

# Anatomy of the Lacrimal System

Cat N. Burkat and Mark J. Lucarelli

Successful lacrimal surgery begins with a thorough history and preoperative clinical examination, both of which guide the surgeon to the correct diagnosis and appropriate management. A thorough understanding of the anatomy of the lacrimal system will further facilitate the chance of a successful surgical outcome.

The following components of the lacrimal drainage system anatomy will be discussed in detail:

1. Embryology
2. Osteology
3. Nasal and paranasal sinuses
4. Secretory system
5. Excretory system

## Embryology

Familiarity with lacrimal system embryology is necessary to understand congenital abnormalities of the nasolacrimal drainage system. The orbital walls are embryologically derived from neural crest cells. Ossification of the orbital walls is completed by birth except at the orbital apex. The lesser wing of the sphenoid is initially cartilaginous, unlike the greater wing of the sphenoid and other orbital bones that develop via intramembranous ossification. The membranous bones surrounding the lacrimal excretory system are well developed at 4 months of embryologic age and ossify by birth.

The lacrimal gland begins development at the 22- to 25-mm embryologic stage as solid epithelial buds arise from the ectoderm of the superolateral conjunctival fornix.<sup>1-5</sup> Mesenchymal condensation around these buds forms the secretory lacrimal gland. The early epithelial buds form the orbital lobe in the first 2 months, whereas the secondary buds, which appear later in the 40- to 60-mm stage, develop into the palpebral lobe.<sup>1-3</sup> Canalization of the epithelial buds to form ducts occurs, on average, at the 60-mm stage, but may be seen in as early as the 28.5-mm stage.<sup>1,3,5</sup> The developing tendon of the levator palpebrae

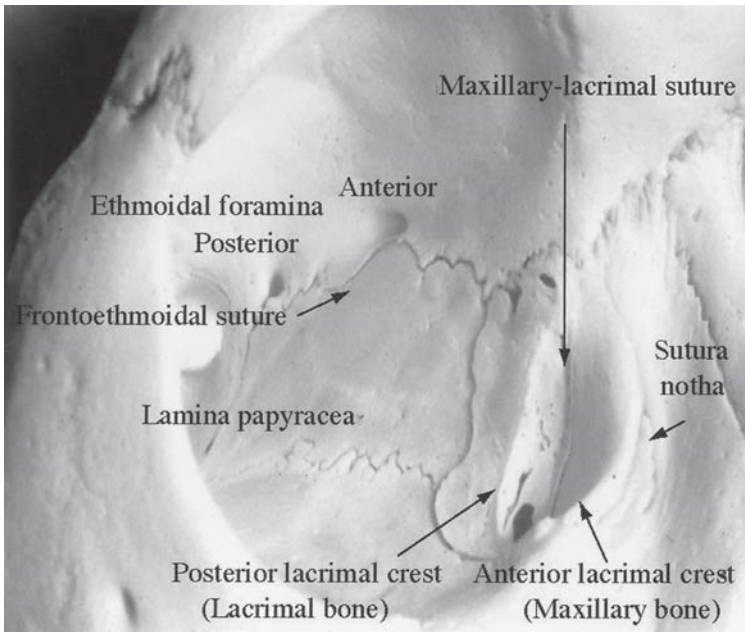
superioris muscle divides the gland into two lobes around the tenth week of development.<sup>1,5</sup> The lacrimal gland continues to develop until 3–4 years after birth.<sup>3</sup>

The excretory system begins its development at an earlier stage. In the 7-mm embryo, a depression termed the naso-optic fissure develops, bordered superiorly by the lateral nasal process and inferiorly by the maxillary process. The naso-optic fissure or groove gradually shallows as the structures bordering it grow and coalesce. Before it is completely obliterated, however, a solid strand of surface epithelium thickens along the floor of the rudimentary fissure extending from the orbit to the nose. The thickened cord of epithelium becomes buried to form a rod connected to the surface epithelium at only the orbital and nasal ends. This separation from the surface typically occurs at 43 days of embryologic age.<sup>6</sup> The superior end of the rod enlarges to form the lacrimal sac, and gives off two columns of cells that grow into the eyelid margins to become the canaliculi.<sup>7,8</sup>

Canalization of this nasolacrimal ectodermal rod begins at the fourth month or the 32- to 36-mm stage of development, proceeding first in the lacrimal sac, the canaliculi, and lastly in the nasolacrimal duct.<sup>7-9</sup> The central cells of the rod degenerate by necrobiosis, forming a lumen closed at the superior end by conjunctival and canalicular epithelium and closed at the inferior end by nasal and nasolacrimal epithelium. The superior membrane at the puncta is usually completely canalized when the eyelids separate at 7 months of gestation, and therefore is normally patent by birth. In contrast, the inferior membrane frequently persists in newborns, resulting in congenital nasolacrimal obstruction.<sup>10-12</sup> Abnormalities of development in this region, occurring typically after the fourth month of gestation, can result in congenital absence of any segment of the nasolacrimal system, supernumerary puncta, and lacrimal fistulae.<sup>6-9,12-15</sup>

