SURGICAL ANATOMY OF THE OCULAR ADNEXA
Ophthalmology Monographs

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David R. Jordan
Louise Mawn
Richard L. Anderson
I am pleased to write the foreword to this text, *Surgical Anatomy of the Ocular Adnexa*. What should be included in a valuable anatomy book written for surgeons? How about:

- A concise description of the clinical anatomy
- An correlation of how the anatomy relates to the pathophysiology of the disorders we see daily
- How surgical manipulation of the anatomy can correct an abnormality

This information is exactly what Dr. Jordan outlined in his preface to this text. You, as a reader and surgeon, will be happy to see that David and his coauthors, Louise Mawn and Rick Anderson, have provided this information and more.

Why is a new anatomy text important? After all, anatomy hasn’t changed for millennia. Anatomy, of course, is the foundation of our surgical practices. As unchanging as anatomy is, the pertinent complexities of the periorbital and facial anatomy change as we ask new and more detailed questions about existing clinical problems and face new clinical challenges. For example, the recent descriptions of the osseo cutaneous ligaments of the face have given us a new understanding of the lid cheek junction improving lower blepharoplasty results. Work on the motor innervation of the eyelid has explained why the standard external DCR incision can decrease blinking in the early post operative course. As we learn to develop new clinical tools and techniques, areas of less traditional anatomic interest become more important. Prior to botulinum toxin, there was not much interest in learning the anatomy of the glabella including the individual contributions of the eyebrow elevators and depressors. As the field of ophthalmic plastic surgery evolves, new areas of clinical interest are developed, such as the facial cosmetic surgery and complex skull base procedures. The authors have nicely incorporated these anatomic areas in the text making the anatomy and clinical correlates accessible and applicable to all readers.
I am pleased to say that each of the authors is a friend, a colleague and a mentor. The authors share common traits:

- Passion for their work
- Curiosity and innovative spirit
- Active incorporation of scholarly work into busy clinical practice
- The generosity to share their experience and skill with others

We can all benefit from emulating these ideals in becoming better clinicians and scholars.

Each of us has our own style of learning. With a densely packed text such as this, I prefer to skim the text to get a feel for the content and the organization. I will go back to an area that I am interested in, or perhaps start again from the beginning reading a section several times over a period of a few days. I like to learn in layers, making sure that I have the overall principles in mind before moving into the details. For me, this technique works especially well for anatomy. Finally, I might follow up on the suggested readings for other details. Whatever your style of learning, you will benefit from a study of this text.

Congratulations to the Drs Jordan, Mawn and Anderson on an excellent book that will be of great use to clinicians for years to come.

Jeffrey A. Nerad
A
n appreciation of the anatomy of the eyelid, orbit, nasolacrimal system, and periocular region
is essential to an understanding of the wide variety of diseases and conditions that occur in
these areas. The second edition of this monograph is organized into seven chapters highlight-
ing the major adnexal structures and systems. In each chapter, there are drawings of important
areas to help the reader conceptualize the anatomy. These are supplemented with cadaver photo-
graphs to illustrate a more lifelike situation. Salient anatomic features are correlated to real clinical
situations in succinct vignettes entitled “Clinical Application.”

The educational objectives of the monograph are as follows:

- develop a thorough understanding of the anatomy in the eyelid, orbit, nasolacrimal, and
  periocular regions;
- foster an appreciation of how knowledge of the anatomy leads to a better understanding of
  the pathophysiology of various disease processes involving the eyelid, orbit, nasolacrimal,
  and periocular regions; and
- convey the importance of anatomy in the surgical approach to various disease processes in
  the eyelid, orbit, nasolacrimal, and periocular regions.

David R. Jordan, M.D.
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The authors wish to acknowledge their appreciation of the efforts of many persons who contributed to the development and production of the monograph, including editors Catherine Barnes and Catharine Carlin. Special thanks for the tireless efforts of Tim Hengst for providing all of the outstanding illustrations. Gratitude is extended to the late A. Gardner Watson, M.D. (1918–2003), who provided anatomic dissection notes that he had accumulated during his distinguished career. Dr. Watson organized these notes into a dissection manual for ophthalmology residents, which has been in use at the University of Ottawa for more than 45 years and which formed the basis for the first edition of this manual. Appreciation is expressed to my co-authors (Louise Mawn and Rick Anderson) for their chapter contributions and editorial comments, as well as to the ophthalmology residents at the University of Ottawa for their cadaver dissections; the photographs in this monograph are a product of those dissections. Special thanks for the inspiration offered by the late Dr. Ronald E. Jordan (1931–1994) for suggesting a pathway in medicine and ophthalmology. Tremendous gratitude is extended to Dr. D. Tse, Dr. J. Nerad, and Dr. R. Anderson for sharing their knowledge and skills in oculoplastics surgery during my fellowship years and for providing so much encouragement. Last but not least, the hours upon hours of editing, re-editing, updating, and reorganizing this monograph over 12 months could not have been carried out without the never-ending support of my dear spouse, Judith Allen.
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This book is dedicated to my spouse, Judith Allen, without whose support it could never have been written; to my children, Ryan, Jeff, and Tyler, who have had less of my attention because of it; and to my parents, Ronald and Wilona Jordan.
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SURGICAL ANATOMY OF THE OCULAR ADNEXA
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Numerous oculoplastic surgical procedures are performed on the forehead, eyebrows, eyelids, and canthi. An understanding of the anatomy of these structures, as well as of the nearby temporal artery and facial nerve, is essential for the surgeon working in this region. In this chapter, the surface anatomy is described first, followed by a more detailed description of the tissue beneath.

1–1 FOREHEAD

The skin of the forehead and cranium, or the “scalp,” is traditionally considered as five layers (Fig. 1-1): skin, subcutaneous tissue, galea aponeurosis, loose areolar tissue, and periosteum. These layers are present consistently throughout the head, with some slight modifications in certain areas (e.g., the brow area). These layers can be easily remembered with the mnemonic “SCALP” (S = skin, C = subcutaneous tissue, A = galea aponeurotica, L = loose areolar tissue, P = pericranium). The skin of the forehead and temporal region is usually relatively thick and rich in sebaceous glands. However, in some elderly individuals the skin of the temporal forehead can be quite thin and consequently requires a greater degree of care during surgical procedures (e.g., endobrow lift) and resurfacing (e.g., laser or chemical).

1–1–1 Eyebrows

Although the eyebrows are technically part of the scalp rather than of the eyelids, they have important functional and surgical relationships to the lids. The eyebrows lie at the junction between the upper eyelids and the forehead. They lie over each superior orbital rim, are separated by the glabella, and are formed by thick, strong, skin-bearing hairs. The underlying muscle fibers, with
their cutaneous insertions, move the brows freely over a suborbicularis fat pad adjacent to the underlying periosteum.

Each brow has a head, a body, and a tail. The head lies between the supraorbital ridge and the orbital margin, overlying the frontal sinus. The medial brow hairs are almost vertical; the body of the brow follows the supraorbital margin and has hair in a more horizontal direction (Fig. 1-2). The tail overlies the lateral angular process of the frontal bone and might extend to the zygomatico-frontal suture. The brow varies in width, generally being widest nasally and narrowest laterally. The brow height is generally at the level of the superior orbital rim (or slightly below it) in men and just above the superior orbital rim in women. A male brow is characteristically flatter than a female brow. The highest point of the brow (the brow arch) is approximately the lateral limbus in males and females, but it is higher and more defined in the female than in the male. Women usually prefer thinner, more arched brows and will remove or pluck the hairs in order to obtain this appearance, whereas men’s brows are straighter and thicker in most individuals.

The brows are functionally and cosmetically important structures. They serve to shade the eyes from strong light and to divert sweat from running into the eyes. The mobility of the brow is an important component of facial expression.

The brows are composed of several layers that vary slightly from the SCALP mnemonic discussed earlier as a result of muscle interdigitation, division of the galea into several layers, and a brow fat pad. The brow layers include skin, muscle, fat, aponeurosis (galea), and periosteum (also called pericranium). The skin of the eyebrow has numerous hair follicles, sebaceous glands, and sweat glands. The muscle layer of the brow is a composite of five muscle groups: frontalis, procerus, corrugator supercili, depressor supercili, and orbicularis. These muscle fibers interdigitate in the brow area and are responsible for moving the brow into its many different positions. The galea splits in the brow area to encase not only the frontalis muscle but also a brow fat pad located over the temporal brow area (Fig. 1-3A).
Clinical Application

- Brow lift procedures can be carried out through a trans-blepharoplasty route, directly above the brow hair (direct brow lift), through one of the prominent horizontal forehead lines (mid-forehead lift), along the temporal hairline (temporal hairline lift), through an endoscopic approach (endobrow lift) through five small incisions along the hairline and temple area, or via a coronal incision (not as commonly performed since endoscopic techniques came out).
- The orientation of the brow hair is important to note during a direct brow lift. Skin incisions made perpendicular to the skin surface might transect some lash follicles, resulting in a loss of brow hair and exposure of the scar. The skin incision should be made parallel to the orientation of the brow hair.
- During the repair of brow lacerations, the brow hair orientation can be used to help orient and align the laceration margin.

1–1-2 Forehead Musculature and Galea Aponeurotica

The forehead musculature is made up of one elevator, the frontalis, and four depressors: the procerus, the corrugator supercilli, the depressor supercilli, and the orbicularis oculi. If each of the four depressors were neutralized, the frontalis would be unopposed, and the result would be brow elevation.

FRONTALIS MUSCLE AND GALEA APONEUROTICA

The vertically oriented frontalis muscle arises from the galea aponeurotica, which splits to lie anterior and posterior to the frontalis muscle. As the frontalis approaches the brow, it interdigitates
Surgical Anatomy of the Ocular Adnexa

with the orbicularis muscle and the corrugator supercili. The frontalis muscle has a cutaneous
insertion but no bony insertion (Fig. 1-3A, 1-3B). It is responsible for the horizontal forehead
lines seen in the mid-forehead region when someone raises his or her brows. It is innervated by the
frontal (temporal) branch of the facial nerve.

It is important to remember that the galea extends anteriorly with the frontalis muscle and
posteriorly with the occipitalis muscle. Temporally, the galea extends as the superficial temporalis

![FIGURE 1-3 Brow and upper lid anatomy. (A) The frontalis muscle has a cutaneous insertion but no bony
insertion. The galea is present anterior and posterior to the frontalis. Temporally, there is a brow fat pad that
allows for mobility of the temporal brow and which also has galea anterior and posterior to it. (B) Vertically
oriented fibers of the frontalis extend downward to meet the orbicularis muscle. Medially, it blends in with
the procerus muscle (black arrow). The superficial temporal artery is readily seen (white arrow).]
fascia (also known as the temporoparietal fascia) and lies superficial to the deep temporal fascia or temporalis fascia proper. In the mid- and lower face, the superficial temporal fascia layer is in continuity with the superficial musculoaponeurotic system (SMAS), which is continuous with the platysma in the neck. Depending upon where one is dissecting, different names are used for the galeal layer. Thus, in the temporal region, although the galea continues as the superficial temporal fascia (the temporoparietal fascia), we refer to it as one of these latter names rather than as the galea.

PROCERUS MUSCLE

The procerus muscle originates from the fascia that covers the inferior portion of the nasal bones (see Fig. 1-4). It inserts into the skin between the eyebrows in the glabellar region. As it courses superiorly, the fibers become continuous with the fibers of the medial frontalis muscle. The procerus muscle resides in the same plane as the frontalis muscle. It may be innervated by the frontal (temporal) branch of the facial nerve, or by a branch originating from a zygomatic-buccal branch of the facial nerve via the lower eyelid and medial canthus. Contraction of the procerus muscle causes horizontal glabellar rhytids over the root of the nose. Transection or extirpation of this muscle during endoscopic forehead surgery decreases these glabellar rhytids and assists with the brow lift by allowing unopposed frontalis action.

CORRUGATOR SUPERCILII MUSCLE

The corrugator supercilii muscle arises from the periosteum of the superomedial orbital rim, where it lies deep to the frontalis and the orbicularis muscle. The muscle is usually located between 1.7 and 2.7 cm lateral to the midline of the glabella. It travels obliquely, superiorly, and laterally,
where fibers travel more superficially to interdigitate with fibers of the orbicularis and frontalis. After travelling “through” the frontalis, it inserts into the dermis of the medial brow skin (Fig. 1-4).

Some authors feel that there are two separate heads to the corrugator—a transverse head and an oblique head. The transverse head of the corrugator originates from the medial aspect of the superior orbital rim and inserts into the dermis just superior to the middle third of the eyebrow. The oblique head of the corrugator and the depressor supercilii muscle originate from the superior portion of the medial orbital rim and share a parallel course leading to their insertion into the dermis under the medial eyebrow. The transverse head is innervated by the frontal (temporal) branch of the facial nerve, and the oblique head and depressor supercilii are innervated by a zygomatic-buccal branch of the facial nerve via the lower eyelid and medial canthus. In some patients, the innervation of the corrugator can be entirely via the lower lid zygomatic-buccal branch of the facial nerve.

Contraction of the corrugator muscle pulls the eyebrow medially and inferiorly, producing vertical and oblique glabellar folds, best seen when a person is concerned or angry. Because the oblique head has not been commonly recognized, the transverse head has been generally conceptualized as constituting the entire corrugator supercilii muscle. However, each head of the corrugator is thought to have a separate action on the glabellar skin, and each head appears to have a different source of motor nerve supply. Contraction of the transverse head of the corrugator moves the eyebrow medially and not only produces vertical glabellar skin creases but also contributes to the oblique glabellar skin creases. Contraction of the oblique head depresses the medial brow, as do the depressor supercilii and the medial head of the orbital portion of the orbicularis oculi. The combined action of these three muscles produces more pronounced oblique glabellar skin lines.

Clinical Application

- Botulinum toxin injection into the corrugator and procerus muscles will significantly decrease the vertical and oblique glabellar furrows as a result of knocking out the innervation to these muscle groups. In addition, the brows tend to elevate, as the major brow depressors have been weakened. The patients lose their angry or concerned look and have a more pleasant (but natural) appearance.
- Most migraine headaches have been theorized to be related to irritation, entrapment, and/or compression of peripheral nerve trigger points. The supraorbital and supratrochlear nerves have been implicated as the frontal trigger sites. This theory has been supported in part by the fact that improvement in symptoms has been demonstrated in a significant proportion of patients after chemodenervation of the corrugator supercilii muscle by botulinum toxin. Resection of the corrugator is another treatment option and gives complete or significant amelioration of migraine headaches in 80% of patients.
- Care must be taken when surgically weakening the corrugators, either during endoscopic brow elevation or through a more direct eyelid approach, to preserve the supraorbital and supratrochlear nerves and prevent loss of sensation in the forehead region. The forehead sensory area of the supraorbital nerve almost always overlaps that of the supratrochlear nerve. Transection of some of the fine branches of the supratrochlear nerve is usually temporary (eight weeks) as a result of the overlap and some regeneration.
MEDIAL SUPERIOR PORTION OF ORBICULARIS OCULI MUSCLE (MEDIAL HEAD OF THE ORBITAL PORTION OF THE ORBICULARIS OCULI)

The medial superior portion of the orbicularis oculi or medial head of the orbital portion of the orbicularis oculi muscle arises from the frontal bone (medially) and the medial canthal tendon. These fibers are superficial to the corrugator supercili and depressor supercili and insert into the dermis under the medial brow after interdigitating with fibers of the frontalis. They act primarily as medial brow depressors and can be innervated by the frontal (temporal) branch of the facial nerve or by a branch originating from a zygomatic-buccal branch of the facial nerve via the lower eyelid and medial canthus.

DEPRESSOR SUPERCILI MUSCLES

The depressor supercilli muscle has been recognized since the early 1900s and is distinct from the corrugator supercili muscle and the medial orbicularis oculi muscle. It acts as another one of the medial brow depressors. The depressor supercili muscle fibers are redder in color than the nearby orbicularis fibers and arise from the frontal process of the maxilla approximately 1 cm above the medial canthal tendon (slightly posterior and superior to the posterior lacrimal crest; see Fig. 1-4). The origin is slightly inferior to the point of origin of the oblique head of the corrugator supercili muscle on the orbital rim. It travels superiorly to insert into the dermis under the medial brow. Along its course superiorly the depressor supercili muscle belly will pass over the origin of the oblique head of the corrugator supercili muscle. The oblique head of the corrugator supercili muscle has a course almost parallel to that of the depressor supercili muscle, and it inserts into the medial eyebrow dermis near the insertion point of the depressor supercili muscle (but slightly medial to it). The procerus muscle is located medially to the depressor supercili muscle, the oblique head of the corrugator, and the medial head of the orbicularis oculi muscles (see Fig. 1-4). The depressor supercili might be supplied by the frontal (temporal) branch of the facial nerve or by a branch of the facial nerve originating from the zygomatic-buccal branch of the facial nerve via the lower eyelid and medial canthus.

Clinical Application

- Recent anatomic studies have provided a more detailed understanding of the facial nerve distribution of the eyelids and the periorbital region, which are important to know about when doing surgery in the medial canthus area (e.g., external dacryocystorhinostomy [DCR] surgery). Superficial buccal branches of the facial nerve might not only supply the levator labii superioris, the lower medial eyelid portion of the orbicularis oculi, and the levator labii superioris alaequi nasi, but might also course superiorly over the medial canthal tendon with the angular artery to innervate the upper medial eyelid portion of the orbicularis, the depressor supercili, the inferior portion of the procerus, and the medial corrugator supercili. Other studies have found that zygomatic and buccal branches of the facial nerve coalesce in the lower medial eyelid to form what some
authors have termed the “angular nerve,” which tracks superiorly to supply the same muscles. Thus, in some individuals, the upper eyelid medial orbicularis, depressor supercilii, procerus, and oblique head of the corrugator supercilii muscles might be supplied purely by a zygomatic branch of the facial nerve via the lower medial eyelid; in others the zygomatic branch is accompanied by a buccal branch of the facial nerve (angular nerve), and in still others the motor innervation to the medial upper eyelid orbicularis, medial corrugator, depressor supercilii, and procerus is entirely via the superficial buccal branch of the facial nerve.

- The external DCR incision and dissection may be situated in the path of these medial-coursing branches of the zygomatic and buccal nerves. The disruption of these nerve fibers, whether from surgical traction or thermal injury from cautery, results in abnormal eyelid closure. A decreased blink rate, lagophthalmos and tearing secondary to reflex tearing, and/or a decreased pump function might occur with injury to these branches and take three or more months to resolve. Supportive care using artificial tears and lubricating ointment should be used in the interim. Furthermore, in cases of suspected early surgical failure or persistent tearing after external DCR surgery, lacrimal pump dysfunction secondary to orbicularis weakness should be considered, and repeat surgery should be avoided until the recovery of nerve function.

1–1-3 Brow Motility and the Brow Fat Pad

As the galea heads toward the orbital rim, it splits to form a thin, superficial layer over the frontalis muscle and a deeper, more well-defined layer passing beneath the muscle that attaches firmly to the supraorbital margin (Fig. 1-3A). The superficial aponeurotic covering and the cutaneous insertion of the frontalis muscle allow the eyebrow to move readily with various facial expressions.

Also contributing to brow motility is a submuscular fibroadipose tissue layer (brow fat pad), which develops within a split in the posterior galeal aponeurotic layer at the brow level. The anterior portion of this posterior galeal layer (which also lies adjacent to the posterior surface of the frontalis and orbicularis muscles) forms the anterior boundary of the eyebrow fat pad. The posterior layer of this posterior galeal layer forms the posterior boundary of the fat pad (Fig. 1-3A), lies adjacent to the periosteum (pericranium), and is firmly attached to this portion of the supraorbital margin. This posterior layer of the posterior galea also continues into the eyelid and contributes to the formation of the superior orbital septum. This submuscular fibroadipose tissue layer, or eyebrow fat pad (also known as the retro-orbicularis oculi fat, or ROOF), extends superiorly above the superior orbital rim, remains posterior to the muscular layer of the eyebrow (orbicularis/frontalis), and might extend into the upper eyelid anterior to the orbital septum (Fig. 1-3A). It consists of loose fibrous septa, with the interseptal spaces filled by fat. The frontal bone attachment of the posterior galea on the underside of the brow fat pad allows for a vertical sliding movement in the overlying skin and muscles of the eyebrow anterior to this fatty layer. Thus, the fat layer in the eyebrow separates the muscle of the eyebrow from the posterior galeal layer, periosteum (pericranium), and bone in the area of the orbital rim and enhances brow mobility. It is important to
differentiate the ROOF from fat located immediately anterior to the muscle layer, which is simply subcutaneous fat, as well as from the fat located immediately posterior to the orbital septum (the preaponeurotic fat).

Clinical Applications

- Eyebrow ptosis is commonly seen as an involutional change, as well as in patients with facial nerve paralysis (e.g., Bell’s palsy). In involutional brow ptosis, there is laxity of the tissues within the forehead, allowing the brow to migrate downward with gravity. This appearance tends to be more exaggerated laterally where the mobile brow fat pad is located. With facial nerve palsy, with a loss of frontalis muscle tone in addition to whatever aging changes are present, the eyebrow droop is more profound.
- In any patient presenting for “assessment of droopy eyelids,” it’s important to consider three components that might be playing a role: brow position, lid skin, and lid height; each of these needs assessment. Some patients will have problems in all three areas, others two areas, and some only one area. Each component should be noted in the chart, and the physician needs to decide which requires treatment in any particular patient.
- An understanding of eyebrow anatomy is also very important in preoperative blepharoplasty evaluation. Brow ptosis exaggerates the upper eyelid dermatochalasis and can contribute to superior visual field loss. The surgeon needs to determine the degree of brow ptosis in the blepharoplasty candidate and whether the brow requires repositioning for its entire length or only temporally. An upper eyelid blepharoplasty might exaggerate a preexisting brow ptosis by pulling the brow downward following skin excision. A brow elevation will restore brow position and prevent the downward shift.
- In addition to brow ptosis, the brow fat pad becomes important in the blepharoplasty patient if it has shifted downward as a result of involutional changes. This often gives rise to a temporal fullness and further sagging in the temporal region in patients seeking blepharoplasty assessment. Following skin–orbicularis and preaponeurotic fat removal, the surgeon might notice that there is still fullness to the temporal eyelid as a result of a migrated brow fat pad. This fat pad is identified deep to the orbicularis, but superficial to the orbital septum, just beneath the orbital rim. Careful trimming of the brow fat pad will remove the eyelid temporal fullness, allow some temporal brow elevation, and give sharper definition to the orbital margin.
- The brow fat pad is most well developed in the eyebrow, but it might extend quite far inferiorly into the eyelid, nearly to the point where the orbital septum joins the levator aponeurosis. It must not be confused with the preaponeurotic fat pads. This relationship is important to keep in mind (i.e., brow fat might sit on the orbital septum; preaponeurotic fat sits on the levator). If the brow fat is mistaken for preaponeurotic fat and the structure immediately beneath it (septum) is mistaken for the levator and is advanced during a ptosis procedure, severe lagophthalmos will result.
- Knowledge of the anatomy in the brow region is also extremely important during botulinum toxin administration. The vertical glabellar furrows can be readily reduced with selective injections of botulinum toxin placed immediately above the medial brow in the area of
the corrugator and procerus muscles. To obtain a little brow elevation, an additional injection of botulinum can be given just under the lateral brow skin where the temporal line of fusion is felt. This will knock out the down-pulling orbicularis muscle fibers in this area, allowing the frontalis to act unopposed and therefore raise the temporal brow 1 to 2 mm.

- Although the causation of the horizontal glabellar lines is clearly the result of action by the vertically oriented procerus muscle and the vertical glabellar lines are clearly the result of action of the horizontally oriented transverse head of the corrugator supercilii muscle, the oblique glabellar skin lines are caused in part by the transverse head of the corrugator muscle; there are also contributions from the other eyebrow depressor muscles in the area (oblique head of corrugator, depressor supercilii, and medial orbicularis).
- The supratrochlear neurovascular bundle and the supraorbital neurovascular bundle should be marked out prior to any brow lift surgery. They are commonly located 1.7 cm and 2.7 cm from a midline mark equally spaced between the medial brows over the glabella. This is basically the same location as that of the corrugator muscle.
- Elevation of the brows can transmit forces to the eyelid and contribute to some eyelid elevation. This function is learned early in patients with congenital ptosis or acquired ptosis and is the basis for the frontalis suspension procedure used to repair poor function upper eyelid ptosis.
- It is important to immobilize the frontalis muscle function when assessing levator function in a child or an adult, especially those with a poorly functioning levator muscle who might be using the frontalis muscle to raise their eyelid.

1–2 TEMPORAL REGION ANATOMY, SUPERFICIAL TEMPORAL ARTERY, AND SEVENTH NERVE

Endoscopic brow elevation, temporal hairline brow elevation, direct brow elevation through a mid-forehead furrow, and eyelid approach brow elevation are common procedures for oculofacial plastic surgeons. Oculofacial plastic surgeons are often called upon to obtain superficial temporal artery biopsies in the evaluation of temporal arteritis. It is frequently necessary for oculofacial plastic surgeons to work in the tissues lateral to the orbital rim for eyelid reconstruction, to excise orbital tumors, or to repair a zygomatic (tripod) fracture. Thus, an understanding of the anatomy in the temporal region and facial nerve is important.

1–2-1 Superficial Temporal Region

It is important for the surgeon to be familiar with the anatomy of the temporal region if safe forehead elevation is to be performed. The temporal region is where the facial nerve is at the greatest risk of injury. In order to prevent damage to the facial nerve, dissection must take place below its path by staying deep to the superficial temporalis fascia and immediately on top of the glistening white deep temporalis fascia. As one gets within 2 cm of the zygomatic arch, it is safest to go
beneath the superficial layer of the deep temporal fascia on the surface of the superficial temporal fat pad (see below) in order to protect the frontal branch. The anatomy of the temporal region is similar to that of the scalp because it is broken into several layers that stay constant throughout the region. The terminology of the anatomy is often confusing because several names can be found in the literature describing the same structure. Unfortunately, there is no agreed-upon standard terminology. However, the names used in this discussion will be the ones most commonly used by most endoscopic forehead surgeons. The two most important layers of the temporal region to identify during endoscopic forehead lifting are the superficial temporal fascia and the deep temporal fascia (Figs. 1-5, 1-6). Important structures to identify in this same area are the temporal line of fusion (also called the conjoint fascia), which separates the temporal dissection space from the central forehead dissection space, the sentinel vein, which signals to the surgeon that he or she is close to the facial nerve and needs to proceed cautiously with dissection, and the superficial temporal fat pad, which is the safest plane to be in when one has to approach the arch itself, as it is below the plane of the facial nerve.

**FIGURE 1-5** Anatomy of various fascial layers in the temporal region. Inset: pathway of the seventh nerve over the zygomatic arch.
SUPERFICIAL TEMPORAL FASCIA

Another commonly used name for the superficial temporal fascia (STF) is the temporoparietal fascia. The STF is continuous with the galea aponeurotica above, the frontalis muscle anteriorly, the occipitalis posteriorly, and the SMAS in the mid- and lower face. In the temporal region, it is the layer that contains the superficial temporal artery and the frontal (temporal) branch of the facial nerve. Deep to the STF is a loose areolar plane that, when it is recognized as a distinct fascial layer, is called the inominate fascia (others have referred to this layer as the “parotid-temporal fascia” or “the subaponeurotic plane”) (Fig. 1-5). This inominate fascial plane is avascular and continuous superiorly with the subgaleal plane, and it extends inferiorly over the zygomatic arch, where it is found in loose continuity with the fascia immediately over the parotid gland (parotid fascia, parotid-masseteric fascia). Immediately deep to the inominate fascia in the temporal region is the glistening white deep temporalis fascia.

