3%) when compared with the right orbit ($p < 0.005$) (Tab. 2). Female cadavers had an increased prevalence of having some type of a CLS-MF (65.0%) when compared with male cadavers (55.2%). Although the data suggest an increased prevalence, the sample size was not large enough to detect a statistical significance for this latter comparison (Tab. 3).

Twenty-nine cadavers had bilateral orbits that met inclusion criteria. The remaining cadavers had unilateral data, as the contralateral side did not meet inclusion criteria. Various combinations of different CLS-MFs were observed within the bilateral specimens such that 22 cadavers (75.9%) had different types of CLS-MFs when comparing paired systems. Two cadavers (6.9%) had the same type of CLS-MFs bilaterally, and the remaining 5 cadavers had no CLS-MFs bilaterally (17.2%). Seven cadavers (24.1%) had no CLS-MF present in one lacrimal sac but a CLS-MF was present on the contralateral side. All combinations of different CLS-MFs occurred with similar prevalences. No particular combination had a significantly higher prevalence than others that were observed.

DISCUSSION

Although Lester Jones[1–4] was the first to describe the prevalence of the common canaliculus >50 years ago, it is uncertain how the data were acquired. A recent study used DMD to identify an ~2% prevalence of a common canaliculus in 247 patients that presented with epiphora.[7] Using cadaveric specimens from various cadaver labs in the greater New York City area, we found a similar prevalence of 2 separate canalicular orifices (<1%).

In developing the dissection technique, our preliminary studies utilized direct canalicular probing with Bowman probes to identify the canalicular orifices in the sac. Although this technique, which was adapted from intraoperative experience, seemed the most intuitive, it produced a high incidence of false passages and difficulty preserving the anatomy around the canalicular/lacrimal sac junction. However, injecting the canalicular system with surgical lubricant allowed restoration of the canalicular system to best resemble the premorbid state. Additionally, avoiding the probing portion of the protocol and solely relying on the injection of the surgical lubricant provided an atraumatic method of directly visualizing the canalicular/lacrimal sac junction.