## Osteology

Whitnall<sup>16</sup> described the orbital rim as a spiral with its two ends overlapping medially on either side of the lacrimal sac fossa. The medial orbital rim is formed anteriorly by the frontal process of the maxillary bone rising to meet the maxillary process of the frontal bone. The lacrimal sac fossa is a depression in the inferomedial orbital rim, formed by the maxillary and lacrimal bones. It is bordered by the anterior lacrimal crest of the maxillary bone and the posterior lacrimal crest of the lacrimal bone. The fossa is approximately 16-mm high, 4- to 9-mm wide, and 2-mm deep,<sup>16,17</sup> and is narrower in women.<sup>18</sup> The fossa is widest at its base, where it is confluent with the opening of the nasolacrimal canal. On the frontal process of the maxilla just anterior to the lacrimal sac fossa, a fine groove termed the *sutura notha* or *sutura longitudinalis imperfecta* of Weber, runs parallel to the anterior lacrimal crest (Figure 1.1).<sup>16</sup> It is a vascular groove through which small twigs of the infraorbital artery pass through to supply the bone and nasal



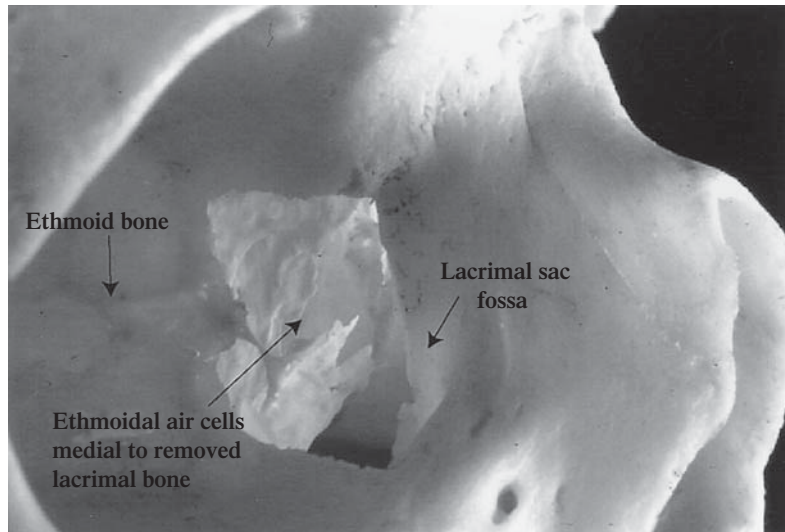
**FIGURE 1.1.** Bony anatomy of the lacrimal sac fossa and medial orbital wall. The anterior and posterior lacrimal crests are formed by the maxillary and lacrimal bones, respectively.

mucosa, and should be anticipated during lacrimal surgery to avoid bleeding.

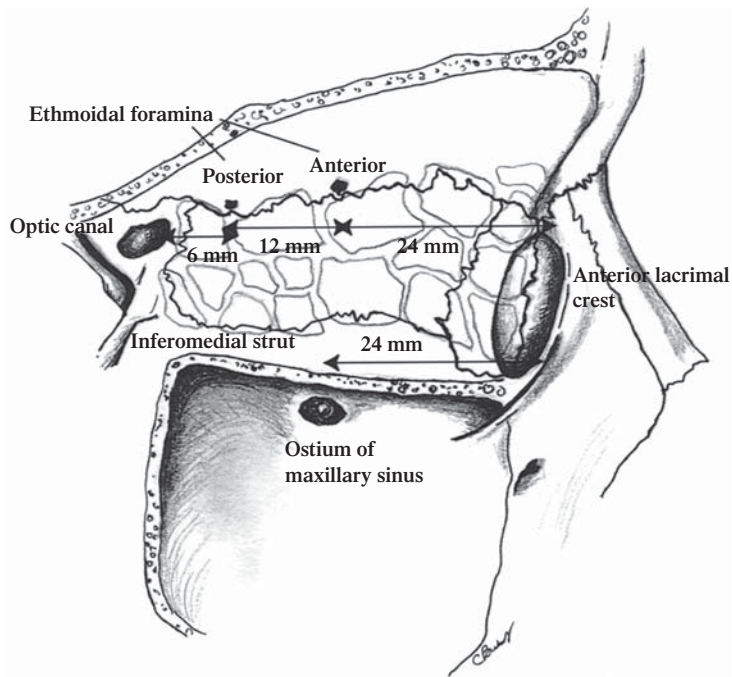
The medial orbital wall is formed, from anterior to posterior, by the frontal process of the maxilla, the lacrimal bone, the ethmoid bone, and the lesser wing of the sphenoid bone. The thinnest portion of the medial wall is the lamina papyracea, which covers the ethmoid sinuses laterally. The many bullae of ethmoid pneumatization appear as a honeycomb pattern medial to the ethmoid bone (Figure 1.2). The medial wall becomes thicker posteriorly at the body of the sphenoid and again anteriorly at the posterior lacrimal crest of the lacrimal bone.

The frontoethmoidal suture is important in orbital bony decompression or lacrimal surgery as it marks the roof of the ethmoid sinus. Bony dissection superior to this suture may expose the dura of the cranial cavity. The anterior and posterior ethmoidal foramina conveying branches of the ophthalmic artery and the nasociliary nerve are located at the frontoethmoidal suture, 24- and 36-mm posterior to the anterior lacrimal crest, respectively (Figure 1.3).<sup>19</sup>

The anterior lacrimal crest is an important landmark during external dacryocystorhinostomy, as the anterior limb of the medial canthal tendon attaches to the anterior lacrimal crest superiorly. This attachment of the medial canthal tendon is often detached from the underlying bone along with the periosteum in order to gain better exposure during surgery.



**FIGURE 1.2.** The ethmoidal air cells are medial to the removed lacrimal bone, and may extend anteriorly to pneumatize the maxillary bone of the lacrimal sac fossa.