FIGURE 1-6 The superficial temporal fascia with superficial temporal artery (blue arrows) has been peeled off of the deeper, glistening white deep temporalis fascia and pulled anteriorly so that it is slightly overlapped on itself. A window in the deep temporalis fascia has been made (lying on the handle of a scalpel blade). Beneath the temporalis fascia is the temporalis muscle (black arrow). The temporal line of fusion, or conjoint tendon, is outlined by the green arrows.
DEEP TEMPORALIS FASCIA

The deep temporalis fascia is also known as the temporalis fascia proper. It has a shiny white or glinting white appearance and covers the temporalis muscle (Fig. 1-6). The deep temporalis fascia splits into two layers at the level of the supraorbital margin. The superficial layer of the deep temporal fascia (also called the “intermediate fascia,” the “superficial lamina,” and sometimes the “inominate fascia”) and the deep layer of the deep temporal fascia are separated by the superficial temporal fat pad (also called Yassergil’s fat pad or the intermediate temporal fat pad) (Fig. 1-5).

TEMPORAL LINE OF FUSION

The temporal line of fusion is where the STF and the galea aponeurotica fuse with the deep temporal fascia and the peristium of the central forehead region to form the conjoint fascia. This junction also marks the beginning of the temporalis fossa and the origin of the temporalis muscle (Fig. 1-6). One can often feel this area as a ridge along the bone extending from the lateral orbital rim posteriorly into the temple area. If the patient is asked to clench the teeth, the contracting temporalis muscle will help identify it. The point at which this ridge meets the superior orbital margin also marks the lateral extent of the frontalis muscle.

Clinical Application

- When connecting the temporal dissection space with the subperiosteal central forehead dissection space, the temporal line of fusion or conjoint fascia must be dissected away from bone. In order to minimize risk to the facial nerve, the conjoint fascia should initially be penetrated with a periosteal elevator starting from the temporal space (deep to the STF) and proceeding to the central space. Going the opposite way risks the creation of a superficial plane anterior to the STF, which could damage the facial nerve.

THE SENTINEL VEIN

The sentinel vein, a branch of the internal maxillary vein, is a useful landmark during endoscopic brow lifting, signaling the presence of the nearby facial nerve. The major morbidity associated with brow lifts is trauma to the frontal (temporal) branch of the facial nerve, and its location is important for the oculofacial surgeon. The sentinel vein and the frontal branch location can be marked out on the skin presurgery. The general course of the facial nerve has been well documented and generally runs from a point 0.5 cm below the tragus to a point 1.5 cm above the lateral end of the eyebrow (“the Pitanguy line”) (Figs. 1-7, 1-8). The sentinel vein is consistently found to lie lateral to the orbital rim (approximately 5 mm lateral to the zygomaticofrontal suture line), passing from the subcutaneous layers through the STF, through a perforation or attenuation in the deep temporal fascia to the temporalis muscle. The frontal branch of the facial nerve is usually found cephalad to the sentinel vein, and at their nearest point they are a mean distance of 6.4 mm apart (range: 2 to 9 mm).
FIGURE 1-7 Superficial temporal artery pathway. The “danger zone” represents the area to avoid during a temporal artery biopsy. The Pitanguy line runs along the anterior limit of this danger zone and marks out the approximate course of the facial nerve.

FIGURE 1-8 Seventh nerve anatomy over the zygomatic arch. The Pitanguy line is an approximate location of the seventh nerve and should be routinely drawn out when doing any surgery in this area. It runs from a point 1.5 cm above the lateral brow to a point 0.5 cm below the tragus.
Occasionaly there is a second sentinel vein located lateral to the first. The zygomaticotemporal nerve (a branch of the maxillary division of the trigeminal nerve) is occasionally seen about 1 cm lateral to the sentinel vein, passing between a perforation in the deep temporalis fascia and the skin surface. It is closely related to the frontal branch of the facial nerve at the level of the STF in those cases in which it is seen. Their location defines a “zone of caution,” enabling the surgeon to operate rapidly and with confidence until this “zone” is reached, at which time the dissection is slower as the vein is approached. Dissection is kept immediately on the surface of the deep temporal fascia. Once the sentinel vein is identified during endoscopic brow elevation surgery, caution should be exercised with traction in the area. If bleeding of the vein occurs, monopolar cautery is not advised because of the risk of a conducted thermal injury to the seventh nerve, which might cause permanent injury. If there is a need to coagulate the sentinel vein, bipolar cautery is preferred on the surface of the deep temporal fascia. Dissection inferior to the sentinel vein toward the arch should take place deep to the superficial layer of the deep temporal fascia.

SUPERFICIAL TEMPORAL FAT PAD AND DEEP TEMPORAL FAT PAD

The superficial temporal fat pad is different from the temporal brow fat pad (located beneath the temporal brow) described earlier. Although the temporal brow fat pad is nearby, it is completely separate from the superficial temporal fat pad and has a totally different significance. The superficial temporal fat pad is located between two layers of the deep temporal fascia, as discussed above (Fig. 1-5). It starts approximately 2.5 cm above the zygomatic arch, or at about the level of the supraorbital margin. Here the deep temporal fascia splits into two layers: the superficial layer of the deep temporal fascia and the deep layer of the deep temporal fascia, as discussed above. Between these two layers is the superficial temporal fat pad (also referred to as Yassergils fat pad or the intermediate temporal fat pad). The superficial temporal fat pad extends medially to the lateral orbital rim and inferiorly to the zygomatic arch. Although it has been described as part of the buccal fat pad by some, this fat pad is totally separated from the buccal fat by the deep layer of the deep temporal fascia (Fig. 1-5). The superficial temporal fat pad differs in appearance from the buccal fat, is not in continuity with the masticatory space, and has a different blood supply than the buccal fat pad. Dissection can be safely carried out toward the zygomatic arch itself and the lateral orbital rim if it is kept just within this superficial temporal fat pad (i.e., just deep to the superficial layer of deep temporalis fascia). This will prevent damage to the overlying facial nerve.

Along most of its surface, the temporalis muscle is directly covered by the deep layer of the deep temporal fascia. Between 2 and 4 cm above the zygomatic arch, the inferior portion of the temporalis muscle and its tendon are covered by the deep temporal fat pad, which is an extension of the buccal fat pad that traverses beneath the zygomatic arch (Fig. 1-5). Thus, this superior extension of the buccal fat pad separates the temporalis muscle from the overlying zygomatic arch and the deep temporal fascia. The buccal fat pad serves to line the masticatory space, separating the masticatory muscles from each other and from overlying boney prominences. In this fashion, it allows smooth gliding between the muscles and is important in masticatory function.
FASCIAL INSERTIONS INTO THE ZYGOMATIC ARCH

The insertions into the zygomatic arch of the STF (temporoparietal fascia) and the superficial and deep layers of the temporalis fascia are complex. Inferiorly, they blend with the insertions of the SMAS, the parotid-masseteric fascia, and the deep masseteric fascia.

The superficial layer of the deep temporal fascia attaches to the superficial superior margin of the zygomatic arch. This fascia directly overlies the periosteum of the arch and blends in with the parotid-masseteric fascia inferiorly, which inserts into the superficial inferior margin of the arch. Thus, these two fascial layers are continuous across the superficial surface of the zygomatic arch (Fig. 1-5).

The deep layer of the deep temporal fascia attaches to the posterosuperior margin of the zygomatic arch and continues along the deep surface of the arch. Inferiorly, the posterior masseteric fascia inserts into the posteroinferior margin of the arch and blends with the attachments of the deep layer of the deep temporal fascia. These two fascial layers are thus continuous across the deep surface of the zygomatic arch.

The superior margin of the zygomatic arch is in contact with only the superficial temporal fat pad, which separates the insertions of the two layers of the deep temporal fascia.

The STF represents a continuation of the SMAS across the zygomatic arch. Its attachments to the arch are more superficial and overlie the attachments of the superficial layer of the deep temporal fat pad, from which it can be separated with careful dissection. The STF is not in direct continuity with the arch periosteum. The frontal branch lies immediately beneath this layer in the inominate fascial plane (Fig. 1-5).

THE COURSE OF THE SEVENTH NERVE OVER THE ZYGOMATIC ARCH

Anatomic descriptions of the fascial planes in the temporal region are often contradictory and confusing, in part because of the dense adhesions between fascial layers in this area, and they are further complicated by the inconsistent use of nomenclature. In addition, many past anatomical studies used preserved cadaver heads, in which the fascial planes can be much more difficult to separate and identify as compared with those in more recent publications. The confusion stems in part from the dense adherence of fascial planes to one another as they cross the arch, a problem that is compounded when trying to dissect the planes in preserved cadavers, in which the layers are even more adherent.

Although the traditional and often quoted understanding is that the seventh nerve branches travel “within the superficial temporal fascia (temporoparietal fascia) across the zygomatic arch,” they more accurately travel in the layer distinct from, and deep to, the STF and SMAS as they cross the zygomatic arch known as the “inominate fascia,” discussed earlier (Fig. 1-5). An appreciation of the inominate fascia as a distinct and significant fascial plane and of the relationship of the nerve branches within it is key to a clear understanding of the anatomy in the region. From the point at which the seventh nerve branches exit the parotid gland to their point of transition into the STF in the fascial transition zone above the zygomatic arch, these seventh nerve fibers run just above the periosteum within the inominate fascia, which is a fibrofatty layer that can be elevated as a distinct
layer deep to the SMAS and the STF. At the fascial transition zone, dense adhesions exist between planes which limit dissection and serve to protect the nerve from injury. This anatomical characteristic serves to caution the surgeon as this region is approached during face-lift and brow lift surgery, and therefore aids in the performance of safe surgery. The “fascial transition zone” is located approximately 1.5 to 3.0 cm above the superior border of the zygomatic arch and approximately 0.9 to 1.4 cm posterior to the lateral orbital rim.

Clinical Application

- Over the lateral portion of the zygomatic arch, during face-lift surgery, elevation of the SMAS up to and slightly above the superior border of the arch can be performed easily and without resistance. As the central portion of the arch is approached, however, adhesions between the SMAS and the underlying inominate fascia are encountered, and limited blunt dissection along the lower border of the arch is recommended.
- When dissecting in the temporal region during endoscopic brow surgery, a safe plane of dissection is along the surface of the superficial layer of the deep temporal fascia, provided that the inominate layer is carefully swept up with the overlying STF. As the fascial transition zone is approached, the crossing of the sentinel vein is encountered, followed by dense adhesions that mark the end of the safe dissection plane. Access to the arch should then proceed deep to the superficial layer of the deep temporal fascia along the anterior surface of the superficial temporal fat pad, or along the surface of the temporalis muscle (just behind the superficial temporal fat pad), in order to best avoid nerve injury.
- The characteristics of an ideal brow have been described as an arch in which the brow apex terminates above the lateral limbus of the iris, with the medial and lateral ends of the brow at the same horizontal level. Despite studies that provide criteria for ideal brow aesthetics, reports in the literature not uncommonly suggest that brow lift procedures create brows with an unnatural shape and position. Medial brows might be too high and above the supraorbital rim, or the apex of the brow might be flat or medial in position. Some have suggested that brow lifts fail to provide the desired result because they tend to elevate the entire brow without lowering the medial segment. Unlike other areas of the body where there is descent of soft tissue, the brows might paradoxically elevate in 28% of individuals, remain stable in 41%, and descend in only 29% of patients. These findings help explain why current brow lift procedures, which tend to preferentially elevate the medial brow, create an unnatural appearance. In addition, brow lift operations often attenuate vertical glabellar furrows by manipulating the corrugator and procerus muscles. The weakening or removal of these muscles allows the medial brows to elevate and separate with the brows sitting in an aesthetically unfavorable position, lateral to the nasal ala. Based on these findings, a reappraisal of current brow lift techniques has been suggested in order to improve clinical outcomes. Because there is heterogeneity in anatomy and in how the brow ages, a “cookie-cutter” approach to brow rejuvenation should be abandoned, and operations should be tailored on the basis of preoperative findings and patient preference. Most patients require brow reshaping via the restoration of the brow apex to above the lateral limbus of the iris. This suggests,
in most instances, preferential elevation of the lateral brow, minimal or no elevation of the medial brow, and no manipulation of the glabellar musculature. Techniques that selectively elevate the lateral brows are more likely to have a rejuvenating effect on the upper third of the female face. Persistent forehead and glabellar rhytids can subsequently be treated with botulinum toxin as needed. In summary, unlike other areas of the body in which there is a relative descent of soft tissues, the medial, mid-, and lateral brow position might elevate, remain stable, or descend with time. The apex lateral contour of the youthful brow might be transformed into a flattened brow (apex neutral) over time as a result of tissue descent laterally or of the medial brow tissue’s elevating with age. Careful preoperative assessment and discussion with the patient is important in planning brow lift surgery in order to determine the patient’s preference in terms of brow shape and position. When aiming to rejuvenate the forehead region, a youthful brow contour is more likely to be achieved if it is repositioned strategically along its course, rather than simply “elevating” it.

1–2-2 Superficial Temporal Artery and Vein

The superfi cial temporal artery arises as one of the two terminal branches of the external carotid, the maxillary being the other. It arises from within the parotid gland and ascends superiorly to cross the zygomatic process of the temporal bone, approximately 1 cm anterior to the tragus, where it is easily palpated. As the superfi cial temporal artery crosses the zygomatic arch, it enters and ascends within the STF (Fig. 1-6). The proximal superfi cial temporal artery has four main branches (transverse facial, zygomatic, frontal, and parietal) and at least five different branching patterns (Fig. 1-7). The transverse facial (or zygomaticomalar) branch arises just below the level of the zygomatic arch and runs in a medial direction parallel to the lower border of the zygomatic arch. It courses transversely across the side of the face to supply the parotid gland and masseter muscle and anastomoses with branches of the infraorbital artery (which anastomoses with palpebral and angular vessels of internal carotid origin). The zygomatic (or middle temporal) branch in most patients also arises below the level of the zygomatic arch and travels superiorly along the upper border of the arch before it penetrates the superfi cial fascial planes to supply the underlying deep temporalis fascia. It also supplies the orbicularis at the lateral canthus and anastomoses with the zygomaticofacial artery and the lateral palpebral branches of the lacrimal artery (internal carotid origin). The last two branches of the superfi cial temporal artery are the frontal branch and the parietal (postauricular) branch. In 80% of patients, the bifurcation of the frontal and parietal branches occurs above the zygomatic arch (Fig. 1-7). The frontal branch of the superfi cial temporal artery crosses the forehead just above the lateral brow. It supplies the frontalis muscle, skin, and pericranium and anastomoses with branches of the supraorbital artery. The parietal branch of the superfi cial temporal artery curves upward and backward (posterior to the ear) on the side of the head, lying superfi cial to the temporalis fascia and anastomosing with its fellow of the opposite side and with the posterior auricular and occipital arteries. The frontal and parietal branches, along with the transverse facial, supraorbital, and supratrochlear arteries, arborize extensively to form a rich arterial plexus within this region. Collectively, these vessels supply the STF and the overlying skin.
The superficial temporal vein begins on the side and vertex of the skull in a plexus that communicates with the frontal and supraorbital veins, with the corresponding vein of the opposite side, and with the posterior auricular and occipital veins. From this network, frontal and parietal branches arise and unite above the zygomatic arch to form the trunk of the vein, which is joined by the middle temporal branch from the temporalis muscle. It crosses the posterior portion of the zygomatic arch, enters the parotid gland, and unites with the internal maxillary vein to form the posterior facial vein.

The superficial temporal vein receives in its course some parotid veins, articular veins from the temporomandibular joint, anterior auricular veins from the ear, and the transverse facial vein from the side of the face. The middle temporal branch receives the superior palpebral vein running along the superior orbital rim, which also anastomoses with the supraorbital vein. The lateral palpebral vein also sends anastomotic branches over the lateral orbital rim to the superficial temporal vein.

The superficial temporal artery and vein are usually within 8 mm of each other but have been reported to be as distant as 30 mm. Temporal artery biopsies usually involve the frontal branch, either just anterior to the ear or along the temporal hairline, because it is so readily accessible (Fig. 1-7).

1–2-3 Seventh Nerve

The seventh nerve, or facial nerve, exits from the styloid canal in the mastoid process of the temporal bone and emerges from behind the external auditory canal to enter the parotid gland (Fig. 1-8). At that point it divides into a superior (frontozygomatic or temporofacial) branch and an inferior (cervicofacial) branch. The superior branch further divides into a frontal (or temporal) and a zygomatic branch, and the inferior branch divides into buccal, mandibular, and cervical branches. These are the five commonly listed branches of the facial nerve. There can be great variation between the right and left sides in the same individual regarding the number of nerve branches, and also the pattern of distribution. Despite numerous and variable branching patterns, all of the facial nerve fibers travel within the same plane as they leave the parotid on its superior anterior surface within the parotid-masseteric fascia (the fascia immediately overlying the parotid, also called the parotid fascia) deep to the SMAS. Branches of the seventh nerve arborize extensively with one another once the nerve leaves the parotid. Because of these multiple anastomoses, clinical recovery may occur after seventh nerve injury.

Clinical Applications

- Abnormal facial contractions or unintentional facial movements (synkinesis) might also occur during recovery and reinnervation of the facial musculature post seventh nerve injury. These synkinetic movements are due to aberrant regeneration of the seventh nerve, with nerve fibers innervating muscles that they don’t usually stimulate. As an example, following a seventh nerve palsy, when a patient is asked to close the eyelids, the corner of the mouth might contract and pull up due to aberrant regeneration of the zygomaticus major and
minor muscles by seventh nerve fibers that would ordinarily travel to the orbicularis oculi muscle. The frontal and mandibular branches are most at risk of permanent injury, because they are usually terminal branches without anastomotic connections.

The branches of the seventh nerve that supply the muscles in the periorcular region are primarily the frontal (temporal) and zygomatic branches, with contributions from a zygomatic-buccal or buccal branch as discussed earlier. The frontal branch lies within the “inominate fascia” (parotid-temporal fascia, subaponeurotic plane), immediately deep to the SMAS (Fig. 1-5) over the proximal third of the zygomatic arch, approximately 2.5 cm from the anterior border of the external auditory meatus (range: 0.8 to 3.5 cm). The nerve travels in a superomedial direction, passing from a point approximately 0.5 cm below the tragus to a point approximately 1.5 cm above the lateral end of the eyebrow (the Pitanguy line) to innervate the forehead and brow musculature from the undersurface (Fig. 1-8). Two to five rami of the frontal (temporal) branch have been noted to cross the zygomatic arch. The anterior and middle rami most commonly innervate the frontalis muscle and the superior orbicularis oculi muscle; the posterior rami most commonly innervate the anterior auricular muscle and the temporoparietal muscle (originating from the temporal fascia above the ear). The anterior branches begin splitting to dive into the upper orbicularis muscle at the superior border of the zygomatic arch. These fine branches enter the deep aspect of the orbital portion of the orbicularis muscle and terminate without crossing the superior orbital rim into the upper eyelid. Terminal branches of the facial nerve have not yet been identified within the upper eyelid. There has been some suggestion that the facial nerve anastomoses with the supraorbital nerve in the upper eyelid, fibers of which are readily identifiable. Therefore, the vertical directed nerves seen during upper eyelid surgery just posterior to the orbicularis, identified as branches of the supraorbital nerve, might actually be mixed nerves carrying seventh nerve motor fibers as well.

The frontal (temporal) branch of the facial nerve supplies motor innervation to the frontalis muscle, the superior half of the orbicularis oculi, part of the corrugator supercili (transverse head), and the upper portion of the procerus (at times). Recent studies examining the innervation of the muscles over the mid-brow have demonstrated a consistent nerve branch originating from a zygomatic, buccal-zygomatic, or buccal branch that courses medially in the lower eyelid to innervate the nasalis muscle and continues upward along the side of the nose to innervate the procerus, the oblique head of the corrugator, the depressor supercilii, and the medial upper lid orbicularis (see below).

The zygomatic branch of the facial nerve is the main branch to the lower eyelid but can have a superior branch running along a parallel course and arborizing with the frontal (temporal) branch discussed above. The zygomatic branch courses from deep to the parotid-masseteric fascia to the immediate proximity of the zygomatic cutaneous retaining ligaments (see further on), where it usually divides into two branches. One branch travels anterior to the origin of the zygomaticus major while another travels deep to it, with both travelling in a horizontal direction toward the zygomaticus minor muscle and medial eyelid. The branches that innervate the lower lid orbicularis oculi originate off the zygomatic branch travelling anterior to the zygomaticus major, which remains at a “deep level” within the soft yellow fat at the base of the zygomatic retaining ligaments (see Figs. 1-30A and 1-30B). These motor fibers become more superficial as they enter
the suborbicularis oculi fat (SOOF) and then the orbicularis oculi muscle itself. These zygomatic nerve branches enter the pars orbitalis at or near its periphery, and seem to do so in four locations (two sites lateral to the temporal limbus and two sites medial to the temporal limbus). At one time these nerve fibers were thought to travel parallel to the orbicularis fibers in the lower eyelid, but it is now clear that once they leave the parent branch en route to the orbicularis, they travel perpendicular to the orbicularis fibers as they head toward the eyelid margin. In addition to innervating the orbicularis oculi muscle in the lower eyelid, nerve fibers also can branch toward the medial canthral area en route to the depressor supercilii, the lower portion of the procerus, the oblique head of the corrugator muscles, and, at times, the medial portion of the orbicularis muscle in the upper lid. Recent anatomical studies have illustrated more clearly the anatomy of the facial nerve in the lower medial eyelid. The depressor supercilii, the lower portion of the procerus, the oblique head of the corrugator muscles, and the medial portion of the orbicularis muscle in the upper lid can be innervated by a branch originating from a zygomatic, buccal-zygomatic, or buccal branch of the facial nerve via the lower eyelid and medial canthus, as discussed earlier. Thus, in some individuals these medial brow depressor muscles might be innervated purely by a zygomatic branch, in others by the superficial branch of the buccal, and in still others by a branch from the coalescence of the two referred to by some as the “angular nerve.”

Clinical Applications

- In the Gillies technique for zygomatic fracture repair, the surgeon dissects through skin (just posterior to the temporal hairline over the temporalis muscle), down to the STF, and then through this layer to the glistening white deep temporalis fascia. An incision is made in the temporalis fascia, and an elevator (e.g., a large curved Kelly) is advanced immediately inside this layer toward the zygomatic arch. The elevator has no choice but to travel deep to the zygomatic arch, and in so doing it avoids the seventh nerve. Once the elevator is beneath the zygomatic arch and the body of the zygoma, it can be lifted anteriorly to mobilize the zygoma back to its normal location, whereupon it is plated in position.
- During an eyelid reconstruction, dissection laterally can be done with blunt and sharp dissection deep to the orbicularis muscle until a point just beyond the lateral margin of the orbit is reached. There, because of the increasing thickness of the skin and subcutaneous tissue, the dissection can be made more superficial to the peripheral part of the orbicularis muscle in the subdermal fatty layer (above the level of the STF). If the dissection progresses further laterally, it should not be at a level deeper than this, so as to avoid damage to the frontal branch of the facial nerve.
- Pedicle flaps, bipedicle flaps, and rhomboid flaps beyond the lateral orbital rim should be in the subcutaneous plane anterior to the STF in order to avoid the frontal branch of the seventh nerve. Patients should always be warned about seventh nerve injury and paralysis, as traction and/or thermal cautery might also injure the nerve despite their being in a more superficial dissection plane.
- During a temporal artery biopsy, the frontal (temporal) branch of the seventh nerve is most vulnerable to injury just lateral to the orbital rim, between the zygomatic arch and a line
drawn horizontally 1.5 cm above the lateral brow toward a point 0.5 cm below the tragus (Pitanguy line), which is very close to the anterior limit of the “danger zone” in Figure 1-7. It is best to avoid this region during superficial temporal artery biopsy. When surgery has to be performed within this zone, the surgeon should take extra care to remain above the STF in order to avoid injury to the frontal branch of the facial nerve (which travels along the undersurface of the STF).

OTHER OBSERVATIONS ABOUT THE SEVENTH NERVE

Recent anatomical studies have confirmed that distant zygomatic and buccal branches of the seventh nerve (motor) intermingle and join with branches of the infraorbital nerve (sensory). In histologic sections, before fusing, each nerve branch had its own epineurium. After fusing, the nerves lost their individual epineurium and instead had one thick epineurium. This admixing of the cutaneous sensory nerves (infraorbital nerve) and fine motor branches (facial nerve) in the infraorbital area has been termed “parasitization” of sensory nerves by motor nerves. There is strong evidence that in the inner canthus and nasal lower eyelid area, the parasitization of sensory nerves (infraorbital and infratrochlear) by the seventh nerve fibers augments their innervation and field of effect.

In a similar fashion, marginal mandibular branches might intermingle with branches of the mental nerve just before entering the lower lip depressors. After the intermingling, it is impossible to anatomically separate the nerve twigs into motor and sensory parts.

As discussed earlier, terminal fibers of the frontal branch of the facial nerve have not been identified below the orbital rim in the upper eyelid. There has been some suggestion that the frontal branch fibers might anastomose with the supraorbital nerve fibers in a fashion similar to what occurs in the lower eyelid to extend its field of effect.

1–3 UPPER EYELID

The eyelids (palpebrae) serve as protective curtains for the eyeball, preventing dehydration and injury by foreign objects, chemicals, and excessive light. They also help to support the orbital contents. Their periodic involuntary movement (blinking) exchanges the tear film, helps to move tears toward the medial canthus and lacrimal system (tear pump), and keeps the surface of the globe moist and free of exposure and debris.

The upper and lower eyelids, musculomembranous folds of skin, are anatomically analogous. Each eyelid is a modified fold of skin, within which is a protractor muscle, the orbicularis oculi; a retractor, the levator muscle and its aponeurosis in the upper eyelid and the capsulopalpebral fascia in the lower eyelid; and a supportive structure of dense fibrous connective tissue with large sebaceous glands, the tarsal plate. The margin of the eyelid bears long, curved hairs, the eyelashes, or cilia. The eyelashes play an important role in sweeping airborne particles from in front of the eye and initiate a protective blink when something touches them.
Clinical Application

- Blinking can be either voluntary or reflexive in nature. The latter type can be divided into several categories. A corneal or tactile reflexive blink will occur when something touches the eyelashes or the eye itself. A dazzle reflexive blink will occur when a menacing object approaches the eye or when one is exposed to sudden bright light. An auditory reflexive blink will occur with a sudden loud noise. The majority of everyday blinks are very brief (0.4 seconds) and do not interrupt vision, and we are unaware of their occurrence. They vary in frequency and purpose according to the circumstance one is in. The rate of blinking in humans varies so widely in a single person under different circumstances that it is difficult to speak of an average rate without giving the circumstances at the time. An average rate of 16 blinks/min was identified in 100 persons traveling in streetcars, whereas a rate of 25 blinks/min was seen in people engaged in normal conversation, and that decreased to 3 blinks/min in the same individuals when they were reading aloud.

1-3-1 Surface Anatomy of Eyelids

The free borders of the upper and lower eyelids bound between them a transverse opening, the palpebral fissure, which generally ranges from 10 to 12 mm in height and from 28 to 30 mm in horizontal length. In primary gaze, the upper eyelid margin rests 1 to 2 mm below the superior limbus (at about the 10 and 2 o’clock positions). The lower eyelid margin is generally at the inferior edge of the limbus. Laterally and medially, the borders of the fissure meet at an acute angle (approximately 60 degrees) to form the lateral and medial canthal angles. Laterally, the interpalpebral fissure is usually inclined slightly upward such that the lateral canthal angle is 2 to 3 mm higher than the medial canthal angle. The lateral canthus rests directly against the eyeball. The medial canthus is separated from it by a small area, the lacus lacrimalis, in the floor of which is a small reddish mass, the caruncle, which partly covers a fold of mucous membrane, the plica semilunaris (see below) (Fig. 1-9).