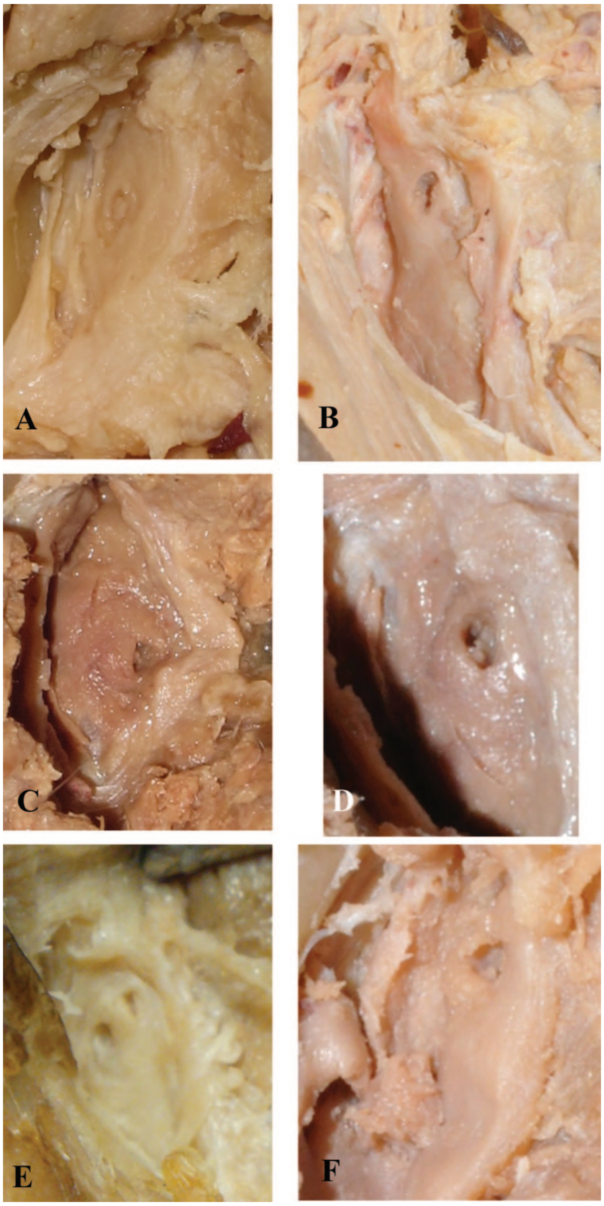

FIG. 2. Cadaveric photographs of the various types of canalicular/lacrimal sac mucosal folds (CLS-MFs), left orbit. **A,** 360° CLS-MF. The CLS-MF in this specimen does not directly cover the canalicular/lacrimal sac orifice. **B,** Anterior 180° CLS-MF. **C,** Posterior 180° CLS-MF. **D,** Inferior 180° CLS-MF. Note that there is some artifactual debris canalicular/lacrimal sac orifice that accumulated after the injection of surgical lubricant. **E,** Lacrimal sac with 2 canalicular/lacrimal sac orifices and no surrounding CLS-MF. **F,** Superior 180° CLS-MF.

Although DMD produces bone-free images that provide a high degree of sensitivity in identifying areas of lacrimal

TABLE 2. Variations in canalicular/lacrimal sac mucosal folds based on laterality (right vs. left orbits)

	No. in indicated orbit		
Valve type	Right	Left	$p < 0.005$
Anterior 180	14	6	*
Posterior 180	4	9	*
360 valve	28	8	*
Inferior 180	1	0	—
Superior 180	0	1	—
Anterior 270	2	1	—
No valve	24	26	*
Total	73	51	—

system obstruction,[9] its role in evaluating the canalicular/lacrimal sac junction anatomy may be misleading in cases of lacrimal sac or canalicular obstruction.[10] This is particularly important, since all of the patients included in the DMD study by Yazici and Yazici[7] had obstructive epiphora, and an unspecified number of them were imaged after being treated for acute dacryocystitis. Overall, these authors found 3 variations of the canalicular segments such that the 94.1% (n = 321) had a common canalicular orifice, 3.8% (n = 13) had separate canaliculi but they met at the sac to create a common orifice, and 2.0% (n = 7) had 2 separate orifices.[7] When evaluating the DMD images that were published by Yazici and Yazici,[7] we found that the resolution is often inadequate at the canalicular/lacrimal sac junction to distinguish those that were described as having 2 separate canaliculi meeting to form a common orifice in the lacrimal sac from those that had a common canaliculus with a short segment, particularly in the patients with a large sac. Only direct dissection around each canalicular segment or a casting study, as performed by Tucker et al.,[11] allows the evaluation of this subcategory, which was not a part of our study's protocol. It is uncertain how the patient selection may have yielded different results if patients without lacrimal system disease were evaluated. Yazici and Yazici[12] later published a study that suggested anatomical changes in orientation of the common canaliculus in patients with lacrimal sac enlargement secondary to nasolacrimal duct obstruction.

Our study supports the recent findings of a higher prevalence of a common canalicular entrance than previously thought (present in >99% of patients). Although the use of pigtail probes has become less common due to the perceived high rate of creating a false passage,[13,14] our study supports the careful use of pigtail probes in canalicular repairs.

TABLE 3. Variations in canalicular/lacrimal sac mucosal folds based on gender

	No. of indicated gender	
Valve type	Male	Female
Anterior 180	9	11
Posterior 180	8	5
360 valve	18	18
Inferior 180	0	1
Superior 180	0	1
Anterior 270	2	1
No valve	30	20
Total	67	57