**FIGURE 1.3.** Anteroposterior distances of the foramina from the anterior lacrimal crest. The ostium of the maxillary sinus lies approximately in a vertical line to the anterior ethmoidal foramen.

A vertical suture runs centrally between the anterior and posterior lacrimal crests, representing the anastomosis of the maxillary bone to the lacrimal bone (see Figure 1.1). A suture located more posteriorly within the fossa would indicate predominance of the maxillary bone, whereas a more anteriorly placed suture would indicate predominance of the lacrimal bone. The lacrimal bone at the lacrimal sac fossa has a mean thickness of 106 microns, which allows it to be easily penetrated to enter the nasal cavity at surgery.<sup>20</sup> In a patient with a maxillary bone dominant fossa, the thicker bone makes it more difficult to create the osteotomy.

At the junction of the medial and inferior orbital rims, at the base of the anterior lacrimal crest, a small lacrimal tubercle may be palpated externally to guide the surgeon to the lacrimal sac located posterior and superior to it. In 28%–34% of orbits, the tubercle may project posteriorly as an anterior lacrimal spur.<sup>16,21</sup>

The nasolacrimal canal originates at the base of the lacrimal sac fossa, and is formed by the maxillary bone laterally and the lacrimal and inferior turbinate bones medially. The width of the superior opening of the canal measures, on average, 4–6 mm.<sup>16</sup> The duct courses posteriorly and laterally in the bone shared by the medial wall of the maxillary sinus and the lateral nasal wall for 12 mm to drain into the inferior meatus of the nasal cavity.<sup>22</sup>

## Nasal and Paranasal Sinuses

Knowledge of nasal and paranasal sinus anatomy enhances the understanding of surgical relationships to the orbit, and is particularly important in endonasal approaches.

The bones forming the orbital floor, roof, and medial wall are pneumatized by air sinuses arising from the primitive nasal cavities. They retain communication with the nasal cavity and are thus lined by a continuation of the nasal mucous membrane. The sinuses appear in early childhood, increase actively during puberty, and may continue to grow until 30 years of age.<sup>16</sup>

The maxillary sinus is the largest of the paranasal sinuses, measuring 15 cc.<sup>16</sup> The roof of the maxillary sinus forms the orbital floor that declines from the medial wall to the lateral wall at an angle of approximately 30°. The maxillary sinus drains into the hiatus semilunaris within the middle meatus through an ostium located near the level of the orbital floor, immediately inferior to the midlength portion of the maxilloethmoidal orbital strut. The ostium measures, on average, 24 mm from the orbital rim, which is approximately in a vertical line to the anterior ethmoidal foramen in the medial orbital wall (see Figure 1.3).<sup>23</sup>

The ethmoid sinuses are the first to develop, reaching adult configuration at as early as 12 years of age.<sup>24</sup> Ethmoid bullae are particularly exuberant in their expansion, and may pneumatize the orbital plate of

the frontal bone, and even develop as frontal sinuses. The growth of the ethmoid sinuses frequently extends past the suture of the ethmoid bone and even into the lacrimal and maxillary bones of the lacrimal sac fossa (see Figure 1.2).<sup>25,26</sup>

The ethmoid sinuses are shaped like a rectangular box, slightly wider posteriorly where they articulate with the sphenoid sinus. The ethmoid sinuses comprise three main groups – the anterior, middle, and posterior ethmoidal air cells. The anterior and middle ethmoidal air cells drain into the middle meatus, whereas the posterior cells drain into the superior meatus.

The roof of the orbit slopes down as it travels medially, and this slope continues at the frontoethmoidal suture to become the roof of the ethmoid sinus, or *fovea ethmoidalis*. The ethmoid roof continues to slope inferiorly and medially to overlie the nasal cavity as the cribriform plate. The crista galli bisects the cribriform plate on its superior aspect, and continues inferiorly as the vertical nasal plate, or vomer. Because of this sloping, which is most prominent over the anterior ethmoid air cells, it is important to know the individual anatomy and variations before surgery to avoid inadvertent entry into the cranial cavity and cerebrospinal fluid leak, or more severe intracranial injury.<sup>27</sup>

The anatomic relationship of the anterior ethmoid air cells to the lacrimal sac fossa is important to understand before performing dacryocystorhinostomy, in order to avoid confusion between the ethmoid and nasal cavities during creation of the ostium. A close anatomic relationship between the anterior ethmoid air cells, termed the agger nasi cells, to the lacrimal sac fossa has been demonstrated in several past studies.<sup>24–26,28–30</sup> These agger nasi bullae may pneumatize the lacrimal bone, and rarely extend into the frontal process of the maxillary bone.