At about the junction of the medial one-sixth and lateral five-sixths of each eyelid margin, the papilla lacrimalis is found, in the center of which is an opening, the punctum. This leads into the lacrimal canaliculus, a small canal that runs near the eyelid margin behind the medial canthal tendon to enter the lacrimal sac. The punctum therefore divides the eyelid margin into a medial lacrimal portion (with a smooth, rounded surface free of eyelashes over the canaliculus, although it is not uncommon to have a few cilia right at the medial canthal angle that are of little consequence) and a lateral bulbar or ciliary portion bearing lashes and extending to the lateral canthus. The ciliary portion is thicker and lies close against the globe.

At the medial canthal angle there is a small mound of tissue, the caruncle. This consists of modified skin containing fine hairs, sebaceous glands and sweat glands. Unlike skin, however, it is nonkeratinized and may contains accessory lacrimal gland elements (accessory lacrimal glands of Popoff). Just lateral to the caruncle is a vertical fold of conjunctiva, the semilunar fold (plica semilunaris). The submucosa contains adipose cells and smooth muscle fibers, resembling the nictitating membrane of lower vertebrates (e.g., rabbits). In humans, this represents a vestigial
structure that has been modified to allow enough horizontal laxity at the medial fornix for rotation of the globe.

The highest part of the upper eyelid, referred to as the peak, is just nasal to the center of the pupil when the eye is in primary gaze. In each eyelid, there is a curved horizontal *palpebral or eyelid crease* approximately 8 to 12 mm above the lashes centrally (Fig. 1-9). Medially, the crease curves downward to within 3 to 4 mm of the lid margin, and laterally it ends about 5 to 6 mm above the margin. The palpebral crease divides each eyelid into a *pretarsal* and an *orbital* portion. The palpebral crease in the upper eyelid is deeper than that in the lower. The palpebral crease is formed by the attachment of the levator aponeurosis fibers into the subcutaneous tissues below its fusion with the orbital septum. When the eyelid opens, the crease is pulled superiorly and posteriorly, and the eyelid skin above it (the palpebral fold) overhangs. The upper eyelid crease is generally higher in women than in men.

**Clinical Application**

- It is essential during ptosis surgery to re-create the natural eyelid height and contour. To do this, the surgeon places the initial suture partial thickness through the tarsal plate, just nasal to the pupil. One or two additional sutures might be required medial or lateral to the primary suture in order to fine-tune the contour and secure the height.
- Symmetrical eyelid creases, symmetrical eyelid folds, and normal lash position are other important parameters to consider during ptosis surgery in order to obtain a good result.

![Surface anatomy of the eyelids.](image-url)
Forehead, Eyebrows, Eyelids, and Canthi

The crease position in each eyelid should be assessed prior to beginning the lid procedure. If one is high, it can be adjusted downward by marking out a slightly lower incision line. If the lashes are pointed inferiorly, they can be rotated superiorly by putting in some rotational sutures (skin-aponeurosis-skin) at the end of the case.

The skin in the preseptal or orbital portion of the eyelid is loose-textured with no attachments of the aponeurosis in the subcutaneous tissue, permitting this skin to fold over the eyelid crease when the eyelid opens. The skin inferior to the eyelid crease (pretarsal area) adheres more to the deeper tissues due to distal insertions of the levator aponeurosis into the subcutaneous tissues. With increasing age, the eyelid skin stretches, in part as a result of age-related elastosis and loosening of connective tissue attaching the skin to underlying structures. As a result, the skin becomes redundant and hangs downward—a condition referred to as *dermatochalasis* (Fig. 1-10). In addition, the upper eyelid crease tends to migrate more superiorly with age.

Clinical Application

- A term often used interchangeably with *dermatochalasis* is *blepharochalasis*; the latter should be reserved for a rare disorder that starts in childhood and is associated with recurrent attacks of eyelid edema, the cause of which is unclear. After numerous attacks, the eyelid takes on a characteristic appearance. The skin is finely wrinkled, the levator aponeurosis might disinsert, and the lacrimal gland might prolapse. A pseudoepicanthal fold forms as a result of atrophy of the medial fat pad in the late atrophic stage (Fig. 1-11).
- Blepharoplasty surgery involves the removal of excess skin, muscle, and protruding fat in the upper and lower eyelids. In the upper eyelids, when excess skin hangs over the eyelid margin, a visual field defect can be created, making the surgery more medically necessary than cosmetic in nature. Over the years, blepharoplasty techniques have changed. It used to be felt that fat removal was important in almost everyone, but now fat preservation is a key concept, and individualizing surgery to each particular patient is essential. In the upper lids, the only fat removal that might be required (in some people) is that of a prominent medial fat pad.
Unless the central fat pad is grossly protruding forward, it is best to leave it in position in order to maintain a natural appearance. In some people, a portion of the central fat pad extends laterally in the eyelid to lay immediately anterior to the lacrimal gland and contribute to a temporal fullness of the lid. Gently trimming this portion (without injuring the lacrimal gland) may improve the temporal fullness. As for the lower eyelids, fat preservation with fat transfer over the rim and into the tear trough is an important concept, rather than fat removal. Fat removal in the lower lid can contribute to a sunken appearance to the periorcular region, whereas fat mobilization and fat transfer camouflage the “tear trough” shadows and contribute to a more natural and younger appearance of the lower eyelid. An external scalpel incision in the subciliary eyelid or a transconjunctival incision just beneath the tarsal plate or through the fornix is possible, but the technique used is generally dictated by the patient’s anatomy and the surgeon’s experience and preference.

The upper eyelid extends to the lower edge of the eyebrow; its upper margin coincides in general with the supraorbital margin. The lower eyelid passes usually with no particular line of demarcation into the skin of the cheek; its limits are indicated by two skin folds, the nasojugal and the malar, with the former being the more pronounced (Figs. 1-9 and 1-10). The nasojugal fold runs from the medial canthus down toward the mid-cheek and is commonly referred to as the tear trough. The malar fold runs from the lateral canthus toward the mid-cheek and is often referred to as the lateral tear trough. The nasolabial fold runs from just lateral to the nasal opening (naris) to the corner of the mouth and becomes more pronounced when the person smiles.

1-3-2 Internal Anatomy

The upper eyelid has several layers. Before the layers can be described, the level of eyelid being evaluated must be defined. For example, 5 mm above the eyelid margin, the layers (from anterior to posterior) are skin, orbicularis, aponeurosis, tarsus, and conjunctiva, i.e., 5 layers. Assuming a
tarsal plate height of 10 mm, 15 mm above the eyelid margin the layers are skin, orbicularis, orbital septum, preaponeurotic fat, levator aponeurosis, Müller’s muscle, and conjunctiva, i.e., 7 layers (Fig. 1-12).

Clinical Application

- During eyelid reconstruction, the eyelids should be considered as being made up of an anterior lamella and a posterior lamella. The posterior lamella includes the tarsus and conjunctiva, and the anterior lamella involves skin and muscle. During the reconstruction, each lamella must be considered and repaired. Posterior lamellar reconstructive procedures might include free tarsal grafts; sliding or rotating tarso-conjunctival flaps; or tarsal substitutes such as ear cartilage, nasal cartilage, or sclera. Anterior lamellar reconstructive procedures might involve the use of myocutaneous flaps, pedicle flaps, rhomboid flaps, or free skin grafts. Not only do the anterior and posterior lamellae have to be replaced in any eyelid reconstruction, but also at least one of the lamellae must have a blood supply to support itself as well as the other lamella. A free graft cannot supply another free graft.

Eyelid skin is very thin and is attached to the underlying orbicularis muscle by loose connective tissue. The orbicularis oculi muscle (or the protractor of the eyelids) is under voluntary control
Surgical Anatomy of the Ocular Adnexa

from the facial nerve and plays a primary role in eyelid closure. The orbicularis is a thin, oval sheet of muscle covering the eyelids and the orbital region, with its fibers concentrically arranged around the palpebral fissure (Figs. 1-4 and 1-13). Although a continuous sheet, it can be considered as composed of two main parts:

1. **Pars orbitalis.** This is the broader part, extending superiorly to the eyebrow, laterally to the temple (where it lies over the anterior part of the temporalis muscle), and inferiorly onto the cheek (where it covers the origin of the lip elevator muscles and the infraorbital and zygomaticofacial nerves). The orbicularis muscle fibers originate primarily along the medial orbital margin and the side of the nose, along a line curving from the supraorbital notch to the infraorbital foramen. This line is interrupted by the medial canthal tendon (medial palpebral ligament), from which fibers also arise. The fibers of the pars orbitalis extend beyond the orbital rim and are circular, so that they will eventually end up back at their medial attachment sites; that is, the origin and the insertion are medial.

2. **Pars palpebralis.** This portion is composed of two half-ellipses, one in each eyelid. The muscle fibers, more delicate than those of the orbital portion, take origin from the medial orbital margin and extend over the tarsal plates and orbital septum to insert at the lateral commissure. Here the fibers of the upper and lower eyelids cross each other and interlace, forming the *lateral palpebral raphe*. According to whether the muscle fibers overlie the orbital septum or the tarsal plate, two divisions can be identified as *preseptal* and *pretarsal* portions. The junction of these two divisions in each eyelid is roughly along the line of the palpebral crease, and it is here that the muscle is thinnest.
   a. The *preseptal fibers* of the orbicularis are positioned over the orbital septum in both the upper and lower eyelids (Figs. 1-4 and 1-14). The inferior preseptal muscle arises as a single head from the entire length of the common tendon. In the upper lid, the preseptal muscle in the area of the medial canthal tendon arises as two heads, one superficial and one deep. The superficial head takes origin from the medial canthal tendon and surrounding bone. The deep head has attachments to the lacrimal crest.

![Concentrically arranged fibers of the orbicularis oculi (arrows).](image)
and lacrimal fascia surrounding the lacrimal sac (lacrimal diaphragm). The deep head of the preseptal muscle, originating from the lacrimal fascia, has been referred to as Jones’ muscle, named after Lester Jones, who demonstrated its presence in 1960. It plays an important role in the tear pump. The preseptal orbicularis fibers run laterally to interdigitate and insert along the lateral palpebral raphe overlying the lateral canthal tendon and orbital rim. A few deep slips of muscle also attach to the lateral canthal tendon.

b. The pretarsal fibers lie over the tarsal plates (Figs. 1-4 and 1-14). The pretarsal portion of the orbicularis medially has two heads in the upper and lower eyelids, one superficial and one deep. The superficial head of the pretarsal fibers lies anterior to the canaliculus and contributes to the formation of the anterior limb of the medial canthal tendon. The deep head lies posterior to the canaliculus; it is referred to as the pars lacrimalis muscle, tensor tarsi muscle, or Horner’s muscle, and contributes to the formation of the posterior limb of the medial canthal tendon (Fig. 1-16C). It attaches to the posterior lacrimal crest and lacrimal fascia (lacrimal diaphragm). These deep fibers play an important role in the lacrimal pump mechanism by shortening the canaliculus and moving the punctum medially. It is important to appreciate that the canaliculi, for part of their length, are nearly completely surrounded by fibers of

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**FIGURE 1-14** Insertions of various portions of the orbicularis muscle in the medial canthal area. Jones’ muscle is the deep head of the preseptal orbicularis muscle and is seen through a window cut in the anterior head of the preseptal muscle. Jones’ muscle inserts into the lacrimal fascia and posterior lacrimal crest.
the superficial and deep heads of the pretarsal orbicularis muscle. The pretarsal orbicularis runs along each eyelid as the pars tarsalis (Fig. 1-14). Laterally, the pretarsal orbicularis muscle fibers from the upper and lower eyelids interdigitate along the surface of the lateral canthal tendon, forming the lateral palpebral raphe. Fibrous connective tissue strands extend from the raphe to the lateral canthal tendon. Some fibers also extend to the subcutaneous tissue to help maintain the lateral canthal contour.

The postorbicular or suborbicular fascial plane is an avascular, loose areolar tissue space located between the orbicularis muscle and the orbital septum–levator aponeurosis complex. Under the preseptal portion, this plane might contain a thin layer of fibroadipose tissue continuous with the brow fat pad. This fibroadipose layer is often more prominent in the Asian eyelid. This suborbicular fascial plane is an important surgical plane within the lid. Staying within this plane during eyelid surgery allows for the relatively bloodless dissection and identification of the underlying orbital septum. This space is also responsible for the easy accumulation of fluid and blood in the eyelid after surgery or trauma.

Clinical Application

- The concept of a lacrimal pump is important. The lacrimal excretory pump functions to propel tears through the drainage system into the nose. Its exact physiologic properties remain a matter of dispute, as there are several theories that might explain how it works. The best-known theory was popularized by Jones and Wobig in 1976 and was based on anatomic work by Lester Jones, who, through careful dissection of the orbicularis in the medial canthal region, demonstrated that preseptal fibers originated from the surrounding lacrimal sac fascia (lacrimal diaphragm). The Jones theory for this lacrimal pump involves three components: (1) the deep heads of the pretarsal orbicularis muscle (Horner’s muscle), (2) the deep head of the preseptal muscle (Jones’ muscle), and (3) the lacrimal diaphragm (fascia around the sac).

  With blinking, contraction of the deep preseptal orbicularis fibers (Jones’ muscle) draws the lateral wall of the nasolacrimal sac laterally, creating a negative pressure within the sac and allowing the inspiration of tears into the sac. The tears are forced along the canalicular system by contraction of the deep head of the pretarsal muscle (Horner’s muscle). When the orbicularis relaxes and the eyelid opens, the sac collapses, forcing tears down the nasolacrimal duct. At the same time, the canaliculi open, siphoning tears into their lumen. Closing the eyelids again pushes and propels the accumulated tears into the lacrimal sac.

  Using high-speed cinematography, Doan suggested a different mechanism of tear propulsion through the system. He noted the puncta coming together during the early phases of eyelid closure with his photography. He postulated that occlusion of the puncta occurred as a first step in the tear pump, followed by compression of the canaliculi and lacrimal sac by the contracting pretarsal orbicularis muscles (i.e., a positive pressure is created during a blink in both the canaliculi and the nasolacrimal sac as a result of muscle contraction.
occurring in the pretarsal and preseptal orbicularis fibers). Thus, the collapsing lacrimal drainage conduit was believed to push the tears through the system and into the nose without the suction phase postulated by Jones and Wobig. Other theories have also been suggested, with these same muscle components acting in a different sequence and creating different pressures within the system.

- Paralysis of the orbicularis muscle might be associated with Bell’s palsy, parotid gland surgery, excision of acoustic neuroma, or facial trauma, to mention a few. The resulting decreased blink rate, eyelid malposition (lid retraction, ectropion), and lagophthalmos may cause tearing, ocular irritation, and significant corneal exposure with ulceration. Lubrication, repositioning of the eyelids, and, at times, shortening the eyelid fissure (tarsoraphy) might be required in order to protect the cornea. The insertion of a gold weight into the upper eyelid might help with eyelid closure and decrease lagophthalmos.

### 1–3–3 Canthal Tendons

Beneath the orbicularis and orbital septum laterally lies the lateral palpebral ligament or lateral canthal tendon (LCT) (Fig. 1-15). The LCT is a connective tissue band originating at the ends of the tarsal plate and inserting into the lateral orbital tubercle, also known as Whitnall’s tubercle, a small bony protuberance just inside the lateral orbital rim. The overall length of the LCT (from the

![FIGURE 1-15](image) Right lateral canthal tendon. The orbital rim is outlined by small black arrows. The lacrimal gland (large black arrow) and lower lid preaponeurotic fat pad (white arrow) are shown. The lateral canthal tendon (blue arrow) inserts posterior to the lateral orbital rim. Eisler’s fat pad usually lies over tendon (purple arrow).
lateral canthal angle to its insertion) is approximately 10.5 mm. Superior and inferior crura (the singular is crus) from each tarsal plate join to form a common tendon measuring approximately 3 mm wide and 5 to 7 mm in length. The common tendon broadens as it approaches the lateral orbital rim, reaching a width of approximately 6 to 7 mm as it inserts into the lateral orbital tubercle 1.5 mm inside the orbital rim on the zygomatic bone. The upper and lower pretarsal orbicularis muscle components interdigitate laterally over the LCT and maintain attachment to it. The LCT is not as well defined as the medial canthal tendon (MCT), but it plays an important role in attaching the eyelids to the lateral orbital rim and forming a sharp canthal angle. Along its superior border, the LCT is contiguous with the lateral horn of the levator aponeurosis. Together they form a broad insertion about 10 mm in width. After inserting into Whitnall’s tubercle, they also extend posteriorly along the lateral orbital wall a short distance (3 to 6 mm) and receive attachments from the lateral check ligament from the sheath of the lateral rectus muscle. Other ligamentous structures insert onto the lateral orbital tubercle, including a few inferolateral fibers of Whitnall’s suspensory ligament and the lateral portion of Lockwood’s suspensory ligament. Along with the LCT, lateral horn of levator, and lateral check ligament, they form the lateral retinaculum. The inferior edge of the LCT is well defined and typically curved downward near its insertion on the rim. Anteriorly, fibers from the orbital septa of both the upper and lower lids extend to and blend with superficial fibers of the LCT just lateral to the insertion of the pretarsal orbicularis. The tendon then diverges from the septum back toward the orbital tubercle, and the orbital septum continues laterally to the orbital rim. This portion of the septum is like an anterior limb of the LCT. Between this portion of orbital septum and the LCT is a small fat pad known as Eisler’s fat pad, which is often seen during eyelid surgery around the lateral canthus (Fig. 1-15).

Clinical Application

- The lateral canthus moves laterally an average of 2 mm with extreme abduction of the globe as a result of the fibrous connections between the LCT and the check ligaments of the lateral rectus. It is likely that this lateral movement of the canthal angle serves to increase the temporal visual field during lateral gaze. The LCT therefore has a dual role. Primarily, the LCT provides structural fixation of the lids and lateral canthus by means of a tendinous attachment to the lateral orbital tubercle. The LCT also imparts mobility to the canthal angle via its posterior fibrous attachments to the check ligaments of the lateral rectus muscle.
- With age, the LCT might thin, become lax, and contribute to the pathophysiology of lid laxity associated with a poor tear pump mechanism, involutional entropion, ectropion, or lid laxity associated with the anophthalmic socket. If the LCT actually loses its attachment laterally, the lateral canthus will lose its sharp angle and appear rounded (e.g., aging process, blepharochalasis syndrome). A variety of procedures have been described in the literature to correct canthal tendon laxity defects or eyelid malpositions (entropion, ectropion) and involve replacing the LCT with a strip of tarsus (i.e., the lateral tarsal strip procedure). Attempts to surgically reconstruct the LCT must reconstitute the deep attachment to Whitnall’s tubercle in order to maintain eyelid apposition to the globe.
The **medial palpebral ligament**, or **medial canthal tendon**, is much better defined than the LCT. Medially, the tarsal plates pass into fibrous bands that form the crura of the MCT. These lie between the orbicularis muscle anteriorly and the conjunctiva posteriorly. The superior and inferior crura fuse to form a common tendon that inserts onto the orbital bones via three branches (Figs. 1-16A and 1-16B). The MCT has two main heads, one deep and one superficial. The deep portion is thinner and arises from the common tendon near the junction of the superior and inferior crura, and runs adjacent to the posterior aspect of the canaliculi behind the lacrimal fossa to attach to the posterior lacrimal crest. As it extends along the posterior lateral side of the lacrimal sac, it is attached to the sac by a layer of fibrous tissue. It then fans out as it approaches the posterior lacrimal crest (approximately 6 to 10 mm in height). It inserts into the posterior lacrimal crest just in front of Horner’s muscle (Fig. 1-16C). The posterior portion of the MCT directs the vector forces of the canthal angle posteriorly to maintain close approximation of the lids to the globe.

The **superficial** portion of the MCT is much better defined than the deep portion and lies anterior to the canaliculi and lacrimal sac (Fig. 1-16B). The superficial arm is approximately 8 to 10 mm in length, 1.5 to 2.5 mm wide, and 1 to 2 mm thick. It is attached directly to the frontal process of the maxilla just superior and anterior to the anterior lacrimal crest. It provides the major support for the medial canthal angle.

The MCT also has a **superior supporting branch** (Fig. 1-16B), which arises as a broad band of fibers from both the anterior and the posterior arms. It passes upward 7 to 10 mm, where it inserts onto the orbital process of frontal bone. The posterior head of the preseptal orbicularis muscle also has attachments to this arm, and together this unit forms the soft tissue roof of the lacrimal sac fossa. The superior portion of the MCT might function to provide vertical support to the canthal angle. In conjunction with the preseptal orbicularis fibers, it also might play a role in the tear pump mechanism.

### 1–3-4 Orbital Septum

Beneath the orbital portion of the orbicularis muscle in the upper and lower eyelid is the **orbital septum** (Fig. 1-17). The septum is a thin, multilayered, fibrous connective tissue membrane that originates at the orbital margin and extends into the eyelids. At the orbital rim, the septum is thicker and is referred to as the **arcus marginalis**. The orbital septum defines the anatomic boundary between the eyelid and the orbit. Laterally, the orbital septum of the upper and lower lids maintains close proximity to the LCT and has attachments to it. As the canthal tendon dives deep toward Whitnall’s tubercle, the orbital septum continues superficially toward the orbital rim. The space in between is often occupied by a small pad of fat (Eisler’s fat pad), as discussed in a preceding section. Medially, the orbital septum divides into layers that pass along both the anterior and the posterior lacrimal crest. In the lower lid, the anterior layer inserts onto the anterior lacrimal crest and the inferior edge of the MCT. In the upper lid, the anterior layer is thin and inserts onto the superior arm of the canthal tendon. A thicker intermediate layer separates from the anterior layer in the upper eyelid. It passes posteriorly to insert along the posterior lacrimal crest just in front of Horner’s muscle. In the lower lid, this posterior layer fuses to the periorbita along the orbital opening of the nasolacrimal duct. Thus, the anterior and posterior layers of the orbital
FIGURE 1-16 (A) Medial and lateral canthal tendons and tarsal plates. (B) The three heads of the medial canthal tendons (MCTs) are seen, along with their relation to the nasolacrimal sac and canaliculi. (C) Further details of the anatomy in the medial canthal region, with Horner’s muscle illustrated.
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septum medially effectively surround the lacrimal sac within their own fascial compartment, which becomes known as the lacrimal fascia or lacrimal diaphragm. The walls of this compartment are interrupted only along the canthal tendon, where the canaliculi enter, and at the entrance to the boney nasolacrimal canal. Within the eyelid, the orbital septum forms nearly a continuous layer that separates the anterior eyelid structures from the preaponeurotic fat and orbital contents (see Fig. 1-21). The septum fuses with the levator aponeurosis in the upper eyelid approximately 3 to 5 mm above the superior tarsal border, but this distance is variable. In the lower eyelid, the septum fuses with the capsulopalpebral fascia several millimeters below the tarsus, and there is some controversy as to whether the common fascial sheet then inserts into the inferior edge of the tarsal plate or just below it.

Clinical Application

- In younger individuals, the orbital septum is often better defined and more readily identified in surgery. Its multilayered structure is more noticeable in some individuals. In older patients, the septum might be thin and attenuated, often with spontaneous dehiscences.
- At one time, the orbital septum was considered an important structure, not to be penetrated unless necessary. If violated, it was to be closed in order to re-form the anatomic barriers it represented. This impression has changed dramatically, and the septum is routinely entered during eyelid surgery (for example, blepharoplasty) and left open. Closure of the septum might lead to eyelid scarring and retraction.
- In the upper eyelid, variations of insertion of the septum on the levator aponeurosis allow for variations in the level of the eyelid crease and fold. In the Asian eyelid, the orbital septum meets the levator much lower than in the Caucasian eyelid. This allows for a more inferior extension of the preaponeurotic fat pad, giving rise to a prominent upper eyelid fold and a fuller-appearing eyelid. The inferior extension of the orbital septum also blocks the

FIGURE 1-17 Orbital septum. The superior orbital rim has been removed, and the orbital septum is being held up medially and laterally.
superficial course of the anterior levator aponeurosis that normally creates the eyelid crease. The Asian eyelid therefore not only has a lower eyelid crease, but the crease might also be poorly formed (Figs. 1-18A, through 1-18C).

1-3-5 Nerves

Several important nerves warrant attention during eyelid and brow surgery and might be seen at different times during the procedure—for example, during brow elevation or ptosis surgery. The sensory nerves to the eyelids originate from the ophthalmic ($V_1$) and maxillary ($V_2$) divisions of the trigeminal nerves.
Sensory input from the upper eyelid passes to the ophthalmic division (V\textsubscript{1}) of the trigeminal nerve (via the frontal, nasociliary, and lacrimal nerves) through terminal nerve branches: the supraorbital, supratrochlear, infratrochlear, and lacrimal nerves (Fig. 1-19).

The \textit{supraorbital nerve} (a branch of the frontal nerve) exits the orbit through a supraorbital notch 90\% of the time, but it can also exit through a true bony foramen located 1.0 to 1.5 cm superior to the suporaorbital rim 10\% of the time. When a bony notch is present, there might be a taut fibrous band present that forms the anterior border of the supraorbital notch (camouflaging the fact it is really a notch) and holds the supraorbital nerve trunks against the frontal bone. The supraorbital nerve has a single exit point from the orbit in 82\% to 84\% of patients. However, in 14\% to 16\% there is more than one exit point. It is not uncommon to see the supraorbital nerve exiting the orbit via the supraorbital notch, along with a smaller medial branch, the \textit{internal frontal}. This latter branch might be given off within the orbit, in which case it courses over the orbital margin separately in a frontal notch. After exiting the supraorbital rim (through either a foramen or a notch), the main supraorbital nerve trunk divides into a \textit{superficial branch} and a \textit{deep branch}.

The superficial branch of the supraorbital divides immediately into multiple, smaller branches that penetrate the corrugator and frontalis muscle at various points from the orbital rim to mid-forehead level. These branches pass over the anterior surface of the frontalis muscle in a wide fan-like pattern toward the hairline to provide sensation to the forehead and scalp.

The deep branch of the nerve splits from the trunk at or just above the supraorbital notch. The deep branch might also branch out from the main trunk prior to that point and exit the orbit through a separate, more lateral foramen on the frontal bone. In contrast to the superficial branch, the deep branch runs deep to to the frontalis in a cephalad direction between the galea and the

![Figure 1-19](image-url) Sensory and motor nerves of the upper and lower eyelids.
periosteum superiorly and laterally toward the temporal fusion line. Its course parallels the temporal fusion line, traveling just medial to it by 0.5 to 1.5 cm. The deep division does not usually branch in the mid-forehead area, except for tiny, thread-like strands extending to the underlying periosteum. Just before the level of the coronal suture line of the skull, it usually bifurcates and begins to turn medially to form smaller branches that penetrate the galea aponeurotica to enter the frontoparietal scalp as terminal branches.

In addition to supplying skin over the forehead and scalp, the supraorbital nerve gives off branches to the upper eyelids. These sensory branches run deep to the orbicularis in the suborbicularis fascial plane and fan out in several directions toward the lid margin. They are often seen during anterior approach ptosis surgery or blepharoplasty surgery as multiple vertically oriented and parallel nerve fibers heading toward the eyelid margin. Transection of these fibers is inevitable during lid surgery, and it is not unusual for patients to notice some degree of upper eyelid anesthesia for several months postoperatively. These terminal sensory branches form a pretarsal plexus that eventually supplies the tarsal glands and conjunctiva (described by Bach in 1895), and a marginal plexus (described by von Mises in 1882) that sends multiple superficial branches to the skin.