Prior studies have suggested a valve-like mucosal fold of tissue at the canalicular/lacrimal sac junction.[8] Aubaret credited Rosenmüller with the first description of an irregular mucosal fold located at the superior canalicular/lacrimal sac junction in 1797. Huschke described a similar fold along the inferior portion of the junction. Aubaret examined the functional significance of the canalicular/lacrimal sac folds by injecting colored liquid through the nasolacrimal duct in a retrograde fashion in cadaveric specimens. When the injection was performed at the valve of Hasner, reflux through the puncti occurred in the minority of cases (3 out of 18 specimens), suggesting a functional barrier at this valve. However, he reported punctal reflux in all cases where the injection occurred superior to the valve of Hasner, suggesting no other functional barrier within the nasolacrimal duct. As a result, the "irregular folds at the orifice of the lacrimal canaliculi" were thought to have no functional significance and are omitted in most nasolacrimal system anatomical descriptions.[1–4,8,15–17]

Furthermore, Tucker et al.[11] evaluated the nasolacrimal duct system in cadavers after injecting them with a polymer to create a cast of the system. These authors were not able to identify true valves within the lacrimal sac, but the cast suggested multiple irregular folds near the common canalicular orifice. Although the casting process is ideal for evaluating the canalicular anatomy and its orientation to the lacrimal sac, it may not be as sensitive in identifying valve-like tissue at the canalicular/lacrimal sac junction. The described "irregular fold" near the canalicular/lacrimal sac junction may represent what in our study is a CLS-MF.

Although Rosenmüller and Huschke reported superior and inferior based folds of tissue at the canalicular/lacrimal sac junction, respectively, little has been added to the literature regarding CLS-MFs since Aubaret[8] first described nasolacrimal anatomy in 1908. Our cadaveric data provide a detailed description of the variations of CLS-MFs in 124 cadavers. Nearly 60% of the specimens had some type of a CLS-MF. The remaining 40% did not have evidence of a CLS-MF. The most common CLS-MF type identified was a 360° CLS-MF around the canalicular/lacrimal sac junction (48.9%). The superior and inferior 180 CLS-MFs, which Rosenmüller and Huschke reported, are the least commonly identified CLS-MFs, with prevalence of 2.4% and 0.81%, respectively.

Although some believe it to have little functional significance, the CLS-MF has been implicated in the production of acute lacrimal sac distention by its action as a one-way valve in dacryocystitis.[11,18] The presence of a CLS-MF, and potentially more so with some configurations of CLS-MF, may predispose such patients to develop a noncompressible dacryocystocele, while others can express fluid from the lacrimal sac with digital compression. Studies have suggested that women may have an increased prevalence for dacryocystoceles and acquired nasolacrimal duct obstruction when compared with men. In one particular study, 73% of congenital dacryocystocele cases occurred in females.[19] In another population-based study, up to 73% of patients with acquired nasolacrimal duct obstruction were female.[24] It has been speculated that the smaller diameter of the inferior bony lacrimal fossa and lacrimal canal along with heightened levels of tissue inflammation and hormonal imbalances in women contribute to the increased prevalence of nasolacrimal duct obstruction in female patients.[20–23] Although the difference was not statistically significant, female cadavers in our study had a higher prevalence of having a CLS-MF (65.0%) when compared with males (55.2%). Nevertheless, the presence of a CLS-MF does not appear to be associated with an increased prevalence of lacrimal sac disease in women. Future functional studies may be required to evaluate the CLS-MF's role in congenital dacryocystoceles and acquired nasolacrimal duct obstruction.

The presence of CLS-MFs may potentially play a role in the surgical outcomes of lacrimal procedures. For instance, the CLS-MFs can theoretically be injured during lacrimal surgeries, and as a consequence, may result in canalicular stenosis or obstruction. Several authors have intraoperatively described the CLS-MFs during lacrimal surgery as membranes that may functionally obstruct or anatomically block the common canalicular orifice in the sac.[25,26] Boboridis et al.[25] also recommended that if these particular CLS-MFs are not correctly identified and excised, they may affect the outcome of particular lacrimal surgeries such as external dacryocystorhinostomies.[25] These particular findings may further support the use of silicone intubation during dacryocystorhinostomy surgery.