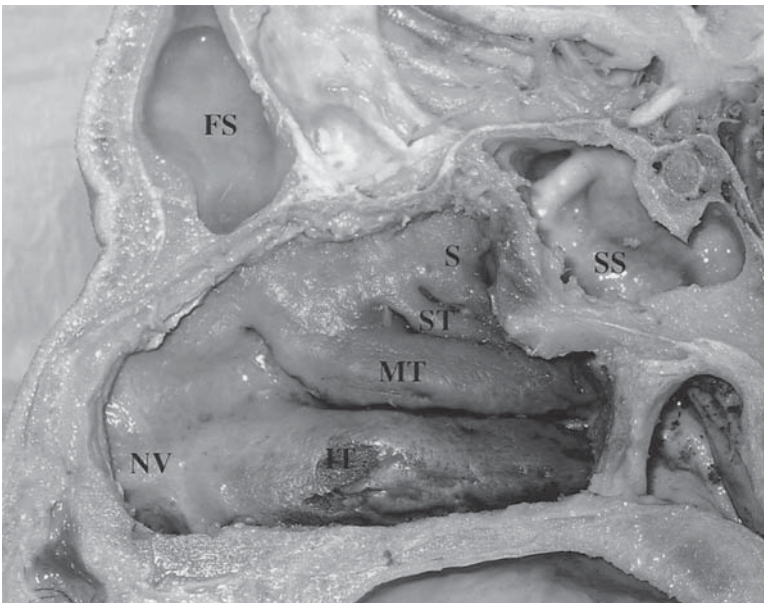
Whitnall<sup>25</sup> described in 1911 the relationship of the anterior ethmoid air cells directly medial to the lacrimal sac fossa in 86% of skulls. In 32% of skulls, the air cells extended anteriorly to the vertical maxillary-lacrimal suture, and in an additional 54%, the air cells extended even farther to the anterior lacrimal crest. The ethmoid cells were located consistently in the superior half of the fossa, with the inferior half of the fossa directly adjacent to the middle meatus of the nasal cavity. Similarly, Blaylock et al.<sup>26</sup> studied computed tomography (CT) scans of 190 orbits with normal ethmoid anatomy and found that in 93% of the orbits, the anterior ethmoid cells extended anterior to the posterior lacrimal crest, with 40% extending anterior to the maxillary-lacrimal bone suture and entering the frontal process of the maxilla. In only 7% of orbits was the nasal cavity directly adjacent to the entire lacrimal sac fossa. The anterior extension of the air cells is most prominent adjacent to the superior half of the lacrimal sac fossa.<sup>24–26,28,30,31</sup>

The ethmoid air cells and sinus mucosa should be removed to allow a proper osteotomy. Understanding the anatomic relationship of the lacrimal sac fossa to the ethmoid sinus also helps avoid complications

such as inadvertent dacryocystorhinostomy fistulization into the ethmoid sinus, cerebrospinal fluid leakage, orbital hemorrhage, and trauma to and subsequent scarring of the nasal mucosa and nasal septum.<sup>32</sup>

The bony nose is formed by the frontonasal process during embryology. The nasal septum bisects the nasal cavity and comprises three portions: the bony perpendicular plate of the ethmoid (superoanterior) and the vomer (posterior and anteroinferior), a cartilaginous anterior triangle, and an inferior membranous columella that divides the nares anteriorly. Laterally, the nasal wall has three or more horizontal ridges termed turbinates, with a corresponding meatus below each (Figure 1.4). During the sixth week of embryologic development, before cartilage forms in the walls of the primitive nasal cavities, linear outgrowths of the lining epithelium occur on the sides and roof of each nasal side. Each outgrowing gutter becomes a meatus, whereas the ridges left behind form the turbinates.<sup>8,16</sup>

The inferior turbinate is the largest, arising from the medial wall of the maxillary sinus. The smaller and more posterior middle, superior, and supreme (if present) turbinates are outcroppings of the ethmoid bone. The supreme turbinate may be found in up to 65% of patients. The inferior turbinate is visualized by directing a nasal speculum parallel to the floor of the nasal cavity. The nasal vestibule is the large

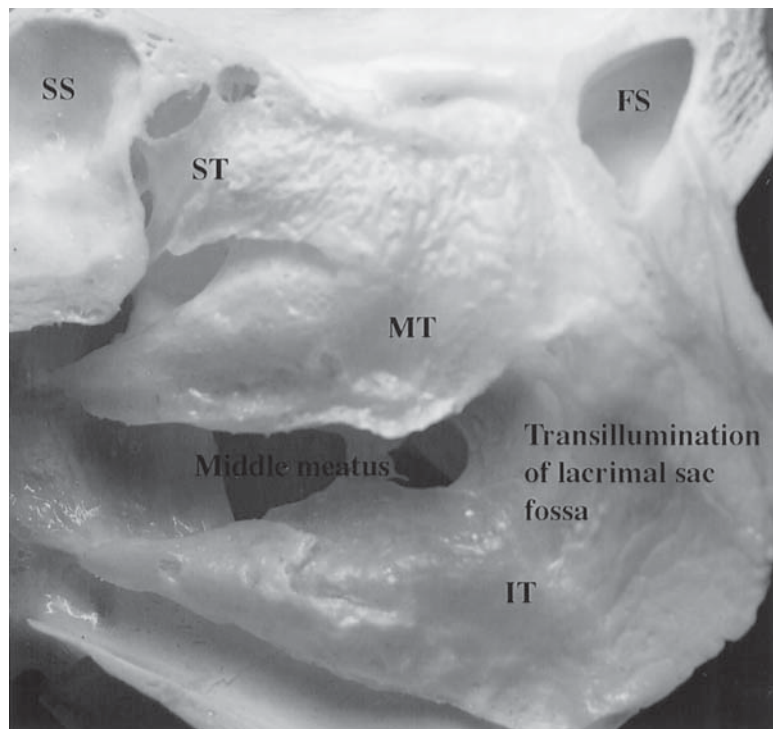


**FIGURE 1.4.** Endonasal sagittal view. Each nasal turbinate has a corresponding meatal space located immediately below. FS, frontal sinus; IT, inferior turbinate; MT, middle turbinate; NV, nasal vestibule; S, supreme turbinate; SS, sphenoid sinus; ST, superior turbinate.

cartilaginous anterior dilatation of the nose above the nares, covered by squamous epithelium with hair follicles, to which the silicone tubes may be secured during surgery.