The supratrochlear nerve (also a branch of the frontal nerve) leaves the orbit medial to the supraorbital nerve and superior to the trochlea in company with the supratrochlear artery (Fig. 1-19). It pierces the orbital septum and enters the medial corrugator (near its boney insertion), where it divides into three or four smaller branches. These branches course cephalad on or just deep to the anterior surface of the corrugator supercilii muscle and then penetrate the frontalis muscle and run on its medial surface. It supplies a narrow band of skin of the forehead above the head of the eyebrow, and also gives off twigs to the eyelids. It also carries sympathetic fibers to the forehead that will innervate blood vessels (see Chapter 5). The forehead sensory area of the supraorbital nerve almost always overlaps that of the supratrochlear nerve.

The infratrochlear nerve, one of the terminal branches of the nasociliary nerve (ophthalmic division of the trigeminal nerve—V\textsubscript{1}), exits the orbit inferior to the trochlea. The infratrochlear nerve supplies skin in the medial canthus, medial eyelids (upper and lower), side of the nose, caruncle, conjunctiva, and nasolacrimal sac (Fig. 1-19). Recent anatomical studies indicate that this nerve also carries sympathetic nerve fibers. Innervation to the sympathetic muscles in the upper and lower eyelids is supplied by the sympathetic fibers in the infratrochlear nerve, as well as by sympathetic fibers travelling in the lacrimal nerve (see Chapter 5).

The lacrimal nerve (Fig. 1-19) arises from the ophthalmic division of the trigeminal nerve (V\textsubscript{1}). After innervating the lacrimal gland, it pierces the orbital septum to supply cutaneous sensory fibers to the lateral upper eyelid and superior temporal conjunctiva. Recent anatomic studies also suggest that innervation to the sympathetic muscles of the upper and lower eyelids occurs via sympathetic fibers travelling in the lacrimal nerve (as well as sympathetic nerve fibers recently identified within the infratrochlear nerve; see Chapter 5).

The zygomatic nerve is a branch off the infraorbital nerve (V\textsubscript{2}) and travels along the lateral orbital wall. It might divide into a zygomaticofacial branch and zygomaticotemporal branch prior to entering the zygomatic bone or within the zygomatic bone itself. The zygomaticotemporal branch exits in the temporalis fossa to supply sensation to the skin in the lateral portion of the upper eyelid and temple, and the zygomaticofacial branch exists over the zygomatic prominence to supply skin in the region (Fig. 1-19). The zygomatic nerve is thought to carry parasympathetic and
sympathetic nerve fibers destined for the lacrimal gland (see Fig. 5-9B). These nerve fibers exit the zygomatic nerve prior to this nerve’s entering into the zygomatic bone, and they join the lacrimal nerve, whereupon they travel to the lacrimal gland and take part in reflex tear secretion.

Clinical Application

- It is commonly believed that the postoperative symptoms of frontoparietal scalp anesthesia and itching associated with a coronal incision are the result of transection of the supraorbital nerve branches as they course from the superior orbital margin over the frontalis muscle onto the scalp. One often-stated advantage of a subcutaneous forehead lift is that this technique preserves scalp sensation. This belief is based on the generally held concept that the supraorbital nerve branches running over the frontalis muscle and thought to innervate the frontoparietal scalp will be preserved. A subcutaneous forehead lift will preserve frontoparietal scalp sensation, but not because the incision spares the supraorbital nerve branches running over the frontalis muscle. Rather, it is because the incision does not penetrate the galea aponeurotica; therefore, the deep division of the supraorbital nerve that supplies frontoparietal scalp sensation is preserved. During endoscopic forehead lifting, numbness and itching in the frontoparietal area are possible if the deep branch is injured during the dissection of pericranium away from bone; however, they are much less common than with a coronal incision.

1–3–6 Blood Vessels

The eyelids are extremely vascular structures, having blood vessels entering medially and laterally with multiple anastomoses throughout the eyelid (Figs. 1-20A and 1-20B). The vascular network of the eyelid is also an area where anastomoses of vessels from the internal carotid system by way of the branches of the ophthalmic (supraorbital, supratrochlear, dorsonasal, and lacrimal arteries) occur with terminal branches of vessels derived from the external carotid system—fine branches of the facial, angular, superficial temporal, and infraorbital arteries. Many of the vessels are commonly encountered during eyelid and anterior orbital surgery.

The supraorbital artery (a branch of the ophthalmic artery) passes through the supraorbital notch and sometimes divides, giving rise to a smaller medial frontal branch. These supply the skin of the forehead and upper eyelid and anastomose with the same vessels from the opposite side and with the superficial temporal artery laterally. They are often seen during a medial orbital surgical approach (Lynch-type incision).

The supratrochlear artery (or frontal artery) is one of the terminal branches of the ophthalmic artery. It pierces the orbital septum in the region of the trochlea and proceeds superiorly, terminating in the medial forehead and scalp.

The dorsonasal artery (or infratrochlear artery) is another terminal branch of the ophthalmic artery. It pierces the orbital septum between the MCT and the trochlea and anastomoses with the angular artery (a direct extension of the facial artery). It supplies the nasal bridge, the scalp, the forehead near the midline, and occasionally the lacrimal sac.
FIGURE 1-20  (A) Arteries in the upper and lower eyelids. (B) Veins in the upper and lower eyelids.
The *facial artery* from the external carotid system passes toward the nasolabial angle, upward beneath the lip levator muscles, and below the infraorbital foramen, to run to the medial angle of the eye along the line of the nasojugal fold. Here known as the *angular artery*, it runs medial to the angular vein and crosses the medial palpebral ligament, anastomosing with the dorsonasal artery. The angular vessels are commonly seen during a DCR incision and might have to be cauterized in order to avoid bleeding.

The *superficial temporal artery*, a terminal branch of the external carotid, gives off a large frontal branch that passes upward and forward across the temple, supplying the frontalis and orbicularis oculi muscles. It anastomoses with the supraorbital vessels, and branches of it might be seen during brow surgery.

The main arterial vessels within the eyelids are branches of the *medial* and *lateral palpebral arteries*, which are in turn end branches of the ophthalmic and lacrimal arteries, respectively. Medially, two palpebral arteries branch off the ophthalmic artery, one heading to the lower eyelid and one to the upper. Laterally, the palpebral artery arises from the lacrimal artery and will divide to send a branch each to the upper eyelid and the lower eyelid (Fig. 1-20A). In the upper eyelid, as the palpebral branch enters the area of the tarsal plate, it divides in two. One branch runs along the superior edge of the tarsus (at the level of Müller’s muscle, posterior to the levator aponeurosis) to anastomose with the corresponding lateral palpebral branch, forming the peripheral vascular arcade, and the other branch runs along the tarsus just above the lash roots to join with its lateral counterpart, forming the marginal vascular arcade vessel. The peripheral arcade is approximately 9 to 10 mm above the eyelid margin, depending on how high the tarsal plate is, and the marginal arcade is usually about 2.0 mm above the eyelid margin. A similar vascular arcade pathway is followed in the lower eyelid; however, the peripheral vascular arcade is less well defined than in the upper eyelid and is often discontinuous.

There are also numerous veins along the orbital rim and within the eyelid (Fig. 1-20B). The *superior palpebral vein* runs horizontally along the superior orbital margin, anastomosing laterally with the middle temporal branch of the superficial temporal vein. Medially, it pierces the orbicularis muscle below the head of the eyebrow to anastomose with the supraorbital and the supratrochlear vein (also called the frontal vein). As it travels inferiorly, the superficial temporal vein lies just anterior to the ear and is joined by parietal branches. Subsequently, it is joined by the *middle temporal vein* (from the substance of the temporalis muscle), as well as by the *transverse facial vein* from the side of the face. It also receives posterior auricular and occipital veins, as well as veins from the auricle, temporomandibular joint, and parotid gland. As it enters the parotid gland, it unites with the internal maxillary vein to form the posterior facial vein, which enters into the external jugular.

The *angular vein* is formed at the medial end of the eyebrow by the junction of the supraorbital and nasofrontal veins. It communicates with the superior ophthalmic vein via a branch passing
into the orbit below the trochlea. This latter communication is known as the \textit{inferior root of the superior ophthalmic vein}. As the angular vein travels inferior to the MCT and lower orbital rim, it becomes known as the \textit{anterior facial vein} (or facial vein). The facial vein courses lateral to the angular artery across the face, toward the anterior border of the masseter muscle and body of the mandible. It has several important anastomotic connections with the orbit and, therefore, the cavernous sinus. Along its course it receives venous channels originally arising from the inferior ophthalmic vein that traveled over the inferior orbital rim to reach the inferior palpebral vein, infraorbital vein, and facial vein. The facial vein also receives venous drainage from the inferior orbit directly through the infraorbital vein, which communicates with the pterygoid plexus and cavernous sinus. Further along its course, the facial vein receives additional connections with the cavernous sinus by way of the \textit{deep facial vein}, which passes into the infratemporal fossa to join the \textit{pterygoid plexus}, which in turn communicates with the cavernous sinus. Other venous connections include the superior and inferior labial vein, the buccinator, and masseteric veins. The anterior facial vein eventually crosses over the body of the mandible and passes obliquely backward beneath the platysma to unite with the \textit{posterior facial vein} and form the \textit{common facial vein}, which crosses the external carotid and enters the \textit{internal jugular vein} below the hyoid bone.

\section*{1–3–7 Preaponeurotic Fat}

The preaponeurotic fat pockets in the upper and lower eyelid are important surgical landmarks, as they identify the plane immediately posterior to the orbital septum and immediately anterior to

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{antererad.png}
\caption{The preaponeurotic fat is located immediately posterior to the orbital septum and is immediately anterior to the levator aponeurosis in the upper eyelid and the lower lid retractors in the lower eyelid.}
\end{figure}
the major eyelid retractors (levator aponeurosis in the upper eyelids, capsulopalpebral fascia in the lower eyelids). The preaponeurotic fat is confined by the orbital septum (Figs. 1-17 and 1-21). With age, the septum thins, allowing the fat to prolapse, producing the puffy, baggy eyelids seen commonly in the aging adult (Fig. 1-9).

The distinction between individual fat pockets in the upper and lower eyelids has been questioned, but studies have demonstrated the compartmentalization of dye in patients undergoing blepharoplasty operations. The upper eyelid is classically thought to have two fat pockets, one medial and one central, separated by fascial connections continuous with the trochlea. Each is covered by a thin capsule that adheres loosely to the underlying levator aponeurosis. The medial fat pocket is whiter than the central and contains more interlobular septa. The central pocket might also extend laterally and appear as a lateral fat pad.

Laterally in the upper eyelid, the lacrimal gland is located just behind the orbital rim. It is located within its own fascial compartment and normally is not seen during upper eyelid surgery. When the fascial support system of the gland becomes lax, it migrates inferiorly and might be mistaken for a lateral fat pocket. Although the central fat pocket commonly extends laterally and lies adjacent to the lacrimal gland, the lacrimal gland’s finely lobulated structure, firmer texture, and pale pinkish-tan color distinguish it as a lacrimal gland.

**Clinical Application**

- During blepharoplasty or ptosis operations in which fat is to be excised, the thin fat capsules must be opened in order to allow fat to prolapse forward. However, when fat is not to be excised, these capsules should be preserved intact in order to prevent fat lobules from migrating inferiorly between the orbicularis and aponeurosis, which might create an “Asian” eyelid appearance.
- Although it is commonly stated that “there is no lateral fat pocket in the upper eyelid” and “if you trim fat in the lateral upper eyelid, you are cutting lacrimal gland,” this is not actually true. It is quite common for the central preaponeurotic fat pocket of the upper eyelid to extend laterally (mimicking a lateral fat pocket) and cover the anterior aspect of the lacrimal gland. The septum over this area can be easily incised and the fat gently teased out and trimmed in order to debulk the lateral upper eyelid. Immediately beneath this lateral fat is the lacrimal gland.
- Following trauma to the eyelids, prolapse of orbital fat into the wound occurs with lacerations of the orbital septum. The orbital fat is a useful landmark, as the surgeon will know the exact layer that he or she is in. Immediately posterior, one should find the levator, and immediately anterior are the septum and orbicularis muscle. During repair of the laceration, the exposed fat is generally not excised. Rather, it is moistened with saline and light cautery is applied over its surface; it can generally be easily cauterized back into the eyelid. The septum is not closed, as this frequently causes shortening of this structure with resultant lagophthalmos. Commonly, the lid skin and orbicularis tear as a unit. They may be closed together but are generally closed as separate layers into their normal anatomical location with 6-0 plain sutures.
1–3–8 Levator Muscle and Whitnall’s Ligament

The levator palpebrae superioris takes origin from the lesser wing of the sphenoid bone adjacent to the annulus of Zinn (some anatomists believe that it arises from the annulus of Zinn as well as from the lesser wing of the sphenoid). The levator is the main upper eyelid retractor and is composed of a muscle portion and an aponeurotic portion. The overall length is about 50 mm (approximately 36 mm of muscle and 14 to 20 mm of aponeurosis). At its origin it is about 4 mm in width, widening to 8 mm in the mid-orbit, and by the time it gets to the superior orbital rim, just prior to turning into the aponeurosis and in the area of Whitnall’s superior transverse ligament, it widens to about 18 mm. As it proceeds anteriorly, it remains in close approximation to the superior rectus muscle (fibrous connective tissue strands extend between the two). The levator also lies adjacent to the periorbita of the orbital plate of the frontal bone. Approximately 15 to 20 mm above the superior border of the tarsus (which is generally the orbital rim level), horizontally oriented connective tissue fibers serve as a suspensory ligament for the upper eyelid—the superior transverse orbital ligament of Whitnall, also known as Whitnall’s ligament (Figs. 1-22A through 1-22C).

Whitnall’s ligament consists of a condensation of connective tissue anterior and posterior to the levator. The anterior component is better defined and is seen routinely during anterior approach ptosis surgery. It runs horizontally just below the orbital rim and is seen as a glistening white structure clinically (Fig. 1-22B). Whitnall’s ligament has strong attachments to the fascia around the trochlear area and to the surrounding orbital bone. A fine band of fibers also extends downward from Whitnall’s ligament along the edge of the medial horn of the levator aponeurosis and joins the medial head of Lockwood’s ligament just behind the canthal angle and medial conjunctival fornix. Whitnall’s ligament extends laterally through the lacrimal gland (supporting it) to insert in the periosteum along the superolateral orbital wall (frontal bone) (Fig. 1-22C). It also sends a small branch to to Whitnall’s tubercle and contributes to the lateral retinaculum. A fine band of fibers also continues downward behind the canthal tendon to join a similar band from Lockwood’s ligament in the lower lid. Another extension from Whitnall’s ligament, in conjunction with fibers from the super rectus muscle sheath, passes to the superior conjunctiva to act as the suspensory ligaments of the superior fornix. Whitnall’s ligament is firmly attached to the medial and lateral levator muscle sheaths, but it is only loosely attached centrally. At Whitnall’s ligament, the levator muscle is reoriented from the anteroposterior to a superoinferior direction. At the same level, it gradually turns into an aponeurosis.

The exact role of Whitnall’s ligament has been a matter of some controversy. In part, it has a suspensory role for the anterior superior orbital tissues. This includes suspension of the anterior levator muscle, superior conjunctival fornix, Tenon’s capsule, and the tendon of the superior oblique muscle. Whitnall’s ligament also adds support to the lacrimal gland and, if cut during ptosis surgery, might lead to lacrimal gland prolapse. Another important function of Whitnall’s ligament is to maintain the topographic relationships among various superior orbital structures during ocular movement, especially upgaze. Thus, the eyelid, conjunctival fornix, and lacrimal gland show coordinated movements with the globe. Whitnall’s ligament might also act as a pulley or fulcrum for the upper eyelid, changing the contraction force of the levator muscle from an
FIGURE 1-22  (A) Levator muscle and Whitnall’s ligament as seen from above. (B) During a ptosis procedure, Whitnall’s ligament is visualized as a horizontal running fascial structure (black arrow). The preaponeurotic fat (blue arrow) and levator aponeurosis (white arrow) are shown.
anteroposterior to a superoinferior direction. In addition, Whitnall’s ligament might serve as a check ligament against posterior excursion of the levator muscle and through its connecting ligaments, the superior rectus muscle. This role, however, is for the most part clinically insignificant.

With Lockwood’s ligament in the lower eyelid, it forms a circumorbital fascial ring. Together, both of these structures function to integrate the entire anterior orbit—including the globe, conjunctiva, canthal tendons, and eyelids—into a single functional unit.

Anterior to Whitnall’s ligament, the levator aponeurosis travels inferiorly some 15 to 20 mm toward the tarsus. The orbital septum fuses with the levator aponeurosis prior to reaching the superior border of the tarsus. At the inferior edge of this fusion, the aponeurosis divides into a fan-like arrangement of fibers sitting on the tarsal plate. Beginning near the upper edge of the tarsus, the aponeurosis sends numerous delicate, interconnecting slips anteriorly through the orbicularis toward the skin, where they form the eyelid crease. The rest of the levator extends more inferiorly to insert into the pretarsal fascia and the tarsal plate, where it is most firmly adherent to the tarsus about 3 mm above the eyelid margin.

The levator aponeurosis adheres to underlying Müller’s muscle via loose connective tissue that can be easily dissected during ptosis surgery or levator recession surgery. This plane not uncommonly contains small collections of fat that might be adherent to the aponeurosis or which might infiltrate into Müller’s muscle. Anteriorly, the aponeurosis is separated from the orbital septum by the preaponeurotic fat pads and from the orbicularis muscle just above the tarsus by the postorbicular araeolar tissue.

As the levator aponeurosis passes into the eyelid from Whitnall’s ligament, it fans out both medially and laterally, creating its “horns.” The lateral horn is stronger and well defined. This horn passes through the lacrimal gland between the orbital and palpebral lobes en route to Whitnall’s
tubercle and the adjacent periosteum, where it inserts. It is contiguous with the superior border of the LCT and contributes to the lateral retinaculum. The medial horn passes medially to attach loosely to the posterior limb of the MCT, as well as attaching to the posterior lacrimal crest and adjacent periosteum of the medial orbital wall. The horns hold the upper eyelid in firm contact with the globe when the eye is opened.

Recently, smooth muscle fibers (separate from those in Müller’s muscle—see below) have been identified within the aponeurosis of both Caucasian and Asian eyelids. Although their exact role is unknown, the finding of smooth muscle fibers within the aponeurosis is compatible with the hypothesis that the levator aponeurosis might regulate tension in the anterior lamella of the upper eyelid, whereas Müller’s muscle might regulate the tension of the posterior lamella.

Clinical Application

- The most common type of adult acquired ptosis is due to thinning (as a result of aging) and stretching of the aponeurosis. Less frequently, the aponeurosis can show spontaneous local areas of dehiscence or, rarely, frank disinsertion from the tarsal plate.
- Ptosis after cataract surgery is not uncommon. It is thought to result from stretching and traction applied to a thin levator aponeurosis as a result of manipulation of the superior rectus and levator muscles. Just behind Whitnall’s ligament, extensive fascial attachments exist between the sheaths of the levator and superior rectus muscles, as well as the superior conjunctival fornix and Tenon’s capsule. With an eyelid speculum pulling the tarsus upward and rotation of the globe downward, with or without a traction suture, there might be disruption of these fascial attachments, as well as stretching of the actual aponeurosis, resulting in a droopy lid postsurgery.
- Ptosis repair is generally directed at the source of the pathology by shortening or reattaching the aponeurosis to the tarsus. Most commonly, the levator aponeurosis is advanced; however, some prefer levator muscle resection and advancement. Others prefer a Fasanella-Servat procedure. In this latter procedure, the superior tarsus, with some conjunctiva and occasionally Müller’s muscle, is resected (through a posterior eyelid approach) in order to raise the lid. The levator aponeurosis and levator muscle are not involved.
- Ptosis surgery can be done through an anterior skin approach or a posterior conjunctival approach. Which is done is a surgeon’s individual preference.
- During anterior approach “aponeurotic” advancement ptosis surgery, Whitnall’s ligament is left intact, and only the central aponeurosis is advanced. During anterior approach “levator muscle” resection with advancement, Whitnall’s ligament is cut medially and laterally. Cutting this structure results in marked proplapse of the levator muscle, which requires significantly more resection than would otherwise be necessary in “aponeurotic” advancement.
- A Whitnall’s sling ptosis procedure involves advancing the levator aponeurosis (up to the level of Whitnall’s ligament) down to the tarsal plate and incorporating some of Whitnall’s ligament into the advancement of aponeurotic tissue onto tarsal plate.
1–3-9 Müller’s Muscle

Smooth muscles innervated by the sympathetic nervous system are present in both the upper and the lower eyelid. In the upper eyelid, the *supratarsal muscle of Müller* takes origin from the undersurface of the levator at about the musculoaponeurotic junction (at or just distal to the level of Whitnall’s ligament) (Figs. 1-23A and 1-23B). Müller’s muscle lies between the levator aponeurosis and the conjunctiva, measures 8 to 12 mm in length and 0.1 to 0.5 mm in thickness, and spans nearly the width of the tarsus. It travels inferiorly to insert onto the superior edge of the tarsal plate. The sympathetic nerve fibers innervating Müller’s muscle in the upper eyelid (and its analogous structure in the lower eyelid) are derived from the paravertebral sympathetic chain via the internal

**FIGURE 1-23** Müller’s muscle. (A) Origin and surrounding structures. (B) During a levator–Müller’s advancement procedure of the left upper lid, the levator was dissected away from the underlying Müller’s muscle and can be seen rolled on itself (black arrow). Müller’s muscle (white arrow) is fatty-infiltrated and has been dissected away from the underlying conjunctiva.
carotid plexus. Innervation is thought to reach these muscles via sympathetic nerve fibers recently identified within the infratrochlear nerve as well as the lacrimal nerve. With age, the muscle often appears yellow due to fatty infiltration.

**Clinical Application**

- Interruption of the ocular sympathetic nerve fibers will produce Horner’s syndrome: ptosis, miosis, apparent enophthalmos, and anhidrosis of the face. Upper eyelid ptosis and elevation of the lower eyelid result from a loss of the sympathetic smooth muscle tone. This gives the eye an appearance of being enopthalmic, although the actual globe position is unchanged—it is due simply to the change in fissure height, and therefore is only an “apparent enophthalmos.”

- Eyelid sympathetic nerves are also implicated in eyelid retraction associated with Graves’ disease (thyroid eye disease). Increased adrenergic stimulation to Müller’s will retract the upper and lower eyelids, giving the patient a characteristic stare. However, cicatricial shortening of the levator and Müller’s muscle, as well as fibrosis along the anterior orbital fascial septa, probably plays a more significant role in causing the eyelid retraction associated with thyroid eye disease.

There is another sympathetically innervated Müller’s muscle within the orbit that has not been well recognized: the **orbital muscle of Müller** (Fig. 1-24). In the region of the inferior orbital fissure, on the superficial aspect of the periorbita, this mass of smooth muscle is also called the *sphenomaxillary muscle*. It fills the inferior orbital fissure, being about 2 or 3 mm thick at its center, and spreads fanwise at its extremities in a thin sheet over the orbital floor. It can be regarded as a vestigial structure in humans. In lower animals, it completes the lateral orbital wall, which is incomplete.

### 1–3–10 Tarsal Plate

The **tarsus** consists of a plate of dense, fibrous connective tissue with a thickness of approximately 0.8 to 1.0 mm. Each measures about 25 mm in length, and they are gently curved to conform to the eyeball. The central vertical height of the tarsal plate is 10 to 12 mm in the upper eyelid and 3 to 4 mm in the lower eyelid. Medially and laterally, the tarsal plates taper to 2 mm in height at the point at which they pass into the canthal tendons. There is no cartilage within the human tarsus. Lower animals, such as the rat, do have tarsal plates made of cartilage. The tarsus provides structural support for the eyelid and must be replaced or repaired during eyelid reconstruction in order to prevent eyelid skin from rolling onto the eye surface.

The **meibomian glands**, located within the tarsus, consist of elongated structures with long axes that are vertical to the free eyelid margin. The upper eyelid contains about 25 to 30 meibomian glands, and the lower eyelid has approximately 15 to 20. They are branching tubuloalveolar sebaceous glands that empty into a central ductule, which opens onto the posterior eyelid margin just behind the gray line. They produce the lipid layer of the precorneal tear film.
Clinical Application

- Obstruction of the meibomian gland ductules by lipid and cellular debris (blepharitis) might result in lipogranulomatous inflammation and frank cellulitis and the clinical manifestations of a chalzion.
- The meibomian glands do not usually produce cilia. In congenital distichiasis and acquired distichiasis associated with chronic inflammatory eyelid diseases, the meibomian glands might start producing cilia. This might represent regressive metaplasia of a specialized sebaceous gland back to a pilosebaceous unit.

1–3-11 Eyelid Margin

At the eyelid margin, a transition occurs between the skin of the eyelid and the palpebral conjunctiva. Eyelid skin is keratinized, stratified squamous epithelium, whereas the eyelid margin is nonkeratinized squamous epithelium, and the conjunctiva is nonkeratinized columnar epithelium. The transition to a nonkeratinized epithelium is known as the mucocutaneous junction and provides the eyelid margin with a smooth, nonabrasive surface. The mucocutaneous junction is
generally located at the posterior lid margin, posterior to the meibomian gland openings; however, its location is variable. It can be seen anywhere from the area of the gray line anterior to the meibomian gland openings to 2 mm inferior to the posterior lid margin (on the lower eyelid). The mucocutaneous junction line is known to migrate posteriorly with exposure (e.g., ectropion) and anteriorly with marginal entropion.

A sagittal cross-section of the eyelid margin reveals two components: the *tarsal portion* (containing the tarsus) and the *ciliary portion* (containing lash follicles and the orbicularis) (Fig. 1-12). The eyelashes or cilia form two or three irregularly arranged rows in each eyelid. Long and thick or full eyelashes are a symbol of beauty and femininity in many cultures, whereas the loss of lashes has been associated with a loss of attractiveness and psychosocial distress. For thousands of years, women have employed techniques to enhance the prominence of their eyelashes, but eyelashes are more than purely aesthetic in nature; by defending the eye against debris and triggering the blink reflex, they serve a protective function against airborne particles. Upper eyelashes are more numerous (100 to 150) and longer (8 to 12 mm) than lower lashes (50 to 75 in number, 6 to 8 mm in length) and, unlike the lower lashes, curve upward. Of all human hairs, eyelashes are the widest and most pigmented. They do not typically turn gray with age. Unlike other hairs, eyelashes are devoid of arrector muscles. They pass into the eyelid obliquely in front of the *muscle of Riolan*. The eyelashes are richly supplied with nerves and are therefore very sensitive to touch. The normal life span of an eyelash is 5 to 12 months. The growth of eyelashes is cyclical, and at any one time some are in their growth phase (1 to 2 months in duration, growing at approximately 0.15 mm/day) while others are dormant. Sebaceous glands attached directly to the follicle of the eyelash are seen along the lid margin and are known as the *glands of Zeis*. These glands are modified sebaceous glands, and there are generally two per lash. The oily secretion produced serves to prevent the eyelash from becoming dry and brittle. The *glands of Moll* are also located along the eyelid margin and are associated with the lash follicle. These glands are modified apocrine glands, or sweat glands, that have become arrested in their development. They open into the lash follicles or directly onto the eyelid margin and occur more frequently in the lower lid. Unlike the glands of Zeis, not every lash follicle has a gland of Moll.