Canalicular probing with a metal guide such as a Bowman probe may frequently lead to a false impression of canalicular obstruction. The probe does not easily conform to the angulations of the canaliculus and its tip may be caught within the CLS-MF, falsely suggesting an obstruction. As a result, some surgeons do not use Bowman probes during lacrimal surgery to avoid canalicular trauma. Yazici[27] described the use of a thin (26-gauge), curved lacrimal cannula with a plastic head as a probe. Interestingly enough, some authors, such as Hecht,[28] have advised against using Bowman probes intraoperatively and prefer to confirm canalicular patency via intracanalicular dye injections such as methylene blue.[27,28]

Such studies raise several important questions about the surgical outcomes in lacrimal surgery. For instance, would the presence of CLS-MFs increase the risk of iatrogenic canalicular injury during lacrimal surgery? Would a “gentler” probe, such as one with olive-shaped tips, similar to the bicanalicular Crawford tubes (FCI Ophthalmics, Pembroke, MA, U.S.A.), create less trauma toward certain CLS-MFs? Alternatively, would one consider avoiding the use of probes distal to the point of the common canaliculus intraoperatively altogether like Hecht proposed and rather rely on viscoelastic inflation of the lacrimal system? These questions are outside the scope of our study but certainly would be worthwhile to evaluate in future studies.

One may speculate that the CLS-MF variations we observed may play some contributing role in the differences of tear drainage between the superior and inferior canaliculi. Quantitative studies using dacryoscintigraphy have shown that, while not statistically significant, there are differences in the contribution of tear drainage between the superior (range: 35%–56% of total) and inferior (range: 55%–64% of total) canaliculi.[29,30] On a similar note, the presence of a CLS-MF may also increase the risk of an inferior or superior canaliculitis. The prevalence of canaliculitis is higher in women and the majority involve the inferior canaliculus (>90% of cases).[31,32] It is not clear whether the existence of a CLS-MF, and if so, which variant may produce differences in tear drainage between the canaliculi or potentially contribute to canaliculitis.

A recent anatomical study by Orhan et al.[33] also evaluated the lacrimal system using direct anatomical cadaveric dissection. Although their study included only 20 cadavers, these authors reported a 90% prevalence of a common canaliculus. The dissection method included the direct passage of Bowman probes through the canalicular system, visualizing the point of entrance in the sac. As described earlier, we found this method to result in a high rate of false passages, which may have affected the study's overall prevalence rate. Of particular interest, though, Orhan et al. also identified CLS-MFs, termed as diverticuli, in up to 53% of their specimens. This percentage is close to our reported 60% prevalence of CLS-MFs. Through the use of an operative microscope, they were able to evaluate the canaliculi in great detail. Direct dissection around each canalicular segment allowed the authors to identify 3 different forms of canaliculi, similar to what Yazici and Yazici[7] reported in 2000.

Our study was limited by the quality of cadavers available for dissection. Although a total 254 lacrimal systems were dissected, 124 lacrimal systems were included in the study and only 29 cadavers underwent bilateral dissections. The cadavers were available only after the head and neck portion of the medical student anatomy course, and as a result, many of them had been dissected around the eyelids and canalicular system. This was often the case in at least one of the orbits of each cadaver, so establishing bilateral data and trends was subsequently difficult. Nevertheless, the cadaver tissues allowed us to examine the canalicular/lacrimal sac junction adequately and directly, and despite not having a larger series of bilateral data, we were able to include a significant number of lacrimal systems for analysis in our study. On a separate note, our study did not use an operative microscope for minute dissection of the canalicular anatomy as performed by Orhan et al.[33] We encountered one specimen with 2 canalicular/lacrimal sac orifices. As a result, we do not have a range of data that evaluate the distance between the 2 orifices and whether we may have missed 2 orifices that may have appeared as one under our surgical loupes (×2.5 magnification).

CONCLUSION

Our study provides direct anatomical support that the prevalence of separate upper and lower canalicular openings into the lacrimal sac is lower than previously believed (<1%) and that there is tissue around the canalicular/lacrimal sac representing a CLS-MF in nearly 60% of the specimens. These observations can potentially play a role in evaluating and treating lacrimal system pathology.

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