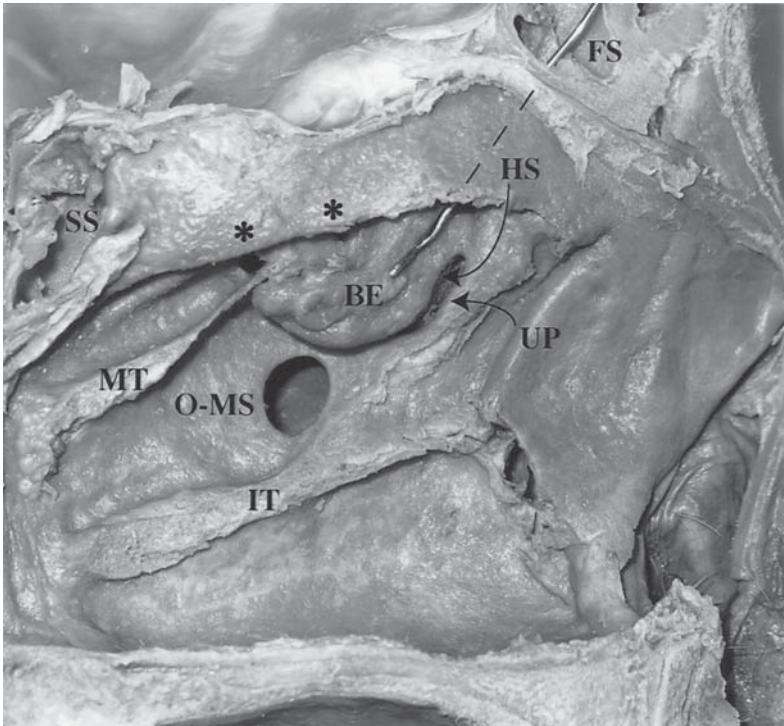
The middle turbinate originates posteriorly from the roof of the nose at the cribriform plate, and arises anteriorly from the medial wall of the maxillary sinus. The lacrimal sac fossa lies anterior and lateral to the anterior tip of the middle turbinate, thus the entry in an external dacryocystorhinostomy is at the anterior tip of the middle turbinate (Figure 1.5). An ostium achieved by the endoscopic approach is usually more inferior to the routine external site.

Within the middle meatus lies a curvilinear gutter, the hiatus semilunaris, which houses the ostium of the maxillary sinus. It is bordered inferiorly by a bony ridge termed the uncinate process, and superiorly by the bulla ethmoidalis prominence which represents the most anterior ethmoid air cells (Figure 1.6).<sup>33</sup> The middle meatus receives the drainage of the ethmoid (anterior and middle), frontal, and maxillary sinuses. The frontonasal duct drains the frontal sinus into the antero-superior portion of the hiatus semilunaris. The posterior ethmoid air cells drain into the superior meatus.



**FIGURE 1.5.** Endonasal site of a dacryocystorhinostomy ostium. Transillumination through the lacrimal sac fossa demonstrates its location at the anterior tip of the middle turbinate. FS, frontal sinus; IT, inferior turbinate; MT, middle turbinate; SS, sphenoid sinus; ST, superior turbinate.





**FIGURE 1.6.** Endonasal view of lateral nasal wall with turbinates removed. BE, bulla ethmoidalis; FS, frontal sinus; HS, hiatus semilunaris; IT, inferior turbinate; MT, middle turbinate; O-MS, ostium of maxillary sinus; SS, sphenoid sinus; UP, uncinate process; \*, ethmoid ostia.

## Secretory System

### Lacrimal Gland and Accessory Glands

The main lacrimal gland is located in the superotemporal orbit in a shallow lacrimal fossa of the frontal bone. The gland is composed of numerous acini that drain into progressively larger tubules and ducts. The acini are made up of a basal myoepithelial cell layer with inner columnar secretory cells. Contraction of the myoepithelial cells helps to force secretions into the tubules and drainage ducts.<sup>34</sup>

The gland measures 20 × 12 × 5 mm and is divided by the lateral horn of the levator aponeurosis into a larger orbital lobe, and a lesser palpebral lobe below.<sup>35,36</sup> The orbital lobe is the larger of the two lobes and lies posterior to the orbital septum and preaponeurotic fat and anterior to the levator aponeurosis.<sup>35</sup> Two to six secretory ducts from the orbital lobe of the lacrimal gland pass through the palpebral lobe or along its fibrous capsule, joining with ducts from the palpebral lobe to form six to 12 tubules that empty into the superolateral conjunctival fornix 4–5 mm above the tarsus.<sup>34,37</sup>

Accessory lacrimal glands are located in the conjunctival fornices and along the superior tarsal border. There are approximately 20–40

accessory glands of Krause in the superior conjunctival fornix, and half that number present in the lower eyelid. Accessory glands of Wolfring are located along the superior tarsal border in the upper eyelid.<sup>35,38</sup>

The lacrimal gland receives innervation from cranial nerves V and VII, as well as from the sympathetics of the superior cervical ganglion.<sup>39</sup> The lacrimal branch of the ophthalmic division of the trigeminal nerve carries sensory stimuli from the lacrimal gland. The lacrimal gland receives arterial supply from the lacrimal artery, with contributions from the recurrent meningeal artery and a branch of the infraorbital artery. The venous drainage follows approximately the same intraorbital course of the artery and drains into the superior ophthalmic vein.