The gray line (*sulcus intermarginalis of Graefe*) represents the junction between the tarsal portion of the eyelid and the ciliary portion. It is continuous with the postorbicular fascial plane described earlier. It also marks the separation plane between the anterior lamella and the posterior lamella. In addition, the gray line represents the surface marking of a thin strip of muscle (*muscle of Riolan*, described below) as seen through the thin skin of the eyelid margin. Clinically, the gray line, as visualized with the slit lamp, is 0.5 to 0.8 mm in width. It appears as a distinct “gray” line because of differential spectral absorption and differential reflectance of muscle viewed beneath thin skin.

A bundle of thin muscle fibers present along the entire length of the eyelid margin located between the tarsal plate and the eyelash follicles is known as the *muscle of Riolan*. These fibers are anatomically separated from the much larger pretarsal orbicularis muscle by a space, in which lie the eyelash bulbs. The muscle of Riolan arises laterally from the deep surface of the pretarsal orbicularis muscle near the junction of the tarsal plate and the LCT. Along the upper and lower eyelid margins, the muscle fibers run in a horizontal band corresponding to the anatomic gray line. Medially, the main portions of the muscles of Riolan insert onto the puncta and ampulla of the
Surgical Anatomy of the Ocular Adnexa

The lacrimal drainage system. Deeper fibers pass posterior to the canaliculi for a short distance before they finally blend into the deep heads of the pretarsal orbicularis muscle (Fig. 1-26) (the origin of Horner’s muscle). This blending of the muscle of Riolan with the deep head of the pretarsal orbicularis is consistent with the clinical observation that no gray line is visualized medial to the punctum.

On closer inspection, the muscle of Riolan is made of three components. The largest component corresponding to that portion running along the gray line is referred to as the pars ciliaris. Some prominent bundles of the pars ciliaris lie in close approximation to the lash follicles of the eyelid. Smaller bundles (pars subtarsalis) also can be seen posterior to the meibomian gland duct openings within the substance of the tarsal plate and subconjunctivally on the palpebral surface of the eyelid. There are also numerous discrete muscle fascicles (pars fascicularis) that pass between these two muscle groups and around individual meibomian gland units. Unlike the orbicularis muscle, the fibers of which run circumferentially around the eyelids, fibers in the muscle of Riolan are arranged in very short, discrete bundles that run in various directions.

At one time, the muscle of Riolan was thought to function in keeping the eyelid edges in close approximation to the surface of the globe. As a result, some investigators suggested that it might play a role in the development of ectropion and entropion. The relationship between the muscle of Riolan (pars ciliaris) and the eyelash bulbs suggests a possible role in eyelash movement during the blink cycle. However, this remains to be clarified. Other fibers (pars fascicularis) penetrate deeply into the distal tarsus, where minute fiber bundles surround the acini and ductules of the meibomian glands. As the orbicularis contracts, these fibers contract, compressing the meibomian gland ductules and aiding in the expression of their contents. The muscle of Riolan might therefore play a direct role in the expression of meibomian gland secretions. As an alternate hypothesis, this muscular complex could compress the meibomian gland orifices in order to prevent glandular flow.

Clinical Application

- In addition to the normal variation in eyelash appearance between individuals, some patients experience the loss of previously normal lashes, a condition termed madarosis or milphosis.
- There are multiple causes of madarosis, including skin diseases (alopecia areata), endocrine diseases (hypo- or hyperthyroidism), drugs (propranolol), trauma (radiation, lid surgery), infectious disease (herpes zoster, leprosy), inflammation (blepharitis), neoplasm (basal cell carcinoma, sebaceous gland adenocarcinoma), and intoxication (arsenic, vitamin A, quinine).
- Isolated lash misdirection, as well as lash loss, is one of the early signs of an eyelid marginal neoplasm (e.g., basal cell carcinoma). There might also be a subtle disruption of the normal lid contour and some fine telangiectasia along the lid margin. If there is any suspicion of neoplasm, a full thickness pentagon of lid tissue should be excised in order to assess the cellular architecture.
- Acquired hypertrichosis of the eyelashes (excessive growth of the hair) is an established side effect associated with topical prostaglandins, such as latanoprost or bimatoprost, used
in glaucoma treatment. This medication prolongs the anagen (growth) phase of the hair cycle. A commercial form (Latisse) is available for those individuals interested in enhancing the appearance of their eyelashes that will grow longer, fuller, more pigmented eyelashes with nightly application along the lash roots. Other causes of hypertrichosis include immunodeficiency states (HIV infection), immunosuppressive medication, malnutrition, and ocular inflammation (uveitis).

- A gland of Zeis or a gland of Moll will not uncommonly become blocked. The blocked Zeis gland appears as a yellow cystic structure at the base of an eyelash. The yellow color is due to the sebum content. A blocked gland of Moll appears as a clear fluid-filled cyst or “water bubble” at the base of an eyelash. Occasionally, a gland of Moll will drain into the duct of a gland of Zeis rather than onto the lid margin. If this particular gland blocks, one will see a clear fluid-filled cyst with some yellow deposits (sebum) within it.

- The gray line is seen better in some individuals than in others and, if surgically incised, will split the eyelid into an anterior and posterior lamella.

- During full thickness eyelid laceration repair, it is important to align the lid margin as precisely as possible in order to obtain a smooth lid contour and avoid notching. To do this, the surgeon can use the meibomian glands, the gray line, or the eyelash line to realign the lids. Which to use often depends on the eyelid in question, as well as the nature of the eyelid laceration. In some individuals, the gray line is not well visualized, and it is best to use one of the other landmarks to realign the lid contour. The gray line is the weakest of the three landmarks, as it represents an anatomical fracture plane between the anterior lamella and the posterior lamella. Because of this, many surgeons prefer using the lash line or the meibomian glands to align the lid margin. However, if the gray line is well visualized, it is a good landmark to use and always can be used in conjunction with one of the other (stronger) landmarks.

1–4 LOWER EYELID AND THE EYELID–CHEEK JUNCTION AREA

The lower eyelid is shorter and less mobile than the upper, but it has analogous anatomic structures. The lower eyelid crease is more noticeable in childhood and becomes less well defined with age. The crease is formed by cutaneous insertions of fibers from the lower eyelid capsulopalpebral fascia or lower eyelid retractors. The crease is usually 2 to 3 mm from the medial eyelid margin and 5 to 6 mm below the eyelid margin laterally. (The orbicularis muscle is described in the section on the upper eyelid.) The superficial musculoaponeurotic system (SMAS) is an important fibrous connective tissue layer that invests facial muscles throughout the face. The SMAS also invests the lower eyelid orbicularis oculi. There are important osseocutaneous ligaments along the orbital rim (orbital malar ligament or orbicularis retaining ligament) and over the zygomatic bone (zygomatic ligaments) that have an important supportive role to the SMAS and adjacent soft tissue. Laxity of these ligaments contributes to the characteristic baggy eyelids associated with the aging process.
**1–4–1 Tarsal Plate**

The lower eyelid tarsal plate is shorter than the upper, averaging 3 to 4 mm in most individuals. It otherwise has the same structure and function as the upper. A sagittal view of the normal lower eyelid anatomy can be seen in Figure 1-25.

**Clinical Application**

- During lower eyelid reconstruction, as in upper eyelid reconstruction, it is important to consider the eyelid as having an anterior and a posterior lamella. Each lamella requires reconstruction following tumor resection or trauma.
- The “middle lamellae” is another term occasionally used when referring to lower lid retraction following lower lid blepharoplasty surgery. One of the contributing factors is felt to be scar tissue involving the lower eyelid capsulopalpebral fascia layer (lower lid retractors), which is the middle lamella of the lower eyelid.

**1–4–2 Orbital Septum and Preaponeurotic Fat**

In the lower eyelid, the orbital septum is the anterior border of the fat compartment, just as it is in the upper. The septum can be multilayered and thins with age, allowing fat to migrate forward.
There are three fat pads in the lower eyelid—medial, central, and lateral—separated by fascial connections between the capsulopalpebral fascia and the orbital septum. The central and lateral fat pockets are separated by a connective tissue band, the arcuate expansion, extending from the capsulopalpebral fascia to the inferolateral orbital rim. During lower blepharoplasty from a skin approach, it is very obvious. The lateral fat pocket can be multiple, which explains the frequent residual lateral lid bulge after lower blepharoplasty surgery. The fat located nasally in the lower eyelid is divided by the inferior oblique muscle and its fascial attachment into two compartments: the medial fat pad, which is whiter and denser than the second compartment, the central fat pad, which appears more yellow (Fig. 1-26).

Clinical Application

- It is important during lower blepharoplasty surgery, when removing fat or transferring fat into the tear trough, to be aware of the location of the inferior oblique muscle. Inadvertently cutting into the inferior oblique will cause excessive bleeding and lead to possible injury, with resultant fibrosis and double vision. Passing a suture through part of it might lead to restriction and resultant double vision, as will excessive cautery in the area.

1–4–3 Capsulopalpebral Fascia, Lower Lid Retractors, and Lockwood’s Ligament

In the lower eyelids, the capsulopalpebral fascia is a fibrous sheet arising from the sheaths around the inferior rectus and inferior oblique muscles (Fig. 1-25). After originating from the inferior rectus muscle (Fig. 1-27), the head of the capsulopalpebral fascia splits into two sections to envelop the inferior oblique muscle. The two portions of the capsulopalpebral head then reunite. From this
position, fascial contributions will help form Lockwood’s ligament. The capsulopalpebral fascia then passes anteriorly and then superiorly in the lower eyelid to fuse with fibers of the orbital septum approximately 4 to 5 mm below the tarsal plate. From this junction, a common fascial sheet continues upward and inserts onto the lower border of the tarsus; however, it is controversial whether it inserts directly into the tarsal border or just inferior to the tarsus. Fine slips of fibrous tissue pass anteriorly from the capsulopalpebral fascia through orbicularis muscle septa toward skin, forming the lower eyelid crease.

The capsulopalpebral fascia (with some contribution from the lower eyelid sympathetic muscle) function as the lower eyelid retractors (Fig. 1-25) and are analogous to the upper eyelid retractors (levator aponeurosis and Müller’s muscle). In the upper eyelid, the levator/Müller’s muscle complex allows a high degree of mobility due to its muscle component. The lower eyelid retractors are primarily a fibrous, tendonous extension from the fascia around the inferior rectus, with only a minor muscle component. Thus, although the lower eyelid has some movement when the eyeball moves in downgaze, it is much less than that noted in the upper eyelid. The range of motion in the upper eyelid (i.e., levator function) is normally 12 to 18 mm from downgaze to upgaze. In the lower, the range of motion (i.e., from upgaze to downgaze) is usually 3 to 5 mm.

Lockwood’s ligament in the lower eyelid is analogous to Whitnall’s ligament in the upper eyelid (Figs. 1-22C, 1-23A, and 1-25). It is a broad suspensory fascial sling of the anterior-inferior orbit, composed of fascia from several structures. It is approximately 40 to 45 mm long, 5 to 8 mm wide, and 1 mm thick, and it lies just anterior to and above the inferior oblique muscle. It has contributions from the lower eyelid capsulopalpebral fascia, Tenon’s capsule (fascia bulbi), intermuscular fibrous septa, and fascia surrounding the inferior oblique and inferior rectus muscles. The lower eyelid capsulopalpebral fascia and inferior oblique fascia are the major contributors. The ligament extends laterally to attach to Whitnall’s tubercle and the lateral retinaculum at the lateral orbital wall (in company with the lateral horn of the levator, the LCT, and the lateral check ligaments). Some fibers pass directly to the lateral extension of Whitnall’s ligament and the lateral horn of the levator aponeurosis. Medially, Lockwood’s has attachments to three areas: the anterior arm of the MCT, the posterior lacrimal crest, and an inferior extension from Whitnall ligament, in company with the posterior portion of orbital septum. Thus, Lockwood’s ligament,
along with Whitnall's ligament and the canthal tendons, forms a nearly encircling fascial system around the entrance of the orbit (Fig. 1-23A).

Another extension from Lockwood's ligament passes forward as a sheet of fine fascial bands layered between Tenon's capsule and the capsulopalpebral fascia to insert into the conjunctiva, where they form the suspensory ligaments of the inferior fornix (Fig. 1-25).

The exact function of Lockwood's ligament has not yet been clearly defined. It appears to serve, at least in part, as a suspensory sling (or hammock) for the anterior-inferior orbit. The multiple connections of Lockwood's ligament suggest a more important role in maintaining complex anatomical relationships during anatomical movement. Such relationships certainly involve movement of the lower eyelid and the inferior conjunctival fornix during changes in position of gaze. Lockwood's might also serve to limit the posterior displacement of inferior orbital structures.

Clinical Application

- The congenital absence of the lower lid crease results in a clinical condition known as epiblepharon. In this entity, the marginal eyelid skin rolls upward during downgaze, mechanically pushing the lashes inward toward the cornea. This should not be confused with the rare occurrence of congenital lower eyelid entropion, in which instability of the tarsus and eyelid retractors results in an inward rotation of the tarsal plate—that is, in epiblepharon the tarsal plate is still upright in its normal position, and in congenital entropion the tarsal plate is rotated inward.
- The lower eyelid crease is more noticeable in childhood and becomes less well defined with age.
- Lockwood's ligament is anatomically important in the absence of an orbital floor, for example, following complex midfacial tumor resections requiring the removal of the maxillary antrum. It helps support the orbital structures and forms a sling or hammock for the globe to rest on.
- Entropion and ectropion are common acquired eyelid malpositions. They frequently result from thinning of the capsulopalpebral fascia, horizontal laxity of the medial and/or lateral canthal tendons, and overriding of the orbicularis muscle. The relative contributions of these various factors will determine the exact nature of the eyelid malposition (i.e., whether the eyelid goes ectropic or entropic).

1–4–4 Sympathetic Muscle Fibers

The sympathetic muscle in the lower eyelid is less well defined than its counterpart (Müller’s muscle) in the upper. Scattered bundles of smooth muscle run between the capsulopalpebral fascia and the conjunctiva as a thin layer that can be discontinuous. These sympathetic fibers arise a short distance distal to Lockwood's ligament and end 2 to 5 mm below the tarsal plate (Fig. 1-23A). As discussed earlier, innervation is thought to reach these muscles via sympathetic nerve fibers recently identified within the infratrochlear nerve as well as the lacrimal nerve. Surgically, the sympathetic muscle in the lower eyelid is more difficult to identify than Müller’s muscle in the upper eyelid, as it is very thin and might be discontinuous.
1–4-5 Nerves

The sensory nerves in the lower eyelid are the zygomaticofacial, the infraorbital, and the infratrochlear (Fig. 1-19). The zygomaticofacial nerve, a branch of the maxillary division of the trigeminal nerve, supplies skin in the lateral lower eyelid and upper cheek. The infraorbital nerve has three main branches: the external nasal (skin of the nose and septum), the superior labial (skin of the upper lip and the mucous membrane in the mouth), and the inferior palpebral, which supplies the skin and the conjunctiva of the lower eyelid. The infratrochlear nerve, one of the terminal branches of the nasociliary nerve (an ophthalmic division of the trigeminal nerve), supplies the skin in the medial canthus, medial eyelids (upper and lower), side of the nose, caruncle, conjunctiva, and nasolacrimal sac. As discussed earlier, recent anatomical studies have identified sympathetic fibers within the infratrochlear nerve. These fibers, as well as sympathetic fibers also identified in the lacrimal nerve, are thought to innervate the sympathetic muscles of the upper and lower eyelids.

Clinical Application

- During a DCR procedure, local anesthetic is deposited beneath the skin over the anterior lacrimal crest, as well as posteriorly in the area of the posterior lacrimal crest. It is the infratrochlear nerve that is the main nerve being anesthetized.

1–4-6 Blood Vessels

The lower eyelid, like the upper, has a medial and a lateral palpebral vessel, arising as an end branch of the ophthalmic and lacrimal artery, respectively (Fig. 1-20A). The medial and lateral palpebral vessels anastomose in the lower eyelid, forming a marginal arcade vessel approximately 2.5 mm from the lower eyelid margin. A peripheral arcade vessel might or might not exist. When present, it is a wispy vessel located approximately 4.5 mm from the eyelid margin, and it might exist for only part of the eyelid. The lower eyelid arcade vessels receive contributions from three other sources of external carotid origin: a branch from the facial artery, a branch from the infraorbital artery, and a branch from the anterior deep temporal artery (arising from the internal maxillary artery in the pterygopalatine fossa and traveling forward toward the orbital rim, where it gives off the anastomotic branch to the lower eyelid).

1–4-7 The Lower Eyelid–Cheek Junction: Superficial Musculoaponeurotic System, Orbital Malar Ligament, Malar Fat, and Suborbicularis Oculi Fat

A superficial fascia that encompasses the facial musculature has been described by many authors. The various muscles of facial expression are cutaneous muscles lying within the layers of the
superficial fascia, which also contains the superficial blood vessels and nerves. This distinct layer has both muscular and connective tissue components and has become known as the superficial musculoaponeurotic system (SMAS). It is believed that the SMAS acts as a distributor of facial muscle contractions to the skin and that facial expressions result from contractions of facial muscles transmitted to the skin by the SMAS network. The SMAS has been shown to invest the mimetic muscles throughout the face (e.g., parotid and cheek area, nose, upper lip, nasolabial fold, chin) so as to form a single anatomic unit. It is continuous with the platysma muscle and cervical fascia of the neck, as well as with the superficial temporalis fascia (temporoparietal fascia) and galea aponeurotica encompassing the skull. Several studies have also documented that the SMAS also invests the orbicularis oculi; however, until recently information regarding its relation to the bony orbit has been lacking. There has been considerable interest in the superficial fascia (SMAS) and its relations to facial muscles in recent years. This interest has become increasingly important with the development and refinement of rhytidectomy and blepharoplasty techniques.

The SMAS sits immediately adjacent to the parotid fascia (or parotid-masseteric fascia) in the pretragal region and is densely attached to the parotid fascia (Fig. 1-5). Superior to the zygomatic arch, the SMAS is continuous with the STF (temporoparietal fascia). Inferior, the SMAS becomes continuous with the platysma muscle. Anterior, the SMAS becomes firmly adherent via bony attachments to the zygomatic arch. Approaching the orbital region, the SMAS invests the orbicularis oculi muscle fibers. It is firmly adherent to the zygoma at the lateral orbital rim. These firm attachments usually extend on to the anterior surface of the zygoma beyond the arcus marginalis for an average of 4 to 5 mm. The SMAS also inserts along the orbital rim circumferentially at the level of the arcus marginalis through connective tissue attachments. This distinct attachment to bone extends from thickened periosteum along the inferior orbital rim through the submuscular fat, becoming lamellar in nature while passing through the orbicularis oculi muscle, and subsequently inserting into skin. This connective tissue attachment is known as the orbital malar ligament or the orbicularis retaining ligament (Figs. 1-28 and 1-29A). Histologically, it has been shown to be made up of collagen and elastin passing through the orbicularis oculi muscle overlying the inferior orbital rim and inserting into the malar dermis. It extends across the inferior orbital rim and helps support the facial musculature and SMAS in the area prior to inserting into the dermis. The orbital malar ligament (or orbicularis retaining ligament) is distinct from the orbital septum. The actual origin of the orbital malar ligament (orbicularis retaining ligament) is 2 to 3 mm away from the insertion of the orbital septum along the inferior orbital rim. There is continuity of the orbital malar ligament (orbicularis retaining ligament) along the inferior orbital rim with the strong attachment of the SMAS to the lateral orbital rim described above. This strong attachment of the SMAS to the lateral orbital rim should be considered the lateral component of the orbital malar ligament. Beyond this, the orbital malar ligament (orbicularis retaining ligament) merges with a condensation of the superficial (SMAS) and deep fascia that cross the frontal process of the zygoma onto the deep temporal fascia. This condensation of fascia has been termed the “lateral orbital thickening.” The lateral orbital thickening, the orbital malar ligament, and the lateral palpebral raphe of the orbicularis oculi form an anatomic unit. This unit is also connected to the LCT through facial connections between the orbicularis and the LCT. Clinically, release of the lateral orbital malar ligament and lateral orbital thickening are required before untethered redraping of the lateral preseptal orbicularis oculi can be
carried out. At the medial orbital rim, the SMAS layer inserts on the anterior lacrimal crest, mirroring the origin of the orbital septum.

The **zygomatic cutaneous ligaments** are additional osseocutaneous ligaments (stronger than the orbital malar ligament) located on the zygomatic body (Fig. 1-28). Their location is just a few millimeters posterior to the origin of the zygomaticus major muscle. They extend in a curvilinear fashion toward the origin of the zygomaticus minor muscle (approximately 7 to 20 mm in length). The inferolateral margin of the orbicularis oculi muscle is in close proximity to the medial portion of the zygomatic cutaneous ligaments. The fibers of the zygomatic ligaments extend through the SMAS, inserting into the dermis. Like the orbital malar ligament, the zygomatic ligaments are rich in elastin tissue. Well-developed connective tissue attachments can also be found arising as discrete condensations of fascia over the masseter muscle. These attachments extend to the deep surface of the SMAS and then through the SMAS to insert into the dermis, although the dermal attachments might not always be present. These **masseteric cutaneous ligaments** begin approximately 40 mm anterior to the tragus (Fig. 1-28). Their superior extent is the zygomatic arch in close proximity to the zygomatic-cutaneous ligaments, and their inferior extent is the jaw line.

The SMAS divides the subcutaneous fat into two layers: that which is directly subcutaneous, lying between the skin and the SMAS, and that which is submuscular or sub-SMAS. In the malar region, the subcutaneous fat anterior to the SMAS is known as **malar fat** (Figs. 1-29A and 1-29B). The malar fat contributes significantly to the midfacial soft tissue volume. This fat generally extends anterior to the orbicularis to the level of the inferior orbital rim. The thickest portion of this subcutaneous fat pad is approximately 40 mm directly inferior to the lateral canthus. In the aging face, this measurement increases. The thickness of this fat pad is variable but can range from 2 to 10+ mm.
FIGURE 1-29  (A) The orbital malar ligament or orbicularis retaining ligament is seen to indirectly attach to the orbicularis oculi at the periosteum of the orbital rim. The superficial musculoaponeurotic system (SMAS) is located anteriorly and posteriorly to the orbicularis muscle. Note the difference in location of the malar fat from the suborbicularis oculi fat (SOOF). (B) A schematic drawing of the upper and lower eyelid soft tissue relationships illustrating analogous structures, e.g., ROOF vs. SOOF, SMAS vs. galea, orbital septum vs. orbital septum, Whitnall’s vs. Lockwood’s, levator vs. lower eyelid retractors, etc.
The malar fat is continuous inferiorly with the jowl fat extending beneath the jawline. There is also subcutaneous fat posterior to the SMAS (sub-SMAS fat) in the malar area. This sub-SMAS fat layer extends toward the orbital rim and is known as the suborbicularis oculi fat (SOOF), and is analogous to the brow fat pad, also known as the retro-orbicularis oculi fat (ROOF) (Figs. 1-29B, 1-30A, and 1-30B). Laterally, the malar sub-SMAS fat (SOOF) is bounded by the bony attachments of the SMAS to the zygomatic arch (zygomatic-cutaneous ligaments). Extending medially, the zygomaticus major, zygomaticus minor, and levator labii superioris muscles penetrate the substance of the SOOF (Fig. 1-30B). Further medially, the SOOF terminates near the lateral border of the levator labii superioris alaeque nasi in the region of the nasolabial fold. Extending superiorly, the SOOF continues to the orbital malar ligament (orbicularis retaining ligament) at the orbital rim level. The SOOF is less substantial than the more superficial malar fat, with an average thickness of 3.0 mm (range: 1–5.5 mm). More fibrous connective tissue is present in the SOOF than in the malar fat. The malar fat has varying degrees of continuity with the SOOF through rents in fibers of the orbicularis oculi and zygomaticus major and minor muscles. The SOOF is also in continuity with the buccal fat inferolaterally.

In the prezygomatic region, a closer look at the fat deep to the orbicularis oculi muscle reveals that it is arranged in two well-defined strata separated by a natural cleavage plane or space. A thin layer of connective tissue adheres tightly to the outer surface of the deeper layer of fat (preperiosteal fat) and separates this deeper layer from the more superficial layer of fat (SOOF) immediately adjacent to the orbicularis oculi muscle (Figs. 1-30A and 1-30B). This prezygomatic space is an entity with characteristics similar to those of other well-known spaces within the superficial fascia of the face (e.g., subgaleal, sub-brow, temporal). That is, there is a spatial separation between the superficial and deep facial fascias; the boundaries of the space are defined by the retaining ligaments, and facial nerve branches course not through but around the space within the boundaries. The prezygomatic space is a “glide plane” located over the zygoma immediately deep to the SOOF and bounded superiorly by the orbital malar ligament (orbicularis retaining ligament) and inferiorly by the zygomatic-cutaneous ligaments and the origin of the lip elevators (levator labii superioris, zygomaticus major, zygomaticus minor). This glide plane is triangular in shape, with its apex pointed medially (Figs. 1-30A and 1-30B). No structures cross this prezygomatic space, although the zygomaticofacial nerve and vessels are located more toward the upper boundary than within the space. The zygomatic branches of the facial nerve that innervates the orbicularis oculi are located along the inferior boundary of this prezygomatic space. These motor nerves enter the pars orbitalis at or near its periphery and do so in four distinct locations. They originate off the main zygomatic branch, which remains at a deep level within the soft yellow fat at the base of the zygomatic retaining ligaments. The four branches head superior as they enter the SOOF and then the preseptal portion of the orbicularis muscle itself. The nerve fibers run perpendicular to the orientation of the orbicularis muscle fibers as they travel superior.

The prezygomatic space and glide plane provide for the independent mobility of the orbicularis oculi in the roof of the space from the lip elevator muscles underlying the floor of the space, and vice versa. The considerable movement of the skin of the lower eyelid and upper cheek that occurs upon contraction of the orbicularis must be associated with an equivalent degree of displacement of the underside of the muscle. In order for the prezygomatic space to function in a way
that allows a gliding movement of the overlying orbicularis, the roof itself must be mobile and not directly attached to the underlying deep fascia. Accordingly, it is only the peripheral attachments at the boundaries that stabilize the roof. The septum-like orbital malar ligament (orcularis retaining ligament) of the upper boundary is considerably less strong than the zygomatic-cutaneous ligaments of the lower boundary. The limited rigidity of the ligament of the upper boundary allows
for the significant movement that occurs across this boundary upon orbicularis contraction, as compared with the “fixation” of the lower boundary. In some ways, the prezygomatic space has similarities with the glide plane space that exists above the superior orbital rim deep to the lower part of the frontalis and orbicularis oculi. Similar to other spaces, the prezygomatic space seems tight in younger patients and becomes more apparent and easier to surgically expand in older patients. Presumably, this is because of the development of laxity of the fibrous connective tissue components of the walls and within the superficial fascia forming the roof. This same laxity might also contribute to the formation of malar mounds, another common feature seen in the aging face.

Continuity of the supraorbital (ROOF) and infraorbital (SOOF) submuscular, sub-SMAS fat has recently been demonstrated, rendering terms such as eyebrow fat pad, ROOF, and SOOF specific only for anatomic areas and not descriptive of distinct entities. Hence, anatomically, these areas of submuscular fat are in fact continuous and serve as important landmarks, and they should not be confused with the subcutaneous fat that exists anterior to the muscle layer in the same areas. Recent anatomic studies have also documented the circumferential nature of the orbital malar ligament, which is more commonly being referred to as the orbicularis retaining ligament. The orbicularis retaining ligament was found to be continuous from the medial orbit to the lateral orbit in both upper and lower eyelids. The orbicularis retaining ligament in the upper eyelid was always noted to be distinct from the orbital septum, as is the case in the lower eyelid. The septum inserts into the most inferior part of the superior orbital rim, with the orbicularis retaining ligament attaching 2 to 3 mm above the rim, similar to the anatomy in the lower eyelid. The two merge at the arcus marginale, which is essentially a connective tissue thickening at the orbital rim with contributions from the orbital septum, periosteum, and orbicularis retaining ligament.
Clinical Applications

- Many clinical features of the aging midface have been described. Involutional surface changes of the lower eyelids have been categorized into bags, mounds, and festoons. The aging orbit might appear deeper and wider. The soft tissue of the cheeks and midface descends, and the nasolabial folds become more pronounced. The anatomical explanation for midfacial aging changes is not entirely clear. The examination of photographs of patients in youth and in aging demonstrates that the increasing demarcation along the central lid–cheek junction is in part due to the involution of soft tissues. Typically, the skin thins in this region, the color change between eyelid and cheek skin becomes more obvious, and there tends to be a loss of fat caudally on the cheek side of the lid–cheek interface. The loss of elastic support in the dermis and the attenuation of the attachments of the subcutaneous fat to the underlying SMAS have been suggested as causes of facial ptosis. Several people have suggested sagging or attenuation of the orbicularis oculi muscle. Midfacial aging changes have also been attributed to the migration of fat pads. Changes in deeper supporting structures (masseteric cutaneous ligaments, zygomatic ligaments, orbital malar ligament) have also been proposed as causes of facial ptosis.

- The nasojugal and malar fold (palpebral-malar groove) represent the surface anatomy of the underlying orbital malar ligament (or orbicularis retaining ligament). The cutaneous insertion of their bony attachment descends inferiorly with advancing age, being closest to the orbital rim with youth. As aging occurs, the number and diameter of elastic fibers diminish. Fibers disintegrate, and this leads to a deficiency in functional elastic fibers. As the elastic fibers within the orbitomalar ligament (orbicularis retaining ligament) degenerate, the SMAS, the orbicularis oculi muscle, the nasojugal fold, and the malar fold descend. As a result, the vertical height of the eyelid appears to elongate, and both the malar fold and the nasojugal fold become more prominent. Other changes that might take place with age include thinning of the skin and orbital septum. Thus, with a downward relaxation of the skin and the SMAS, as well as orbital septal thinning and the elongation of the orbital malar ligament, one might observe the orbital fat to extend anteriorly as well as inferiorly (Fig. 1-30C). It is the orbital malar ligament (orbicularis retaining ligament), not the septum orbitale, that defines the lower limit of the descent and the shape of the lower lid fat bulges. The distension of the ligament is not uniform across its length. Fat bulges are most likely to develop centrally, where the ligament is weakest and becomes most distended. The minimal inferior displacement of bulging fat of the medial lower lid correlates with the direct attachments of the medial orbicularis oculi origin along the medial inferior orbital rim. Because the pretarsal part of the orbicularis is more firmly attached to tarsal plate, it is the preseptal portion of the orbicularis muscle and its fascia that undergoes elongation with the downward displacement of the lid–cheek junction. The blepharoplasty surgeon needs to be familiar with these anatomic relationships.

- As the nasojugal fold becomes more prominent as a result of the above-described aging changes, it forms a distinct depression in the medial eyelid tissues, which is commonly referred to as the “tear trough.” The tear trough creates shadows just as the adjacent prolapsing medial fat pad does. The tear trough can be diminished during blepharoplasty surgery by
opening the medial septum along the arcus marginale, lifting the orbital malar ligament, and transferring the medial fat into this pocket. Nonsurgically, the tear trough can be made less noticeable by injecting tissue filler (e.g., hyaluronic acid such as Restylane/Juvederm) immediately deep to it between the orbicularis and the periosteum.

- In cadaver specimens with facial ptosis, the orbital malar ligament appears less discrete (indefinite or not detectable) and projects more inferiorly relative to control specimens without facial ptosis. The zygomatic-cutaneous ligaments and masseteric cutaneous ligaments also become attenuated or undetectable in those with midfacial ptosis. Although there are many suggested etiologies of midfacial ptosis, these findings support the concept that midfacial ptosis results from the inferior migration of skin and subcutaneous fat, with relative sparing of deeper tissues.

- Malar mounds are most often seen as a component of the aging changes of the mid-cheek. Laxity of the tissues forming the roof of the prezygomatic space (orbicularis oculi, SOOF) could be a phenomenon localized to the roof, or it could be secondary to a weakening of the upper peripheral attachments of the roof. This laxity can be demonstrated via the application of finger pressure onto the mound with movement in a side-to-side or superior direction. Although the basis for malar mounds seems to be the downward sliding of the tissues of a poorly supported roof of the prezygomatic space (laxity of the orbital malar ligament) against the resistance of the more strongly supported lower boundary (stronger zygomatic cutaneous ligaments), secondary changes might be observed clinically in the overlying layers, namely, recurring or chronic edema involving the subcutaneous fat, with or without skin pleats.

- Prominent malar mounds are often associated with prominent lower lid fat bags, and it is important to distinguish between the two areas prior to embarking upon lower lid blepharoplasty surgery. Patients with malar mounds might be unhappy and look relatively worse after lower lid blepharoplasty alone. Traditionally, a lower lid blepharoplasty corrects the displaced fat and tightens the anterior lamella of the lid (skin muscle flap), which might then contrast with (and thereby exaggerate) the uncorrected laxity of the roof of the malar mound immediately below it. Fat removal without orbicularis repositioning relocates the lower fat back to the confines of the orbit, but it does not address the overlying laxity in the SMAS-orbicularis-skin complex. In an effort to improve the contour across the eyelid–cheek junction, surgeons have transferred fat as well as grafted fat to this area.

- Numerous and diverse treatments have been tried for the correction of malar mounds over the years, including direct skin excision, laser resurfacing, excision of fat (SOOF, preperiosteal), excision of orbicularis muscle, and soft tissue fillers; however, none has been entirely satisfactory. In the absence of a proven effective treatment for malar mounds, treatment should be directed at the correction of laxity in the roof of the prezygomatic space when it is present. The treatment of other components (e.g., fat excision or dermal tightening with laser resurfacing) should be complementary to the surgical restoration of tone within the roof.

- Damage to the innervation of the orbicularis oculi is the only significant risk when operating in the prezygomatic space. The multiple motor branches to the orbicularis are “at risk” where they cross from the deeper facial plane to the more superficial plane of the orbicularis in the lower and lateral boundaries of the prezygomatic space. This is where they are under
the protection of the retaining ligaments. From here, the branches continue in the plane of the SOOF to the preseptal part of the orbicularis oculi muscle. The lower lid and temporal approaches are relatively safe, as they enter the prezygomatic space from above, on either side of the zygomaticofacial nerve, and do not encounter the zygomatic branches. However, the temporal approach (via a SMAS face-lift) has the potential for traction neurapraxia of the lowest frontal (temporal) branch to the lateral canthus, because it courses immediately posterior to a zygomatic arch ligament.

**SUGGESTED READINGS**


Lindner HH. The anatomy of the fasciae of the face and neck with particular reference to the spread and treatment of intraoral infections (Ludwig’s) that have progressed into adjacent fascial spaces. Ann Surg. 1986;204:705–714.


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CHAPTER 2

ORBITAL BONES

The paired orbital cavities are formed by the facial bones and serve as sockets for the eyes. The orbital bones and the structures contained within the orbit (connective tissue, fat, nerves, vessels) act to support, protect, and maximize the function of the eye.

2–1 OVERVIEW OF ORBIT

In form, the orbit is roughly a quadrilateral pyramid with rounded angles and resembles a pear. Its volume in the average individual is 30 cc, of which the eyeball contributes about 7.5 cc (range: 6.9–9.0 cc). There are four surfaces: the roof, floor, lateral wall, and medial wall (Table 2-1). The base of the pyramid is the opening onto the face (orbital entrance) and is circumscribed by the orbital margin (or orbital rim). The orbit narrows inward to its termination, the apex. The widest portion of the orbital cavity lies 5 to 10 mm behind the orbital rim.

The orbit is made up of seven bones: frontal, sphenoid, zygomatic, malar, palatine, lacrimal, and ethmoid. Superiorly, the orbit is bordered by the anterior cranial fossa and the frontal sinus. Nasally, the ethmoid sinus is separated from the medial orbital wall by the thin lamina papyracea of the ethmoid bone. Inferiorly, the maxillary sinus lies beneath the orbital floor (Fig. 2-1). The lateral orbit is bordered anteriorly by the temporali s fossa, and posteriorly it borders the middle cranial fossa.

The lateral and medial walls of each orbit form an angle of approximately 45° with each other. The two medial walls diverge somewhat posteriorly but are almost parallel to each other (being about 3 mm farther apart posteriorly than at the orbital margin). The lateral orbital walls of the two orbits form a 90° angle with each other. The four walls of each orbit converge posteriorly toward the apex, where the optic canal and superior orbital fissure pass into the middle cranial fossa.

Clinical Application

- The overall dimensions of the orbit (Table 2-1), especially its depth, are quite variable. An orbital surgeon cannot rely on precise measurements as a guide to the exact location of the
The removal of an eye following enucleation or evisceration creates an orbital soft tissue volume deficiency. Insufficient volume replacement results in postenucleation socket syndrome, which can consist of an abnormally deep superior sulcus, upper eyelid ptosis, enophthalmos, and lower eyelid malposition, and which might require a larger than desirable prosthesis.

- The orbital volume approaches 30 cc, whereas the volume of the globe varies between 6.9 and 9.0 cc. An enucleated eye is usually replaced by an 18, 20, or 22 mm orbital implant with a volume of 3.1, 4.2, or 5.6 cc, respectively. The loss of orbital volume is therefore approximately 4 to 5 cc. Atrophy of the orbital fat accentuates the reduction in orbital volume. The orbital volume is partly, but not totally, replaced by the ocular prosthesis (approximately 2.0 to 2.5 cc). The net loss in orbital volume might therefore amount to 2 to 3 cc, which gives rise to the postenucleation socket syndrome mentioned above. This volume deficit can be replaced with an alloplastic floor implant placed subperiosteally in order to add volume and elevate the orbital contents.

- The proper implant volume can be determined either preoperatively or intraoperatively (in enucleation cases) from the axial length of the eye or by determining the volume of fluid that the enucleated eye displaces in a graduated cylinder. Approximately 70% to 80% of the volume of an individual’s normal globe should be replaced with an orbital implant.

| TABLE 2-1 Dimensions of the Average Adult Orbit (mm) |
|---------------------------|-----------|
| Width                     | 40        |
| Height                    | 35        |
| Roof (rim to apex)        | 50        |
| Lateral wall (rim to apex) | 50        |
| Medial wall (anterior lacrimal crest to apex) | 50 |
| Floor (rim to apex)       | 50        |
| Floor (rim to posterior wall of maxillary antrum) | 40 |

![FIGURE 2-1](https://via.placeholder.com/150)  
**FIGURE 2-1** Relationship of the orbit to paranasal sinuses. (A) Side view. (B) Front view.
This generally allows for a prosthetic volume that is ideally 2.0 to 2.5 ml. Although the upper limit of the prosthetic volume is around 4.0 ml, larger prostheses often result in progressive lower eyelid laxity and malposition due to the weight of the prosthesis on the eyelid. Larger prostheses might also have limited socket excursion.

- Individualization of the implant size is important in optimizing orbital volume replacement and in achieving the best possible aesthetic result. Theoretically, the volume of the enucleated globe minus 2.0 to 2.5 ml (the ideal prosthetic eye volume) gives the ideal implant size to use. This calculation often comes out to an implant greater than 22 mm in size. Unfortunately, implants larger than 22 mm might have a higher exposure rate and, if too large, will hinder the fitting of an acceptable custom prosthesis. We typically use 20 to 22 mm spherical implants following enucleation, and 18 to 20 mm implants after evisceration procedures. In pediatric patients, slightly smaller implants might be required, depending on the patient’s age and orbital development.

### 2–2 ORBITAL WALLS

The superior (roof), inferior (floor), and lateral walls are triangular in shape, whereas the medial orbital wall is rectangular. The orbital floor extends approximately 85% of the depth of the orbit, whereas the other walls extend to the apex.

#### 2–2-1 The Orbital Roof

The orbital roof is formed by the orbital plate of the frontal bone and the lesser wing of the sphenoid (Fig. 2–2). It is approximately triangular in shape, flat at the apex but becoming concave in front. Its boundary with the lateral wall is the superior orbital fissure and a line continuing along the direction of the fissure to the lateral angular process of the frontal bone, just above its articulation with the zygoma. From the medial wall, it is separated for some distance by the frontoethmoidal suture.

Anatomic features of the roof are as follows:

1. The fossa for the lacrimal gland is a depression in the frontal bone anteriorly and laterally, lying behind the orbital rim. It houses the lacrimal gland and some orbital fat.
2. The fovea trochlearis is a small depression in the anteromedial angle of the roof, 4 mm from the orbital margin, that houses the fibrocartilaginous trochlea for the superior oblique muscle where the trochlea is attached. A small, bony spine, the spina trochlearis, might be present in this area.
3. The frontosphenoidal suture is usually obliterated in the adult skull. It crosses the apex of the roof from the anterior end of the superior orbital fissure to a point just behind the posterior ethmoidal foramen on the medial wall.
4. The optic foramen lies in the apex of the orbital roof in the lesser wing of the sphenoid and leads into the optic canal.
The roof of the orbit varies in thickness, but not uncommonly it is quite thin and fragile. It is usually smooth, but it might have small holes or depressions within it, referred to as *cribra orbitalia*. In old age, portions of the bone may be absorbed, leaving the periorbita in direct contact with the dura mater of the anterior cranial fossa. The frontal sinus is located within the frontal bone in the anteromedial portion of the roof. The roof might become double-walled to varying degrees by extensions of the frontal or ethmoidal air cells, or both. The size of the frontal sinus is extremely variable, and in some individuals it might extend as far laterally as the lacrimal gland fossa and as far posteriorly as the optic canal.

**Clinical Application**

- The trochlea easily separates from the adjacent bone, along with the periorbita, during medial orbital surgery. Its precise repositioning is important in order to avoid postoperative motility disturbances.
- The orbital roof is very thin and might have spontaneous dehiscences. Care must be taken during orbital surgery along the roof, as instrumentation might perforate this fragile area.

**2–2–2 The Lateral Wall**

The lateral wall of the orbit is the thickest orbital wall and is composed of the zygomatic bone anteriorly, the greater wing of the sphenoid bone posteriorly, and a small part of the frontal bone extending downward (Figs. 2-3A and 2-3B). Posteriorly, it is separated from the floor by the
inferior orbital fissure; a projection of this line to the inferolateral angle of the orbital margin completes the inferior boundary. The superior boundary is created by an imaginary line extending from the superior orbital fissure to the zygomaticofrontal suture line. The lengths of the lateral and medial orbital walls, from orbital rim to apex, are about equal (approximately 50 mm). Because of the oblique orientation of the lateral wall, the lateral rim lies about 1 cm posterior to the medial rim.

Anatomic features of the lateral wall are as follows:

1. The zygomaticofrontal suture (or frontozygomatic suture) runs from the orbital margin back to meet the frontosphenoidal suture.
2. The sphenozygomatic suture begins at the anterior end of the inferior orbital fissure and runs up the lateral wall to meet the juncture of the two sutures named above. It is the thinnest part of the lateral wall and is located about 1 cm posterior to the orbital rim. During lateral orbital surgery, cuts through the bone must be made to this level so that the rim can be fractured outward easily. Approximately 1 cm posterior to the zygomaticosphenoidal suture, the sphenoid bone thickens where it divides to form the anterior corner of the middle cranial fossa. Here, compact bone passes into cancellous bone, a useful landmark when taking down the lateral orbital wall in order to gain access to the orbit.
3. The spina recti lateralis (lateral rectus spine) is a small, bony spur frequently seen on the inferior margin of the superior orbital fissure, at the juncture of its wide and narrow portions. It can be rounded or spinous, and there is considerable variation in the degree of its development; it might also be double. The spur serves as an attachment site for a portion of the lateral rectus muscle.
4. The orbital tubercle (Whitnall’s tubercle) is a small elevation 2 mm inside the orbital margin on the orbital surface of the zygomatic bone. It lies about 8 to 10 mm below the zygomaticofrontal suture and gives attachment to (a) the check ligament of the lateral rectus muscle, (b) Lockwood’s inferior suspensory ligament, (c) the lateral canthal tendon, (d) the lateral horn of the levator aponeurosis, and (e) a small contribution from Whitnall’s ligament (not the main insertion site).
5. The zygomaticofacial and zygomaticotemporal canals and the meningeal foramen (foramen of Hyrtl) are located in the lateral wall.

Clinical Application

- A common surgical approach to the orbit is the lateral orbitotomy, which might require the removal of the lateral orbital bones. An upper eyelid skin crease approach with extension over the lateral orbital rim is used to get down to the lateral orbital rim. Once at the rim, the periosteum is incised along the rim and dissected away on the orbit side as well as on the temporal fossa side (which requires dissecting some of the temporalis muscle away from the bone). The zygomaticofrontal suture is a landmark to identify, and the osteotomy is placed 5 to 10 mm above this junction. Enough periosteum has to be scraped away from the bone so that the surgeon has a clear view of the orbital roof and lateral wall. As the oscillating saw is being used, the surgeon must pay close attention to the direction in which it is angled.
Surgical Anatomy of the Ocular Adnexa

It should be parallel to the roof but angled inferiorly, so that it does not enter the anterior cranial fossa as it cuts the bone inside the orbital rim. The inferior osteotomy bone cut is usually made parallel to the orbital floor. The bone is then displaced laterally and is fractured approximately 25 mm posteriorly, along or near the zygomaticosphenoidal suture line. The lateral orbital wall beyond this becomes thick and cancellous. This is in contrast to the paper-thin medial wall, which is easily fractured with the smallest of surgical instruments. Additional bone removal along the lateral wall requires the use of bone rongeurs and is often accompanied by bleeding from the cancellous bone. As the dissection proceeds posteriorly, the surgeon must watch for the superior and inferior orbital fissures in order to maintain the proper orientation of the dissection.

FIGURE 2-3  Lateral orbital wall. (A) Internal view. (B) External view.
• The lateral orbital wall is often removed with a high-speed drill for decompression of the orbit in patients with thyroid eye disease. During this surgery, the medial wall or portions of the orbital floor might be removed in order to further expand the orbital space. Either an upper eyelid crease incision is used as described above for the removal of the lateral orbital wall, or a lateral canthal lower lid incision can be used in order to access the lateral wall. The orbital floor can also be accessed through the lower lid lateral canthal incision. Although the medial wall can be accessed this way as well, the transcaruncular approach to the medial wall provides more exposure to this area (see later).

• During lateral canthoplasty surgery (e.g., a lateral tarsal strip procedure), it is important to secure the eyelid to the inside wall of the lateral orbital rim (i.e., to Whitnall’s tubercle). This will allow the eyelid to hug the globe. If the eyelid is simply attached to the anterior rim, there might be an unsightly space laterally.

2–2-3 The Orbital Floor

The floor of the orbit does not reach the apex; thus, it is the shortest of the orbital walls (approximately 40 mm) (Fig. 2-4). It is very thin and is composed of three bones—primarily the orbital plate of the maxilla, with an anterolateral part formed by the orbital surface of the zygomatic bone and a small posterior part formed by the small orbital palatine bone. The floor curves smoothly into the medial wall. The boundary between them may be considered as running from the edge of the nasolacrimal canal along the sutures between the ethmoid bone and the maxilla toward the apex. Below the floor, for most of its extent, lies the maxillary sinus (antrum of Highmore).
The palatine bone lies at the extreme posterior end of the floor, in the orbital apex, and sometimes also bears an air cell. In adults it is usually fused with the maxillary bone.

Anatomic features of the floor are as follows:

1. The maxillozygomatic (or zygomaticomaxillary) suture is a V-shaped suture, with the apex of the V at the middle of the infraorbital margin.
2. The infraorbital sulcus (infraorbital groove) traverses the orbital floor, running approximately straight forward from the inferior orbital fissure. It carries the maxillary division of the trigeminal nerve (infraorbital nerve) and the associated infraorbital artery from the pterygopalatine fossa. At about the mid-portion of the floor, the sulcus becomes bridged over by the maxillary bone to form the infraorbital canal. This thin bridge is pierced by one or more tiny foramina that transmit anastomotic vessels from the infraorbital artery to the inferior muscular branches of the ophthalmic artery. The infraorbital canal continues forward to the orbital rim, where it emerges as the infraorbital foramen. Thus, the path is from the inferior orbital fissure to the infraorbital groove, to the infraorbital canal, and finally to the infraorbital foramen.
3. The fossa of origin of the inferior oblique muscle is a small, shallow depression in the anteromedial angle of the floor, just behind the orbital margin and lateral to the opening of the nasolacrimal canal.

Clinical Application

- The orbital floor can be approached surgically through a direct transconjunctival approach, a lateral canthal transconjunctival swinging eyelid approach following canthotomy and cantholysis, or a subciliary skin incision. Once at the orbital rim, the periorbita is incised and then carefully lifted away from the orbital floor using a periosteal elevator. The infraorbital canal can be identified on the orbital floor during surgery as a slightly elevated ridge. Recognition of its position is critical if injury to the infraorbital nerve is to be avoided during orbital floor surgery. Damage to this nerve results in anesthesia of the cheek and upper lip and is not uncommon after orbit floor blow-out fractures or orbital decompression into the maxillary sinus. It is important to identify the communicating branch of the infraorbital artery during dissection along the orbital floor. This vessel needs to be cauterized as soon as it is seen, or it might bleed profusely and obscure the surgical field.
- It is important to remember that the orbital floor does not extend all the way to the orbital apex, but rather ends at the posterior vertical wall of the maxillary antrum adjacent to the pterygopalatine fossa. The posterior wall of the maxillary antrum is 40 mm from the anterior rim. The length of the orbital floor from the rim to the optic canal is 50 mm. During floor fracture repair, the surgeon can easily dissect to the posterior wall of the maxillary antrum with little risk of injury to the optic nerve. Dissection posterior to this level is extremely risky, as the optic nerve might be injured.
- The orbital floor is thinnest medial to the infraorbital canal, where it might be only 0.5 mm thick. This is a convenient point for initial entrance into the maxillary sinus during orbital
decompression surgery. It is this portion of the floor that is usually involved in blow-out fractures, which can result from rim deformation and compression of orbital contents after blunt trauma. Surgical correction is aimed at restoring the integrity and normal position of the fractured wall, usually with the use of alloplastic implants.

- Removal of the very posterior medial floor allows for significant decompression of the orbital contents when combined with posterior ethmoidectomy. Care must be taken to leave a 3 mm wide strut of bone at the anterior and mid-portion of the interface of the floor and the medial wall to help decrease the shift in orbital tissues toward the combined ethmoidal and maxillary sinus space. Preservation of this boney strut will help decrease the double vision that often occurs with shifts in the orbital contents during orbital decompression.

### 2–2–4 The Medial Wall

The medial wall is the thinnest and smallest of the orbital walls (Fig. 2–5). It measures approximately 4.5 to 5.0 cm in length and is formed by four bones: the frontal process of the maxilla, the lacrimal bone, the ethmoidal bone (lamina papyracea), and a small part of the lateral aspect of the body of the sphenoid. In addition, a downward extension of the frontal bone in some individuals might contribute to the medial wall. Its boundaries with the roof and floor have already been mentioned.

Anatomic features of the medial wall are as follows:

1. Anteriorly, the thick frontal process of the maxillary bone lies at the medial rim. It contains the anterior lacrimal crest and forms the anterior portion of the nasolacrimal fossa. The maxillary and lacrimal bones contribute a varying amount to the nasolacrimal fossa, with the frontal process of the maxilla being the major contributor.
2. The nasolacrimal fossa is a broad groove on the medial orbital margin and is formed by the lacrimal bone behind and the frontal process of the maxilla in front. Posteriorly, the
nasolacrimal fossa is bounded by the posterior lacrimal crest, which is thickened above and ends in a forward-projecting hook-like process, the hamulus lacrimalis, at its lower extremity. This structure curves around laterally and defines the upper opening of the nasolacrimal canal. This posterior crest is rounded and becomes directly continuous with the infraorbital margin.

3. Just anterior to the anterior lacrimal crest is a fine line known as the innominate suture, sutura Notha (false suture), or longitudinal suture of Weber. Located 2 mm anterior to the anterior lacrimal crest, it is not a true suture but a groove in the bone. There might be a small foramen in it that transmits a small artery that is a branch of the infraorbital artery.

4. The lacrimal bone, immediately posterior to the frontal process of the maxilla, is a small, thin, fragile plate forming the posterior portion of the nasolacrimal fossa. Not uncommonly, small perforations will be found in it due to age-related absorption or incomplete ossification.

5. The greatest extent of the medial wall is formed by the lamina papyracea of the ethmoidal bone, which is located immediately posterior to the lacrimal bone. The ethmoidal bone is exceptionally fragile, measuring only 0.2 to 0.4 mm in thickness, but is strengthened by the honeycombed bony lamina surrounding the adjacent ethmoidal air cells, which number three to eight. Despite its paper-like thinness, the ethmoidal bone is not often the site of age-related atrophy, although congenital or pathologic dehiscences might be seen.

6. In its entire extent, the medial wall is related to the accessory air sinuses, chiefly the ethmoidal air cells. Posteriorly, a small area is in contact with the sphenoid sinus.

7. The anterior and posterior ethmoidal foramina are located at the junction of the medial wall and orbital roof along the frontoethmoidal suture line, which is also at the same level as the cribriform plate. These foramina transmit branches of the ophthalmic artery and nasociliary nerve (anterior and posterior ethmoidal arteries and nerves).

Clinical Application

- The medial orbital approach is a common access to the medial wall, for example, for fronto-ethmoidal orbital mucoceles or for orbital decompressions in severe thyroid eye disease. The medial orbit can be approached through a transcaruncular incision or a skin incision (the Lynch approach). The technique used often depends upon the exposure needed. For medial orbital decompressions (in thyroid patients), a transcaruncular approach is sufficient, whereas for medial frontoethmoidal mucoceles, a wider exposure is often required and a skin incision (Lynch approach) is carried out.

- For the Lynch approach, the skin incision is marked out immediately inferior to the brow hairs and is curved downward along the side of the nose, ending just anterior to the medial canthal tendon insertion. After skin and muscle are incised, the periorbita is incised and gently lifted away from the medial orbital wall. The most important anatomic landmarks during this approach are the anterior and posterior ethmoidal foramina. The mnemonic “24-12-6” helps one to identify how far these foramina and the optic canal are (in millimeters) from the anterior orbital rim. The anterior ethmoidal artery should be located early in the dissection
Orbital Bones

(24 mm) and cauterized (preferably with bipolar cautery). The dissection proceeds posteriorly, toward the posterior ethmoidal foramen (12 mm), at which point the vessels are again cauterized. If further dissection is needed, the surgeon knows that the optic foramen is 6 mm away. This information is critical if one is to avoid damage to the optic nerve.