The course of the parasympathetic secretomotor innervation to the lacrimal gland is more complex. Parasympathetic secretomotor fibers originate in the lacrimal nucleus of the pons. These fibers travel a long course within the nervus intermedius, the greater superficial petrosal nerve, the deep petrosal nerve, and the vidian nerve to finally synapse in the pterygopalatine ganglion.<sup>34</sup> Postganglionic parasympathetic fibers leave the pterygopalatine ganglion via the pterygopalatine nerves to innervate the lacrimal gland.<sup>40,41</sup> In addition, some fibers may join the zygomatic nerve as it branches from the maxillary division of the trigeminal nerve and enters the orbit through the inferior orbital fissure. Branches of the zygomatic nerve may ascend and enter the posterior surface of the lacrimal gland either alone or in combination with the lacrimal nerve.<sup>35</sup> However, in a more recent anatomic study by Ruskell<sup>42</sup> in 2004, he found that parasympathetic fibers traveled along a branch of the middle meningeal artery through the superior orbital fissure before joining the ophthalmic or lacrimal artery to supply the lacrimal gland. This was in contrast to the traditional assumption that secretomotor nerves pass to the gland via the zygomatic and lacrimal nerves.

Sympathetic nerves arrive with the lacrimal artery and along with parasympathetics in the zygomatic nerve. The zygomatic branch of the maxillary trigeminal nerve gives off the lacrimal branch before dividing into zygomaticotemporal and zygomaticofacial branches. This lacrimal branch anastomoses with the lacrimal nerve of the ophthalmic trigeminal nerve or travels along the periorbita to independently enter the gland at its posterolateral aspect.

## Excretory System

### Lacrimal Drainage System

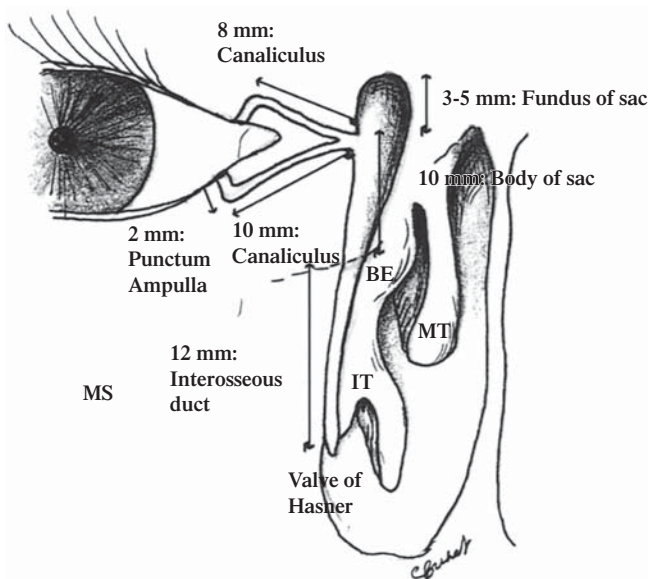
The lacrimal excretory pathway begins at a 0.3-mm opening on the medial portion of each eyelid termed the punctum.<sup>16,37</sup> Because of more rapid growth of the maxilla compared with the frontal bone during embryologic development, the lateral migration pulls the inferior canaliculus laterally, resulting in the lower eyelid punctum being located slightly lateral to the upper eyelid punctum.<sup>8</sup> The punctal opening widens into the ampulla, which is 2 mm in height and directed perpendicular to the eyelid margin, before making a sharp turn into the

canaliculi. The canaliculi measure 8–10 mm in length and 0.5–1.0 mm in diameter, and course parallel to the eyelid margins (Figure 1.7). The canaliculi are lined with stratified squamous epithelium and surrounded by orbicularis muscle.

In more than 90% of individuals, the superior and inferior canaliculi merge to form a common canaliculus before entry into the nasolacrimal sac.<sup>37,43</sup> In a large study using digital subtraction dacryocystograms, the common canaliculus was present in 94% of lacrimal drainage systems. The upper and lower canaliculi joined at the wall of the lacrimal sac without a common canaliculus in an additional 4%, with only 2% of systems having completely separate drainage of the upper and lower canaliculi into the lacrimal sac.<sup>44</sup> The common internal punctum visualized within the lacrimal sac should be free of any mucosal membrane or stricture for success of the dacryocystorhinostomy surgery.

The functional valve between the common canaliculus and the lacrimal sac has traditionally been attributed to the valve of Rosenmüller, although some studies have been unable to document this structure.<sup>6</sup> Tucker demonstrated a consistent pattern of angulation within the canalicular system.<sup>45</sup> The canaliculi first angle posteriorly behind the medial canthal tendon. The canaliculi then bend at the canaliculus–common canaliculus junction at an angle of  $118^\circ$ , before passing anteriorly to enter the lacrimal sac at an acute angle of  $58^\circ$ . This consistent angulation may contribute to a valve-like effect that prevents retrograde flow from the lacrimal sac.