- The anterior and posterior ethmoidal foramina also alert the surgeon not to dissect above this level; otherwise, entry into the cribiform plate might occur, with resultant cerebrospinal fluid leakage.
- The fragility of the lamina papyracea is responsible for the frequency of medial wall fractures after orbital trauma and its easy displacement into the orbit with expanding lesions of the ethmoid sinus.
- The lamina papyracea offers only a minimal barrier to the spread of infection from the ethmoid sinus into the orbit, resulting in orbital edema, cellulitis, and abscess formation associated with ethmoidal sinusitis.
- Surgery along the medial wall can easily penetrate the paper-thin ethmoidal bone, with the possible complication of orbital emphysema, infection, or fistula tract (postexenteration). Postexenteration fistula tracts are a source of mucous build-up, irritation, and water entry into the sinus during swimming, and are a real nuisance for the patient. They are difficult to close surgically.
- The sutura Notha (longitudinal suture of Weber, inominate suture) is an important landmark during dacryocystorhinostomy surgery. As the periosteum is being removed from the lacrimal crest during an external dacryocystorhinostomy, the sutura Notha is routinely visualized. At this point, the surgeon knows that the true anterior lacrimal crest is almost always within 2 to 3 mm of the suture.
- The anterior cranial fossa might be as little as 1 mm above the level of the upper border of medial canthal tendon (the average level is 8.3 mm). At the level of the posterior lacrimal crest, this distance shortens as the floor of the anterior cranial fossa slopes downward and backward. This might explain the occasional occurrence of cerebrospinal fluid leakage during the creation of a bony osteum during dacryocystorhinostomy surgery. Such leakage might be more likely when the medial canthal tendon is removed or when there is torsional force applied with the bony rongeurs during bony removal near the tendon. It is safest to leave the tendon attached and not apply forceful torsional movements during bone removal.

2–3 SPHENOID BONE AND INTRACRANIAL COMPARTMENTS

Looking at a skull is the best way to appreciate the sphenoid bone (Figs. 2-6A through 2-6C). The sphenoid has four distinct parts: the body, the greater wings, the lesser wings, and the pterygoid processes. The superior surface of the body forms the central portion of the floor of the intracranial surface.

The \textit{greater wings of the sphenoid} are strong bones that contribute to the lateral orbital walls. The space between the greater and lesser wings forms the \textit{superior orbital fissure}. The \textit{inferior orbital
Sphenoid bone. (A) Anterior view looking from the orbit side toward the superior orbital fissure and optic foramen. (B) Posterior view looking from the brain side toward the superior orbital fissure.

**FIGURE 2-6** Sphenoid bone. (A) Anterior view looking from the orbit side toward the superior orbital fissure and optic foramen. (B) Posterior view looking from the brain side toward the superior orbital fissure.

The superior portion of the greater wing forms part of the middle cranial fossa. The bone is deeply concave in order to accommodate the temporal lobe.

In its anterior portion is the *foramen rotundum*, which transmits the maxillary division of cranial nerve V. Posterior and lateral to the foramen rotundum is the *foramen ovale*, which transmits the mandibular division of cranial nerve V. Adjacent to the foramen ovale is the *foramen spinosum*, which transmits the middle meningeal artery. The posterior margin of the greater wing forms the anterior wall of the *foramen lacerum*, a large, irregular aperture at the skull base. The carotid canal,
which transmits the carotid artery, lies within the superior aspect of the foramen lacerum. In the anterior wall of the foramen lacerum is the beginning of the pterygoid canal, which transmits the vidian nerve (or the nerve of the pterygoid canal), which supplies parasympathetic and sympathetic fibers to the lacrimal gland.

The lesser wing of the sphenoid supports a portion of the frontal lobe and contributes to the posterior aspect of the orbital roof. The anterior portion articulates with the frontal bone, and the posterior portion forms the anterior clinoid processes. The lesser wing houses the optic foramen and optic canal.

The pterygoid processes project perpendicularly from the inferior surface of the body of the sphenoid as a medial and a lateral plate. The pterygoid canal runs in the sphenoid body, to which the pterygoid processes attach.

The frontal bone of the orbital roof separates the orbit from the anterior cranial fossa, which contains the frontal lobes of the cerebral hemispheres (Fig. 2-6C). The anterior cranial fossa is bounded anteriorly by the inner table of the frontal bone and posteriorly by the lesser wing of the sphenoid bone. Medially, the lesser wing terminates at the anterior clinoid processes, which lie near the roof of the optic canals. The tentorium cerebelli terminate on the anterior clinoids as well. In the midline of the fossa is a central crest, the crista galli, onto which attaches the falx cerebri. On each side of the crista galli is a depression with numerous perforations, the cribriform plates of the ethmoid bones. They form the roof of the nasal cavity, and through them filaments of the olfactory nerve pass en route to the nasal mucosa. The anterior ethmoidal nerve passes into the anterior cranial fossa at the lateral edge of the cribriform plate and then into the nasal cavity through a narrow slit or foramen adjacent to the crista galli.

The middle cranial fossa consists of a narrow midline elevation formed by the body of the sphenoid bone and two lateral depressions that house the temporal lobes of the cerebral cortex.
Within the anterior portion of the fossa, each optic canal opens into the chiasmatic groove, which terminates posteriorly at a shallow elevation, the tuberculum sellae, over which lies the optic chiasm. Immediately posterior to this is a deep depression, the sella turcica, which houses the pituitary gland. Posterior to the sella is a quadrilateral plate of bone, the dorsum sellae, which contains the posterior clinoid processes at its superior end. The tentorium cerebelli attaches onto the posterior clinoids. Just inferior to each posterior clinoid process is a groove for the passage of the abducens nerve. A ligament referred to as the petrosphenoidal ligament of Gruber often covers this groove and forms a canal. This is Dorello’s canal, and through it the sixth cranial nerve runs toward the cavernous sinus. On either side of the sella turcica is a shallow groove that houses the cavernous sinus and the internal carotid artery.

Laterally, the floor of the middle cranial fossa is formed by the greater wings of the sphenoid and the petrous portions of the temporal bone. Anteriorly, bridging over the roof of the cavernous sinus and forming a spine of bone between the optic canal and the superior orbital fissure is the anterior clinoid process. The anterior clinoid processes identify the level of the optic nerve on CT scan images of the orbital apex. If they are not visualized, it is best to reorder the CT scan and request that optic canal views be done; you should see the anterior clinoid processes in those views. Just lateral to the anterior clinoid process and situated vertically between the greater and lesser wings of the sphenoid bone is the superior orbital fissure, which communicates with the orbit. It transmits a branch of the middle meningeal artery, the superior ophthalmic vein, the lacrimal nerve, the frontal nerve, the trochlear nerve, the nasociliary nerve, the abducens nerve, the oculomotor nerve, the sympathetic nerves, and the central retinal artery and vein (see later). Just below the medial end of the superior orbital fissure, and described above, are the foramen rotundum, foramen ovale, foramen spinosum, and foramen lacerum.

2–4 APERTURES

The orbital apertures are also termed foramina or canals (see Fig. 2-7A).

2–4–1 Optic Foramen

Located in the lesser wing of the sphenoid at the orbital apex, the optic foramen opens into the optic canal, which leads to the middle cranial fossa. The optic canal is also in the lesser wing of the sphenoid and is 5 to 11 mm in length. The medial wall indents the superior lateral wall of the sphenoid, as well as the posterior ethmoid air cells. The canal attains adult size by the time a person is three years of age and is vertically oval in shape at its orbital end, where it measures 5 to 6 mm in diameter. It is rounder in the central portion and horizontally oval at its cranial end. The distance between the two orbital openings of the optic canal averages 28 mm, whereas the distance between the cranial openings is half this amount (14 mm). The optic canal transmits the optic nerve, its meningeal sheaths, the ophthalmic artery, and sympathetic fibers from the
carotid plexus. The optic nerve is firmly fixed within the optic canal. The dura is adherent to the bone of the canal and to the optic nerve itself.

Clinical Application

- Deviations in the shape of the optic canal, enlargement to more than 6.5 mm, or asymmetry involving a difference of more than 1 mm between the two sides are suggestive of an abnormality. Compression of the optic nerve within the canal might be seen with slowly expanding intrinsic lesions of the nerve, such as optic gliomas or sheath meningiomas. In such cases, the bony canal is commonly enlarged. Other causes of canal enlargement include neurofibromas, optic nerve extension of retinoblastomas, aneurysms of the ophthalmic artery, arteriovenous malformations, and chronic increased intracranial pressure.
- Visual loss can be seen in 0.5% to 2.5% of cases of closed head trauma. Fractures through the optic canal have been reported in up to 5% of head injuries, but resultant optic nerve compression is unusual. Canal fractures associated with visual loss might be demonstrated radiographically but are frequently difficult to visualize. An immediate loss of vision after blunt head trauma usually results from a contusion of the nerve at the canal where the nerve sheath is fused to the periosteum, resulting in an interruption of the vascular supply. More gradual loss is generally due to edema or hemorrhage resulting in nerve compression. Vision might be salvaged in some traumatic optic neuropathy patients through immediate high-dose intravenous steroids (within eight hours of injury) or surgical decompression of the canal. There are no clinically proven therapies for central nervous system injuries.

2–4-2 Superior Orbital Fissure

Also called the *sphenoidal fissure*, the superior orbital fissure lies between the roof and the lateral wall and between the greater and lesser wings of the sphenoid (Fig. 2-7A). It has a wide medial portion, below and lateral to the optic foramen, and a narrow lateral portion. This fissure shows considerable individual variation in its size and shape. The superior orbital fissure transmits the third, the fourth, the ophthalmic division of the fifth, and the sixth cranial nerves. It also transmits sympathetic nerves, the superior ophthalmic vein, and sometimes the orbital branch of the middle meningeal artery.

The superior orbital fissure is divided into two parts by the fibrous annulus of Zinn (Figs. 2-7B and 2-7C). The annulus of Zinn is a condensation of the periorbita that encircles the optic foramen and the medial half of the superior orbital fissure. The superior half is known as the *superior orbital tendon of Lockwood*, and the inferior half is called the *inferior orbital tendon of Zinn*. The rectus muscles take origin from the annulus of Zinn. The opening created by the fibrous annulus of Zinn (which houses the medial part of the superior orbital fissure and the optic foramen) is referred to as the *oculomotor foramen*. Lateral to the oculomotor foramen, the following
structures pass from lateral to medial (with some individual variation) and can be remembered using the acronym LMSFT (Look: Michigan State Football Team): L = lacrimal nerve, M = branch of the middle meningeal artery, S = superior ophthalmic vein, F = frontal nerve, and T = trochlear nerve. Within the oculomotor foramen, the following structures pass (NASO², pronounced “naso-squared”): N = nasociliary nerve, A = abducens nerve, S = sympathetic nerves, and O = oculomotor nerve (which is in two divisions: superior and inferior). Also, coming through the annulus of Zinn, medially within the oculomotor foramen, is the optic foramen, which has the optic nerve,
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ophthalmic artery, and likely some sympathetic fibers along the optic nerve. The acronyms LMSFT and NASO² are suggested mnemonics for the structures in the superior orbital fissure area.

2–4-3 Meningeal Foramen (Foramen of Hyrtl)

The meningeal foramen (Figs. 2-7A and 2-7B) is usually present near the anterior end of the superior orbital fissure. This small foramen transmits the orbital branch of the middle meningeal artery.

2–4-4 Inferior Orbital Fissure

Also called the sphenomaxillary fissure, the inferior orbital fissure (Fig. 2-7B) originates at the orbital apex and runs between the lateral wall and the floor. This fissure is approximately 15 to 20 mm long, extends to within 15 to 20 mm of the inferior orbital rim, and is continuous with the lower end of the superior orbital fissure. Just below the junction of the inferior and superior orbital fissures can be seen the foramen rotundum, which passes from the middle cranial fossa to the pterygopalatine fossa. The inferior orbital fissure is wider at its extremities than at its center; its anterior extremity can be considerably expanded. It transmits the maxillary division of the trigeminal nerve (via the foramen rotundum), the infraorbital artery, and the infraorbital vein.
Communication through the inferior orbital fissure is established with the pterygopalatine (sphenomaxillary) fossa posteriorly and the infratemporal (zygomatic) fossa anteriorly. Multiple branches from the inferior ophthalmic vein pass through the inferior orbital fissure to communicate with the pterygoid venous plexus. Postganglionic parasympathetic nerve fibers from the pterygopalatine ganglion, as well as postganglionic sympathetic fibers, enter the orbit through the inferior orbital fissure, where they join with the zygomatic nerve for a short distance before joining the lacrimal nerve and the lacrimal gland. The inferior orbital fissure is closed by the periorbita.

2–4–5 Zygomatic Canal

On the lateral orbital wall (zygoma), there is usually a small opening, the zygomatic foramen, which leads into the zygomatic canal. This canal divides within the bone into two branches, one of which opens on the facial aspect as the zygomaticofacial foramen (Fig. 2-7A), about a quarter of an inch lateral to the orbital margin and on the same horizontal level as the inferior orbital margin. The canal transmits the zygomaticofacial branch of the zygomatic nerve (from the maxillary division of the trigeminal nerve) and an artery that supplies the cheek area.

The second division of the canal ascends to open by the zygomaticotemporal foramen into the temporal fossa behind the frontal process (Fig. 2-3B). It transmits an artery and the zygomaticotemporal branch of the zygomatic nerve, which supplies the skin of the lateral aspect of the forehead. It is not unusual to have separate zygomaticotemporal and zygomaticofacial foramina on the orbit side, rather than just a zygomatic foramen; occasionally there will be several foramina on both the orbital and temporal aspects of the zygoma.

Clinical Application

- During a lateral orbitotomy, the zygomatic nerve and canal are usually seen and generally have to be transected when the lateral orbital wall is removed. Postoperatively, the patient commonly describes an area of numbness corresponding to the sensory distribution of the zygomaticotemporal and zygomaticofacial nerves. There is sensory overlap in this portion of the face, so often this symptom resolves with time.

2–4–6 Infraorbital Canal

The infraorbital canal (Fig. 2-4) leads from the infraorbital groove on the floor of the orbit to the infraorbital foramen on the face of the maxilla, about 10 mm below the orbital margin. It transmits the infraorbital nerve, artery, and vein. The artery is a branch from the internal maxillary artery in the pterygopalatine fossa and is of external carotid origin. The vessel enters the orbit through the posterior end of the inferior orbital fissure. Coming off this artery, usually about midway to the rim, is the communicating branch of the infraorbital artery (external carotid origin), which helps
supply soft tissues along the orbital floor, the nasolacrimal sac/duct, and the inferior rectus and inferior oblique muscles where they anastomose with the inferior muscular branches of the ophthalmic artery (internal carotid origin). The infraorbital artery, once it has passed through the infraorbital foramen, sends an anastomotic branch to the inferior eyelid arcade vessels, again establishing communication between the internal carotid system (arcade vessels) and external carotid system (infraorbital).

Clinical Application

- During an orbital floor surgical approach, as the periorbita is dissected from the floor, the communicating branch of the infraorbital artery is visualized. It should be cauterized at that point; otherwise, it might bleed excessively and obscure the operative field.

2–4-7 Infraorbital Foramen

The infraorbital foramen (Fig. 2-7A) is located 4 to 10 mm below the orbital rim. It transmits the infraorbital nerve, artery, and vein. During surgery on the orbital floor, care must be taken not to elevate the periosteum anterior to the rim more than about 4 mm, as doing so might injure the neurovascular structures.

2–4-8 Nasolacrimal Canal

The nasolacrimal canal (Figs. 2-3B, 2-4, 2-5, and 2–7A) is a circular opening in the anteromedial angle of the floor, at the base of the nasolacrimal fossa. It transmits the nasolacrimal duct and opens into the roof of the inferior meatus (the space between the inferior turbinate and the lateral wall of the nose).

2–4-9 Ethmoidal Foramina

The anterior and posterior ethmoidal foramina (Figs. 2-5 and 2-7A), situated between the roof and the medial wall (at the fontoethmoidal suture line), open into the anterior and posterior ethmoidal canals. There is great variability in the position of these foramina. The posterior foramina might be absent, or both foramina might be multiple. The anterior ethmoidal canal is located about 24 mm from the medial orbital rim and transmits the anterior ethmoidal nerve and artery. The canal opens into the superior ethmoidal air cells just inferior to the cribriform plate but might go into the anterior cranial fossa. The posterior ethmoidal canal is 12 mm farther posterior to the anterior ethmoidal canal and transmits the posterior ethmoidal artery and a small nerve (the sphenoethmoidal nerve of Luschka) into the posterior ethmoidal cells and the nasal fossa. The optic
foramen is 6 mm posterior to the posterior ethmoid foramen. A mnemonic for the location of these three structures from the anterior orbital rim is “24-12-6” (24 mm from the anterior orbital rim to the anterior ethmoidal foramen, 12 mm to the posterior ethmoidal foramen, and 6 mm to the optic foramen).

Clinical Application

- During a medial orbitotomy, it is essential to recognize the anterior and posterior ethmoidal arteries. These landmarks are clues as to what depth has been attained and where the intracranial space will start (usually at about the same level).
- When the anterior and posterior ethmoidal arteries are localized during medial orbital surgery, an imaginary line can be drawn between them. This level marks the approximate level of the cribriform plate, and the orbital surgeon must not travel above this level. Unfortunately, there might not be a posterior ethmoidal artery or vein, which makes the surgery more challenging.
- Injury to the ethmoidal arteries can cause excessive orbital bleeding during surgery, as they are high-pressure vessels. It is best to cauterize them when they are seen rather than risk rupture with a loss of visualization of the tissues, as well as retraction into their respective foramina, which makes the bleeding very difficult to control.
- Subperiosteal hematoma following trauma frequently results from rupture of one of these arteries. A buildup of blood within this tissue space might be enough to raise the intraorbital pressure to the point of optic nerve compromise and visual loss. Management might require access to the medial wall on an urgent basis and cautery of the bleeding vessel.

2–5 ORBITAL MARGIN (ORBITAL RIM)

The orbital margin is oval, being slightly wider than it is high (approximately 40 mm wide × 35 mm high) (Fig. 2-7A). The bones along the rim are rounded and thickened and serve to protect the eye from facial impacts. The superior rim is the most prominent, owing to expansion of the underlying frontal sinus.

In the male skull, above the inner half of each supraorbital margin, there is usually a bony prominence, the supraorbital ridge or superciliary ridge. Meeting at the midline, the two ridges form a low eminence, the glabella.

The superior orbital rim is formed entirely by the frontal bone. It forms an arch between the medial and lateral angular processes. At the highest part of the arch, about one-third of the distance from its medial end, its contour is interrupted by the supraorbital notch, which transmits the supraorbital nerve and vessels. In about 25% of the population, the supraorbital notch might be converted into a supraorbital foramen. A second notch, the frontal notch, might also be present a short distance to the medial side of the supraorbital notch.
The rim is flatter and less prominent between the supraorbital notch and the medial canthal tendon. A number of important structures emerge here, including the supratrochlear and infratrochlear nerves and the dorsal nasal artery. Just inside the rim at this level is the cartilaginous trochlea of the superior oblique tendon. Surgical access to the medial wall through a frontoethmoidal (Lynch) incision might interrupt these structures.

The medial orbital margin is not as well defined as the lateral orbital margin. Its upper part is rounded and indistinct; its lower part bears the fossa for the lacrimal sac. Tracing the medial margin downward, the medial orbital margin passes posterior to the lacrimal sac to form the posterior lacrimal crest. As the inferior orbital margin is followed upward, it becomes the anterior lacrimal crest. Thus, the medial rim is discontinuous at the lacrimal fossa.

The lateral orbital margin is formed by the zygomatic process of the frontal bone above and the frontal process of the zygomatic below. These two elements meet at the frontozygomatic suture line (also called the zygomaticofrontal suture line) near the superotemporal corner of the orbit. About 8 to 10 mm below this suture line, 2 mm along the inside edge of the lateral rim, is a small bony mound, the lateral orbital tubercle of Whitnall.

The infraorbital margin is formed by the zygomatic bone laterally and the maxilla medially. The maxillozygomatic suture (or zygomaticomaxillary suture line) lies at about its midpoint. The infraorbital foramen is located 4 to 10 mm below the central portion of the rim.

You should be able to locate with your finger, on your own orbital margin, the following features:

1. the glabella,
2. the supraorbital ridge,
3. the supraorbital notch,
4. the zygomaticofrontal suture,
5. the orbital tubercle,
6. the zygomaticomaxillary suture,
7. the anterior lacrimal crest, and
8. the fossa for the lacrimal sac.

Clinical Application

- The location of the supraorbital notch is an important guide for avoiding injury to the nerve during brow surgery. It should always be marked out either by palpating the notch or, if there is no notch, by marking its position on the skin 27 mm from the midpoint of the glabella with a surgical marker.
- The zygomaticofrontal suture is an important landmark for removing the lateral rim during orbital surgery, because the anterior cranial fossa lies 5 to 15 mm above this horizontal level. The zygomaticofrontal suture is also a weak suture and is frequently the site of separation after facial trauma.
- The orbital rim is buttressed by adjacent bones and is frequently involved in complex facial fractures. The oculofacial surgeon must be aware of the normal anatomic relationships
among orbital bones and the nasal cavity, paranasal sinuses, cranial vault, and temporomandibular joint. Having a dry skull sitting on a table beside the patient who is undergoing complex facial fracture repair can be very helpful when realigning the various fractured bones.

**SUGGESTED READINGS**


A diffuse connective tissue framework exists within the orbital space that supports various orbital structures, maximizing their function and maintaining anatomic relationships between them. Some connective tissue septa are aligned with directions of force and serve to resist displacement of the extraocular muscles during contraction. Other fascial septa suspend and support delicate orbital vascular and neural elements. All orbital structures, including the periorbita, globe, optic nerve, and extraocular muscles, are involved in the organization and suspension of these extensive connective tissue septal systems. This intricate framework has several important components that are often difficult to see clinically and during orbital surgery but which must always be kept in mind as playing a role in the clinical presentation of a particular orbital problem. For example, a blowout fracture of the orbital floor with restricted motility in upgaze might be due to entrapment of the inferior rectus muscle within the fracture, but more commonly it is due to entrapment of the connective tissue framework +/- fat in the inferior orbit.

Clinical Application

- Enophthalmos, a deep superior sulcus, ptosis, and lower eyelid malposition are commonly seen following enucleation surgery. Loss of volume (of the globe) certainly plays a role, but other contributing factors, including a disruption of the connective tissue framework (which helps support the globe), might be playing a role. Trauma to Tenon’s capsule, Whitnall’s ligament, Lockwood’s ligament, or check ligaments associated with the recti muscles, as well as the intermuscular fascial connections, might also contribute to the postenucleation socket abnormalities mentioned above, as their disruption allows the shifting of orbital tissues to occur. Evisceration surgery is associated with less disruption to the connective tissue framework, and as a result features of postenucleation socket syndrome other than loss of volume are not as common.
3–1 OVERVIEW OF ORBITAL CONNECTIVE TISSUE

Historically, four major connective tissue components in the orbit have been described:

1. the bulbar fascia, or Tenon's capsule, which surrounds the globe;
2. the fascial sheaths of the extraocular muscles;
3. the intermuscular septum (the common muscle sheath connecting the four rectus muscles); and
4. the medial and lateral check ligaments.

Early anatomic studies of human connective tissue were done on exenteration specimens or on gross orbital dissections. As a result, the structural and functional intricacies of the orbital connective tissue framework were not appreciated. Recognizing the problems in the study of orbital connective tissue, Dr. Leo Koornneef approached the anatomic dissection of these structures by dissecting intact orbits using an operating microscope, which provided a more accurate picture of the orbital connective tissue framework. This framework not only extended throughout the orbit but also was much more elaborate than was originally conceived. Koornneef essentially described three distinct connective tissue systems:

1. The bulbar fascia or Tenon's capsule, which surrounded the globe and the extraocular muscles in the anterior orbit.
2. The anterior orbital connective tissue system, which connected Tenon's capsule to the periorbita near the anterior orbital margin. This dense, fibrous septal system helped support the globe and maintain its range of extraocular motility.
3. The extraocular muscle connective tissue system, derived from the fascial sheaths of the extraocular muscles. These sheaths produce a diffuse connective tissue framework in the posterior orbit. Anteriorly, the fascial sheaths of the extraocular muscles consolidate to form the medial and lateral check ligaments and the intermuscular fibrous septa.

Although the various components of the connective tissue framework are intricately linked throughout the orbit, for simplicity we find it easiest to conceptualize this framework as consisting of the following three systems:

1. Tenon's capsule (also known as the bulbar fascia),
2. the anterior orbital connective tissue framework, and
3. the posterior orbital connective tissue framework.

3–2 TENON’S CAPSULE

Tenon's capsule is a dense, fibrous layer of elastic connective tissue completely surrounding and closely applied to the eyeball, from the limbus anteriorly to the entrance of the optic nerve...
posteriorly, where it blends with fibers of the optic nerve sheath and sclera (Fig. 3-1). Tenon’s capsule is a barrier between the globe and the remaining structures of the orbit that enhances the functional and anatomic autonomy of the globe. It will be penetrated by all structures attaching to the eyeball, including muscles, arteries, nerves, and veins.

Because Tenon’s capsule envelops the globe, the extraocular muscles must penetrate it prior to their inserting onto the globe. Anterior to the insertion of the rectus muscles, Tenon’s capsule is thin and firmly adherent to episclera. The bulbar conjunctiva covers it externally. Posterior to the rectus muscle insertions, Tenon’s capsule is thicker and is separated from the episclera by a loose potential space that provides a smooth surface for ocular motility. The episcleral space in this area has numerous delicate connective tissue fibers that are easily separated from the globe during enucleation surgery.

As the extraocular muscles approach the globe, their thickened muscle sheaths and the intermuscular septal tissue blend with and become continuous with Tenon’s capsule.

The four recti muscles all pass through Tenon’s capsule in a similar way, but the obliques follow a slightly different path through the connective tissue around the globe as a result of their orientation.

The superior oblique tendon is covered by a delicate fibrous capsule as well as a reflection of the posterior Tenon’s capsule that extends from the trochlea to the globe. As the tendon leaves the trochlea, it travels laterally and posteriorly within this reflection of Tenon’s capsule and pierces the intermuscular septum just medial to the superior rectus muscle, anterior to the equator of the globe. The tendon then passes deep to the superior rectus before inserting into sclera posterior to the equator of the globe.

**FIGURE 3-1** Tenon’s capsule with the four recti muscles entering. Intraconal fat can be seen through the posterior Tenon’s capsule.
The inferior oblique muscle originates external to Tenon’s capsule in the extracranal compart-
ment. Shortly after leaving its origin adjacent to the nasolacrimal foramen, the inferior oblique
penetrates Tenon’s capsule and runs through the capsule a short distance before penetrating it
medial to the inferior rectus muscle. As it crosses the midline, the inferior oblique passes external
and inferior to the inferior rectus muscle. Its fibrous sheath becomes fused with that of the inferior
rectus and with a thickening of Tenon’s capsule to form a central cord that is part of the adjacent
Lockwood’s suspensory ligament of the inferior orbit. As the muscle continues toward its inser-
tion, it pierces the intermuscular septum to enter the intraconal space. The inferior oblique passes
beneath the tendon of the lateral rectus muscle, closer to the globe, and continues to its insertion
on the posterior globe near the macula.