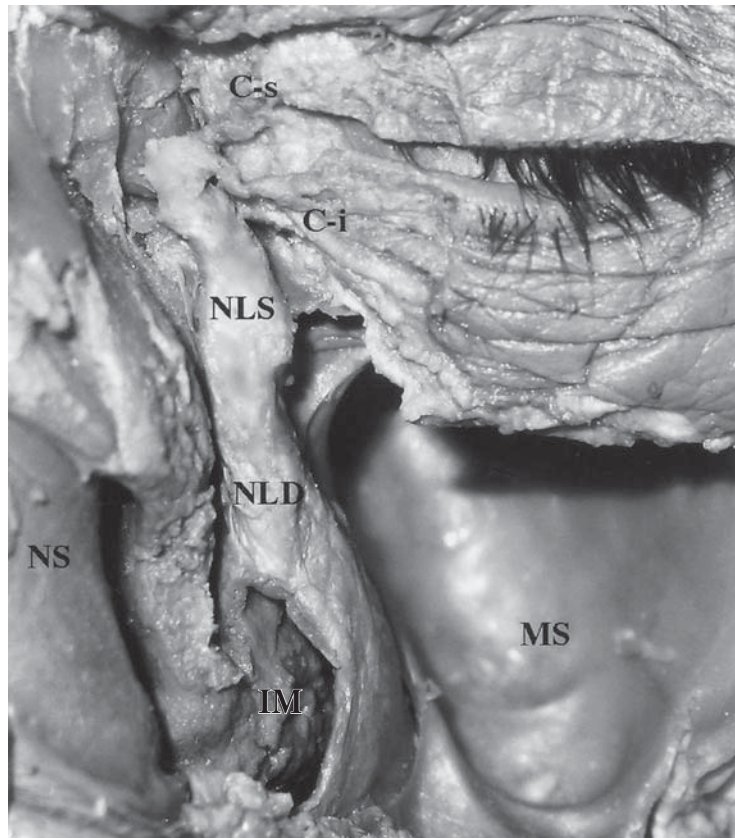
The nasolacrimal sac and duct are portions of the same continuous structure (Figures 1.7 and 1.8). The lacrimal drainage system is lined



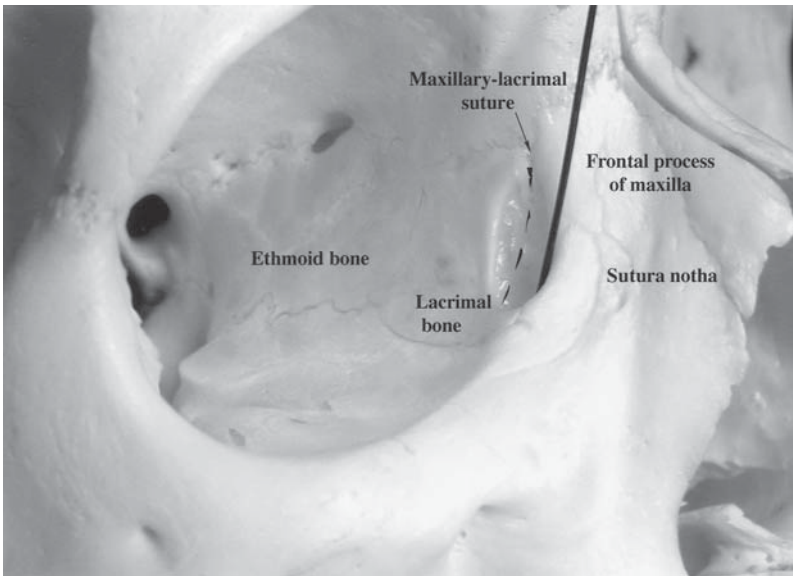
**FIGURE 1.7.** Approximate dimensions of the lacrimal excretory system. BE, bulla ethmoidalis; IT, inferior turbinate; MS, maxillary sinus; MT, middle turbinate.

by nonciliated columnar epithelium. The total sac measures a length of 12–15 mm vertically and 4–8 mm anteroposteriorly. The fundus of the sac extends 3–5 mm above the medial canthal tendon, and the body of the sac measures 10 mm in height.<sup>37</sup> The sac rests in the lacrimal sac fossa, with its medial aspect tightly adherent to the periosteal lining of the fossa. The lower nasolacrimal fossa and the nasolacrimal duct are narrower in females, which may account for the female predominance of nasolacrimal obstruction.<sup>18</sup> The nasolacrimal duct then travels inferolaterally and slightly posteriorly in its bony course to the inferior turbinate for an interosseous distance of 12 mm. The long axis of the duct and canal forms an angle of 15–25° posterior to the frontal plane, or in a line connecting the medial commissure to the first molar tooth (Figure 1.9).<sup>16</sup>

Wormald et al.<sup>46</sup> used CT dacryocystograms to evaluate the relationship of the lacrimal sac to the insertion of the middle turbinate on the lateral nasal wall in 76 patients. The mean height of the lacrimal sac



**FIGURE 1.8.** Anatomic dissection of the lacrimal drainage system within the bony wall between the nasal cavity and maxillary sinus. The nasolacrimal duct drains into the inferior meatus. C-i, inferior canaliculus; C-s, superior canaliculus; IM, inferior meatus; MS, maxillary sinus; NLD, nasolacrimal duct; NLS, nasolacrimal sac; NS, nasal septum.



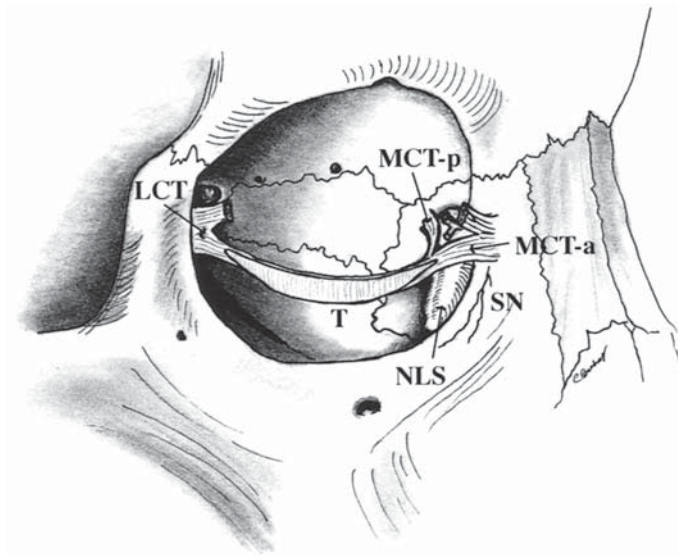
**FIGURE 1.9.** The nasolacrimal duct travels inferolaterally and slightly posteriorly in its bony course to the inferior turbinate, forming an angle of approximately 15–25° posterior to the frontal plane.

above the middle turbinate insertion was measured to be 8.8 mm and below it was 4.1 mm.

Multiple mucosal folds and sinuses have been reported within the lacrimal drainage system, although their role and presence are unclear. The previously mentioned valve of Rosenmüller is located at the junction of the common canaliculus and sac, and the valve of Krause between the sac and duct. A mucosal flap, Hasner's valve (or *plica lacrimalis*), may be present at the opening of the duct into the inferior meatus of the nose.<sup>47</sup> The nasolacrimal duct ostium within the inferior meatus is located 25–30 mm posterior to the lateral margin of the anterior nares.<sup>16</sup>

The inferior oblique muscle arises from a shallow depression in the orbital plate of the maxilla at the anteromedial corner of the orbital floor just lateral to the lacrimal excretory fossa.

The canaliculi are encased in superficial pretarsal orbicularis oculi muscle as they traverse the medial eyelids and medial canthal region. The lacrimal sac is ensheathed in the lacrimal fascia, which refers to the periorbital lining that splits at the posterior lacrimal crest into one layer that lines the fossa, and another layer that encases the lateral sac to reach the anterior lacrimal crest. Additionally, the lacrimal sac is wrapped by the thick anterior and thin posterior limbs of the medial canthal tendon. Almost immediately after the medial canthal tendon arises from the tarsal plates, it divides into a thicker anterior limb that wraps along the anterior upper half of the lacrimal sac before inserting onto the anterior lacrimal crest, and a very thin posterior limb that passes behind the sac to insert onto the posterior lacrimal crest (Figure 1.10). The deep portion of the pretarsal orbicularis muscle important



**FIGURE 1.10.** Relationship of the medial canthal tendon to the lacrimal sac. The thick anterior limb of the medial canthal tendon wraps along the anterior upper half of the lacrimal sac to insert onto the anterior lacrimal crest, whereas the thin posterior limb passes behind the sac to insert onto the posterior lacrimal crest. LCT, lateral canthal tendon; MCT-a, medial canthal tendon-anterior limb; MCT-p, medial canthal tendon-posterior limb; NLS, nasolacrimal sac; SN, suture notha; T, tarsus.

in lacrimal outflow (Horner-Duverney muscle, *tensor tarsi*, or *pars lacrimalis*) passes posterior to the lacrimal sac and the posterior limb of the medial canthal tendon, and inserts onto the upper posterior lacrimal crest.<sup>7,16,37,48</sup> The orbital septum inserts along or just posterior to the inferior posterior lacrimal crest.

Creation of a large osteotomy helps to increase the chance of success of dacryocystorhinostomy surgery. As much as one-third of the lacrimal sac may lie above the medial canthal tendon; therefore, to create an adequate osteotomy for apposition of the entire lacrimal sac and nasal mucosa, the osteotomy should extend superior to the level of the medial canthal tendon. Bone may be removed with the rongeur until thickening of the frontal bone is noted. This point should generally lie 5mm or more above the common internal punctum.

Slightly above the level of the medial canthal tendon lies the anterior cranial fossa. Botek and Goldberg<sup>49</sup> found that the oblique distance between the common internal punctum and the most anterior aspect of the cribriform plate was  $25 \pm 3$ mm. Using a retrospective study of coronal maxillofacial CT scans from 40 adults, McCann and Lucarelli<sup>50</sup> found that the mean vertical dimension between the medial canthal ligament and the level of the cribriform plate was  $17 \pm 4$ mm.

The angular artery branch of the facial artery runs along the line of the nasojugal skinfold and passes superficial to the medial canthal

tendon. The angular vein courses immediately lateral to the artery, with both vessels located approximately 5mm anteromedial to the anterior lacrimal crest, or 8mm medial to the medial commissure of the eyelids.<sup>16</sup>

### Lacrimal Pump

Jones<sup>7,37</sup> popularized the lacrimal pump theory, in which he proposed that contraction of the pretarsal orbicularis muscle fibers during eyelid closure compresses and shortens the canaliculi, pumping tears toward the lacrimal sac. Furthermore, simultaneous lateral movement of the lateral lacrimal sac from contraction of the deep head of the preseptal orbicularis muscle was thought to generate a negative pressure within the lacrimal sac that draws tears into the sac from the canaliculi. In contrast, other anatomic and physiologic studies<sup>48,51-55</sup> have found that a positive-pressure mechanism, rather than a negative-pressure mechanism, is responsible for the lacrimal pump during eyelid closure. Thale used histological, immunohistochemical, and scanning electron microscopic techniques to demonstrate that the wall of the lacrimal sac is composed of collagen, elastic, and reticular fiber bundles arranged in a helical pattern. He proposed that the lacrimal sac distends and is pulled superolaterally because of its medial attachments when the lacrimal orbicularis muscle contracts with blinking. In addition, the helical collagen and elastic fibers encircling the sac may result in the sac being “wrung out” as another proposed mechanism for lacrimal drainage.<sup>56,57</sup>

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