Clinical Application

- The posterior Tenon’s capsule separates the globe from the intraconal orbital fat. Thus, the
  anterior portion of the intraconal fat compartment is bounded centrally by the posterior
  Tenon’s capsule and peripherally by the rectus muscles and the thin intermuscular septum
  between them. Tongues of intraconal fat extend forward over the globe within the narrow
  space between the intermuscular septum and the posterior portion of Tenon’s capsule.
  These tongues extend to about 9 to 10 mm behind the limbus. With age, thinning of Tenon’s
  capsule and of the intermuscular septum occurs. As a result, intraconal fat can extend
  through tissue rents and appear in the superior or inferior temporal fornices as subconjunc-
tival/subtenons fat prolapse.
- Following an enucleation, the glistening white interior of the Tenon’s space is well visual-
  ized. Posteriorly to where the optic nerve is cut, intraconal fat is readily seen. This rent is
  best left open during implant placement. If the medial and lateral edges of the anterior
  Tenon’s capsule are gently held forward (with double-pronged skin hooks or toothed
  forceps), the freshly cut edge of each cut rectus muscle is well seen where the muscles pen-
  etrate Tenon’s capsule. Contrary to some existing beliefs about the rectus muscles, they do
  not retract deep within the orbit when severed from the globe. They are held in position
  through their intricate connections to Tenon’s capsule and to the intermuscular septa (i.e.,
  the connective tissue frame work).

3–3 ANTERIOR ORBITAL CONNECTIVE
TISSUE FRAMEWORK

Koornneef’s dissections through the conjunctival fornix disclosed numerous connective tissue
attachments between the globe and the periorbita. Careful dissection revealed connective
tissue septa with enclosed adipose tissue in a 360° encapsulation. Septa were also noted between
superior and inferior oblique muscles, Tenon’s capsule, and the corresponding rectus muscles.
A condensation of connective tissue was also identified between the inferior oblique and the inferior rectus muscle.

This diffuse anterior connective tissue framework of the orbit primarily serves to support the globe, the lacrimal gland, the superior oblique tendon, the inferior oblique muscle, and the eyelids. It consists of a number of well-developed connective tissue condensations and ligaments, as well as a more diffuse system of fibrous septa. Major components include Whitnall’s suspensory ligament, Lockwood’s inferior ligament, the capsulopalpebral fascia, the medial and lateral check ligaments, the lacrimal suspensory ligaments, the intermuscular septum, and an intricate anterior septal system connecting each rectus muscle to the adjacent walls.

The suspensory ligament of Whitnall is discussed elsewhere in more detail (see Chapter 1, Fig. 1-23A). Whitnall’s ligament essentially consists of a condensation of connective tissue in the superior orbit. It is located both anterior and posterior to the levator aponeurosis in the same area in which the aponeurosis turns into muscle (which is approximately at the orbital rim level). It runs horizontally just below the orbital rim and is seen clinically (during anterior aponeurotic ptosis surgery) as a glistening white structure. Medially, Whitnall’s ligament has strong attachments to the fascia around the trochlear area and the adjacent orbital bone. Laterally, Whitnall’s ligament extends through the lacrimal gland (supporting it) to insert into the peristeum along the superolateral orbital wall (frontal bone). Medially, a fine band extends inferiorly along the edge of the medial horn of the levator aponeurosis to join the medial head of Lockwood’s ligament just posterior to the medial canthal tendon. Laterally, Whitnall’s ligament sends branches to the lateral orbital tubercle (Whitnall’s tubercle), contributes to the lateral retinaculum, as well as a branch positioned more inferiorly, posterior to the lateral canthal tendon, that joins a similar band from Lockwood’s ligament of the lower lid. More centrally, fibrous tissue septa from Whitnall’s, in conjunction with septa from the superior rectus, extend to the superior conjunctiva, acting as suspensory ligaments of the superior fornix. The exact role of Whitnall’s ligament is not entirely clear. Suggested functions include the following:

1. a suspensory role for the anterior superior orbital tissue,
2. a suspensory role for the lacrimal gland,
3. the maintenance of topographic relationships among various orbital structures during ocular movement,
4. a possible pulley effect enacted by redirecting the contracting force of the levator from an anterior-posterior direction to a superior-inferior direction, and
5. a possible action as a check ligament against posterior excursion of the levator muscle.

Lockwood’s ligament and the capsulopalpebral fascia also are described in Chapter 1 (see Figs. 1-22C, 1-23A, and 1-27). Lockwood’s ligament in the lower lid is analogous to Whitnall’s ligament in the upper lid. Like Whitnall’s, it is a condensation of fascial tissue that acts as a broad suspensory sling of the anterior-inferior orbit. It lies just anterior to and superior to the inferior oblique muscle. It has contributions from the following:

1. the lower eyelid capsulopalpebral fascia,
2. Tenon’s capsule (fascia bulbi),
3. intermuscular fibrous septa, and
4. fascia surrounding the inferior oblique and inferior rectus muscles.

The lower eyelid *capsulopalpebral fascia* and *inferior oblique fascia* are the major contributors to Lockwood’s ligament. The ligament extends laterally to attach to Whitnall’s tubercle and the lateral retinaculum at the lateral orbital wall (in company with the lateral horn of the levator, the lateral canthal tendon, and the lateral check ligaments). Some fibers pass directly to the inferior extension of Whitnall’s ligament and the lateral horn of the levator aponeurosis. Medially, Lockwood’s has attachments to three areas: the anterior arm of the medial canthal tendon, the posterior lacrimal crest, and an inferior extension from Whitnall’s ligament, in company with the posterior portion of the orbital septum. Thus, Lockwood’s ligament, along with Whitnall’s ligament and the canthal tendons, forms a nearly encircling fascial system around the entrance of the orbit. Centrally, another extension from Lockwood’s ligament passes as fine septa to insert into the inferior conjunctiva, forming the *suspensory ligament of the inferior fornix* (Fig. 1-25). Suggested functions of Lockwood’s include the following:

1. a suspensory sling (or hammock) for the anterior-inferior orbit,
2. the maintenance of the complex anatomical relationships of the lower lids and fornix during changes in gaze position, and
3. possibly serving to limit the posterior displacement of inferior orbital structures.

The *capsulopalpebral fascia* is a fibrous sheet arising from the sheaths around the inferior rectus and inferior oblique muscles. After originating from the inferior rectus muscle (see Fig. 1-25), the capsulopalpebral fascia splits into two sections to envelop the inferior oblique muscle. The two portions of the capsulopalpebral head reunite and help form Lockwood’s ligament. From this position, the capsulopalpebral fascia passes anteriorly and then superiorly into the lower eyelid to fuse with fibers of the orbital septum approximately 4 to 5 mm below the tarsal plate. From this junction, a common fascial sheet continues upward and inserts onto the lower border of the tarsus; however, it is controversial whether it inserts directly into the tarsal border or just inferior to the tarsus. Fine slips of fibrous tissue pass anteriorly from the capsulopalpebral fascia through the orbicularis muscle septa and toward the skin, forming the lower eyelid crease (as discussed earlier). The capsulopalpebral fascia (with some contribution from the lower eyelid Müller’s muscle) function as the lower eyelid retractors and are analogous to the upper eyelid retractors (levator aponeurosis and Müller’s muscle). The lower eyelid retractors, however, are primarily fibrous, with only a minor muscle component. Although the lower eyelid has some movement in down gaze, it is much less than that of its analogous structure in the upper lid during up gaze (3 to 5 mm versus 12 to 18 mm).

The *medial check ligament* originates in the medial rectus muscle sheath and the adjacent Tenon’s capsule. It inserts, along with the orbital septum and the medial horn of the levator aponeurosis, onto the lacrimal and ethmoid bones. Its fibers can be intermingled with the orbital sepal tissue, or they can appear as a separate fibromuscular band of tissue or as fine fibromuscular wisps of tissue between the muscle sheath and the medial orbital wall.

The *lateral check ligament* is formed by a group of thin fibrous connections between the lateral orbital wall and the sheath of the lateral rectus muscle. These fibers extend over a broad area from
the lateral orbital tubercle to approximately 14 mm posterior to the orbital rim. Along with the lateral canthal tendon and the lateral horn of levator, which also extend posteriorly (3 to 6 mm) after inserting onto Whitnall’s tubercle, these merged fibrous connective tissue elements form the lateral retinaculum.

Sympathetic muscle fibers have been identified in the medial and lateral connective tissue bands making up the check ligaments, suggesting the possibility of a dynamic component. One hypothesis suggests that these connections might act like an active pulley system to help adjust the ocular alignment in various positions of gaze (see Chapter 4).

The lacrimal gland is supported in its fossa by various attachments (the lacrimal suspensory ligaments). The major supportive structures of the lacrimal gland are Whitnall’s ligament and the lateral horn of levator, as described earlier. Whitnall’s ligament intermingles with the connective tissue of the lacrimal gland and inserts high on the lateral orbital wall. The lateral horn of the aponeurosis divides the lacrimal gland into orbital and palpebral lobes and supports it as it travels to the lateral orbital tubercle. The suspensory ligaments of Sommering (another supportive structure), also help attach the superior surface of the gland to the periorbita of the frontal bone. This ligament consists of loose connective tissue septa that pass from the stroma of the gland to the periorbita. These septa can be few and flimsy or numerous and strong. One other minor supportive structure of the posterior portion of the lacrimal gland comes from septa arising from the lateral orbital suspensory system. These have become known as the inferior ligaments of Schwalbe.

Clinical Application

- With advancing age, the lacrimal suspensory ligaments can become lax, allowing the lacrimal gland to migrate inferiorly and appear as a lateral fullness in the eyelid. During upper blepharoplasty, this must not be confused with fat that often extends laterally and at times covers the lacrimal gland prolapse. The fat should be removed carefully in this area. If a prolapsed lacrimal gland is identified, it can be repositioned into the lacrimal fossa by suturing the gland to the orbital periosseum. A double-armed 5-0 permanent suture is passed right through the superficial aspect of the gland. Both needles are then passed through the periosseum in the lacrimal fossa, whereupon they are tied. Passing the suture into the superficial gland has no effect on its function.

The intermuscular septum is often depicted as a connective tissue sheet extending between the rectus muscles and enclosing the intraconal orbital space. In reality, there are multiple intermuscular septal membranes in the anterior suspensory system (Figs. 3-2C through 3-2E). These membranes form an interconnected array of septal planes passing irregularly between the various muscle sheaths and from these to the adjacent orbital walls. Nowhere in the anterior orbit is there a single encircling septum in the classic sense; instead there is a system of roughly parallel and partially broken layers that are more prominent in the plane of the rectus muscles. The only exception to this is in the area of the annulus of Zinn and the superolateral orbit, where the intermuscular septum is thicker and thus appears more like a true intermuscular septum. As the extraocular muscles approach the globe, the multiple intermuscular septal membranes become fused to Tenon’s capsule.
FIGURE 3-2  (A) Cross-sectional planes to illustrate the orbital connective tissue at varying levels. (B) The anterior orbital connective tissue framework, at mid-globe level.
FIGURE 3-2  (C) The connective tissue framework just posterior to the globe. (D) The posterior orbital connective tissue framework, posterior mid-orbit.
The "intraconal space" is the space referred to as being inside the recti muscles if the muscles were all interconnected to one another with a uniform intermuscular septum. The "extraconal space" is the space outside the recti muscles. Although these are useful anatomic conceptions, the intermuscular septum (as described above) is not as well defined as most people think. Rather, it comprises an interconnected array of septal planes passing irregularly from the various muscle sheaths, and from these to the adjacent orbital walls.

In the anterior half of the orbit, a complex system of suspensory septa link the extraocular muscles to one another and to the orbital walls. Each of the recti muscles lies within a complex system
of septa that primarily perform suspensory functions. They surround the individual muscles and pass from the muscle sheath to the adjacent periosteum. Weaker connections often extend to adjacent recti muscles (Fig. 3-2B). Inferiorly, approximately 10 mm behind the orbital rim, the anchoring septa between the inferior rectus and the floor are lost as Lockwood’s ligament becomes better defined. Here, the inferior rectus muscle sheath develops extensive fascial connections to the sheath of the inferior oblique as part of Lockwood’s suspensory complex forms. Connective tissue septa extend from Lockwood’s complex to Tenon’s capsule, to the medial and lateral canthal tendons, and into the lower eyelid. Superiorly, the superior rectus muscle complex is suspended from the orbital roof by numerous fascial connections to the periorbita of the frontal bone. As the levator muscle changes into its aponeurosis, Whitnall’s superior suspensory ligament becomes evident as a glistening white condensation of connective tissue that blends with the adjacent fibrous connective septa associated with the superior rectus–levator complex. Whitnall’s has extensive connections to the adjacent orbital walls.

3–4 POSTERIOR ORBITAL CONNECTIVE TISSUE FRAMEWORK

Koonneef’s dissections revealed a connective tissue system derived from the fascial sheaths of the extraocular muscles (Figs. 3-2C through 3-2E, 3-3A, and 3-3B). Each extraocular muscle has its own separate, distinct connective tissue system, each with large areas of attachment and support. The numerous fascial extensions of the rectus muscles maximize their efficient action. Posteriorly, the intermuscular fibrous septa are not continuous; the recti muscles also lie in closer proximity to the orbital walls. Thus, there is no real anatomic distinction between the intraconal and extraconal spaces, contrary to popular belief.

The posterior connective tissue framework is less well defined than the more intricate and complex connective tissue framework in the anterior orbit. Each of the extraocular muscles has various attachments to surrounding periorbita and other extraocular muscles, with the medial rectus having the most diffuse attachments of all of the extraocular muscles (orbital floor, inferior rectus, levator–superior rectus complex).

The lateral rectus has connective tissue attachments to the periorbita of the lateral wall and the inferior orbital fissure, the optic nerve, the superior ophthalmic vein, the levator–superior rectus complex, and the inferior oblique.

Thelevator–superior rectus fascial complex has numerous attachments to the frontal bone. Connective tissue septa from this complex form a hammock for the superior ophthalmic vein, and they also have attachments to the medial and lateral rectus muscles.

The superior oblique muscle is supported by an arch-like band of connective tissue in the superior medial aspect of the orbit. It does not have many attachments until it reaches the posterior portion of the globe, where it has connective tissue attachments to the medial rectus.

In the orbital apex is located the fibrous annulus of Zinn, a condensation of connective tissue continuous with the periorbita that encircles the optic foramen and the medial half of the superior orbital fissure, creating an opening known as the oculomotor foramen (Figs. 2-7C and 3-2F).
FIGURE 3-3 (A) Sagittal plane used to illustrate the connective tissue framework. (B) The connective tissue framework and various orbital structures.
The annulus consists of two approximate half-circles, the tendon of Lockwood superiorly and the tendon of Zinn inferiorly. The recti muscles take origin from the fibrous annulus of Zinn. As the extraocular muscles thicken, the prominent fibrous structure of the annulus of Zinn thins rapidly, finally remaining only as several fine septa extending between the expanding muscle bellies and merging into the muscle sheaths. Thus, only here does a true encircling intermuscular septum exist. However, only a few millimeters more anterior, this structure quickly passes into an irregular system of fascial septa with more prominent connections to the orbital walls and the optic nerve. From the lower edge of the tendon of Zinn, fascial strands extend inferiorly to join the connective tissue and orbital muscle of Müller’s (smooth muscle), which bridges over the inferior orbital fissure. Between the annulus of Zinn and Müller’s muscle are dilated venous channels derived from the inferior ophthalmic vein that connect with the pterygoid plexus of veins. Here they anastomose with branches from the infraorbital vein, through which blood once again communicates with the facial venous system.

Clinical Application

- The extensive fascial septal planes of the orbit provide an intricate, interconnected system that unites many structures, limits movement, and maintains order within a constantly shifting, dynamic environment. If it were not for these fibrous connective tissue septa, the orbital fat lobules would redistribute, as can sometimes be seen following enucleation or extensive orbital surgery, when the fascial framework is disrupted.
- The orbital fascial framework also supports more delicate structures such as veins and nerves and provides pathways along which fluid may drain to the lymphatics of the eyelids or to the cavernous sinus.
- Restrictive motility following an orbital floor fracture is more commonly due to herniation of the periorbita, orbital fat, and connective tissue septa into the maxillary sinus, with traction on the muscle sheath through its complex septal connections, than it is due to incarceration of the inferior rectus muscle itself.
- During orbital decompression surgery, the removal of large sections of the orbital walls might lead to a shift of the position of portions of the orbital connective tissue framework. This might lead to a shift of the globe or a change in the patient’s motility.
- In Graves orbitopathy, motility restriction might be due to fibrosis within the extraocular muscles, but it also can be due to hypertrophy of the fascial septa resulting from chronic inflammation. This thickening of septal planes is also responsible for the failure of fat to prolapse during and after orbital decompression surgeries.
- The orbital congestion seen as an early sign in Graves orbitopathy might be related to alterations in orbital vascular dynamics. The superior ophthalmic vein, for example, runs within a fascial hammock in close approximation to the superior rectus muscle. Fibrosis within these septal layers, along with only minimal enlargement or inflammation of the superior rectus, could compress the vein in some individuals and contribute to the congestion not uncommonly seen in the active phase of the disease.
SUGGESTED READINGS


Whereas skeletal muscles generally perform specific limited roles, extraocular muscles (EOMs) have to be responsive over a wider dynamic range. As a result, EOMs have fundamentally distinct structural, functional, biochemical, and immunological properties as compared to other skeletal muscles.

At birth, the extraocular muscles are at approximately 50% to 60% of their final dimension. Their relative growth within the enlarging orbit and their angular relations with the globe remain nearly constant from infancy to adulthood. The adult rectus muscles are approximately the same length (40 mm) but differ in thickness and in the length of their tendons.

There are six extrinsic, or extraocular, muscles of the eye: four recti and two obliques (Figs. 4-1A through 4-1C). Only the horizontal and vertical recti insert on the eyeball in front of its equator. Both obliques have their insertions behind the equator of the globe. All six muscles consist of striated muscle fibers with abundant elastic fibers. The EOMs have muscle fibers and innervations that differ from those of skeletal muscle. There are three distinct types of muscle fibers (fine, granular, and coarse) that contribute to the action of the EOMs. The fine fibers are thought to be responsible for slow twitch movements, the granular fibers for fast twitch movements, and the coarse fibers for slow tonic movements. The EOMs are more richly innervated than other voluntary muscles of the body and have three types of nerve terminals: single endplate (driving eye movements), multiple endplates (tonic tension), and palisade endings (can be sensory receptors). In addition, there are both singly and multiply innervated nerve fibers present.

EOMs are able to vary their contractile force by small increments. The maximum firing frequency of ocular motor units is about four times greater than those of limb muscle motor units. To allow them to operate at a higher frequency, EOMs also have faster contractile properties, with their time to peak tension and their one-half relaxation time being at least half of those in limb muscles. The higher firing frequency, faster contractile properties, and higher percentage of recruitment of ocular motor units in almost every eye movement all contribute to make the properties of EOMs more energy-demanding than those of limb muscles. As a result, EOMs need a high fatigue resistance in order to fulfill their more energy-demanding properties. In order to maintain such a
high fatigue resistance, EOMs possess a highly developed microvascular bed, a higher blood flow, a higher mitochondrial content, and a higher metabolic rate.

Each EOM can be divided into two main layers: a thin orbital layer adjacent to the bony walls of the orbit, and an inner global layer immediately adjacent to the globe. Fibers in the orbital layer have a relatively higher mitochondrial content as compared to corresponding fibers in the global layer. The difference in the mitochondrial content might be due to a difference in their functional specialization. One hypothesis suggests that the global layer inserts onto the sclera mainly to rotate the globe, whereas the orbital layer inserts via connective tissue bands to the anterior orbital walls. Sympathetic muscle fibers have been identified in these connective tissue bands, suggesting a
The Extraocular Muscles

Dynamic component to them. These connections might allow the orbital layer of the EOM to adjust the position of the fibers in the global layer during various ocular movements, almost like an active pulley system (i.e., the Active Pulley Hypothesis of Miller). In order to support the continuous elastic loading of the pulley system, the orbital layer would need a higher fatigue resistance and thus has a higher mitochondrial content. More recent evidence suggests that the pulley system might not be as clear as once thought. These connective bands have been described in classic anatomic studies and textbooks for over 75 years. They are referred to as check ligaments and are thought to limit excursion of the EOMs to some extent. Whether they are the functional insertion sites for the orbital layer of the EOM has become a controversial question. Other investigators have found that all EOM motor neurons are consistently involved with every eye movement, and distinct populations of motor neurons with specific firing patterns have not been identified. This does not mean there isn’t a pulley system. If there are pulley-like restraints on the dynamics of eye movement, it is more likely due to another mechanism. Another hypothesis suggests that the pulley is the sling of tissue encircling the portal for the EOM as it passes through the fascia bulbi (Tenon’s capsule). This fascia also has connective tissue attachments to the bones of the anterior orbit, which help support the EOMs. The movement of the pulley would be accomplished by the shortening of the entire muscle (both global and orbital portions) during muscle contractions that rotate the eye. No differential action of the orbital fibers of the EOM is required, and yet the pulley is moved along with the muscle to maintain the distance between the pulley and the scleral insertion of the tendon.

Clinical Application

- There are numerous differences between the EOMs and other skeletal muscles, so much so that they can be classified into a distinct allotype separate from the limb/diaphragm
and masticatory muscles. EOMs also have disease susceptibilities that differ from those of other skeletal muscles. They are selectively spared in Duchenne muscular dystrophy and motor neuron disease but selectively targeted in chronic progressive external ophthalmoplegia, myasthenia gravis, and Graves orbitopathy. The unique orbital location, EOM fibers, innervations, and mitochondrial distribution likely account for this predisposition to some diseases.

4–1 ORIGINS

4–1-1 Rectus Muscles

The four rectus muscles take origin from a common tendinous structure, the annulus of Zinn (Figs. 2-7C and 3-2F). The annulus forms from dura coming down the optic canal to the orbital entrance. It splits at this point, with one part becoming continuous with the periorbita and the other continuing as the sheath of the optic nerve. The splitting of the dura forms a cleft in which the base of the annulus is inserted. The tubular annulus is oval in cross section. The inferior half is better developed than the superior half and is known as the tendon of Zinn. The superior half is known as the tendon of Lockwood. The annulus of Zinn is attached to the apex of the orbit in such a way that it embraces both the optic foramen and the medial half of the superior orbital fissure. Where it crosses the fissure, the annulus is attached to the greater wing of the sphenoid bone.

The portion of the orbital apex enclosed by the annulus is called the oculomotor foramen. The ophthalmic artery and several nerves transmitted through the optic foramen and the medial portion of the superior orbital fissure enter the orbit through the oculomotor foramen to supply structures within the muscle cone (NASO²). Through the lateral end of the superior orbital fissure (outside the oculomotor foramen), several other nerves and veins enter (LMSFT), as described in Chapter 2 (see Fig. 2-7C).

The superior and medial recti arise from the annulus of Zinn above and medial to the optic foramen, respectively. Because the optic foramen is set obliquely (facing forward, outward, and downward), the superior and medial recti have their origins somewhat anterior to the others and are more closely related to the sheath of the optic nerve. The superior and medial rectus muscles are actually adherent to the optic nerve sheath at the annulus of Zinn. Above the origin of the superior rectus is the levator palpebrae superioris, which arises via a short, narrow tendon from the lesser wing of the sphenoid. This tendon blends with that of the superior rectus, and some anatomists feel that it takes origin from both the annulus of Zinn and the lesser wing of the sphenoid.

The inferior rectus arises from the annulus below the optic nerve. The lateral rectus arises from that portion of the annulus that crosses the superior orbital fissure. In addition, part of the lateral rectus might take origin from a small, bony prominence on the greater wing of the sphenoid called the spina recti lateralis.
Clinical Application

- The fact that the superior and medial rectus muscles are adherent to the optic nerve sheath at the annulus of Zinn suggests an explanation for the painful ocular motility that occurs with retrobulbar neuritis. Contraction of these muscles is transmitted directly to the inflamed dura at the entrance to the optic canal.

4-1-2 Oblique Muscles

The superior oblique muscle arises from the lesser wing of the sphenoid via a short, narrow tendon anterior and medial to the optic foramen, in the angle between the annulus of Zinn and the peri-orbita of the medial wall. This angle is at the junction of the frontal, ethmoidal, and lesser wing of the sphenoid bones. It then passes forward just above the frontoethmoidal suture line in the superior medial orbit. As it runs forward, it is intimately involved in a connective tissue system that supports the globe and suspends the muscle from the frontal bone.

The inferior oblique takes its origin from a small, shallow fossa in the floor of the orbit, just within the orbital margin and slightly lateral to the opening of the nasolacrimal canal. During a dacryocystorhinostomy procedure, these fibers can be seen.

Clinical Application

- The origin of the inferior oblique can easily be injured during extraperiosteal dissections along the orbital floor and medial wall, for example, during blow-out fracture repair and during orbital decompression surgery. It is best to remain posterior to the posterior lacrimal crest during such operations.

- Enlargement of the EOMs might be seen in a variety of pathologic processes. The most common cause is thyroid eye disease, or thyroid orbitopathy, in which chronic lymphocytic infiltration and edema are associated with the intramuscular accumulation of glycoprotein and acid mucopolysaccharide. The often massive enlargement of these muscles can increase orbital volume by as much as 400% and cause a “compressive” optic neuropathy because of the limited space within the orbital apex. The enlarged EOMs, along with expansion of the fat space, might also displace the globe enough anteriorly to cause a “stretch” optic neuropathy. Some patients might have components of both “stretch” and “compressive” optic neuropathy. Thyroid orbitopathy is typically a bilateral disease, although it is frequently asymmetrical, and it usually affects several EOMs. This process involves only the muscle fibers, with sparing of the muscle tendons. As the muscles enlarge, axial proptosis and forward herniation of the extraconal fat into the eyelids are characteristic early features of the disease. Later, inflammatory fibrotic contracture of the EOMs can result in restrictive motility disturbances. Inflammation and fibrosis within the levator muscle and Müller’s sympathetic muscle, as well as inflammation and fibrosis in the lower eyelid smooth muscle and
capsulopalpebral fascia with traction on the capsulopalpebral fascia from inferior rectus muscle contracture, contribute to progressive upper/lower eyelid retraction. Abnormal stimulation of Müller’s muscle might also contribute to the lid retraction. Inflammation and fibrosis within the connective tissue framework throughout the anterior orbit exacerbate the process.

- Nonspecific orbital inflammation of the EOMs (“myositis”) is another common inflammatory process that presents acutely with enlarged EOMs. Rapid onset of pain, proptosis, and diplopia associated with eyelid swelling, chemosis, and injection suggest an inflammatory process. This process usually affects a single muscle on one side, and the motility restriction is in the field of action of the affected muscle. In contrast to thyroid eye disease, the muscle and tendon are usually involved in this situation. The process usually (and characteristically) responds dramatically to systemic corticosteroids.

- Orbital trauma causing blow-out fractures of the orbital floor and/or medial wall frequently cause isolated EOM restriction with some degree of enlargement, at times secondary to edema and hemorrhage within the muscle. It is important to follow these individuals closely in the first two weeks and watch for resolution. If a significant motility disturbance remains, entrapment of the muscle and/or the associated fibrous connective tissue framework within the fracture site might be causing enough mechanical restriction that surgical release is required.

- Other causes of enlarged muscles are less common, but numerous. Examples include sarcoidosis, inflammatory bowel disease (Crohn’s), collagen vascular disease (systemic lupus, dermatomyositis), primary tumor (lymphoma, rhabdomyosarcoma, meningioma), metastatic tumor (breast, lung, cutaneous melanoma), vascular (carotid-cavernous sinus fistula, varix, dural venous shunt, arteriovenous malformation), infection (orbital cellulitis, tuberculosis, syphilis, mucormycosis, cysticercosis), or other causes (e.g., acromegaly, amyloid).

- Myasthenia gravis, the most common disease affecting the neuromuscular junction, is a disorder of impaired neuromuscular transmission due to antibodies that are directed against acetylcholine receptors. It is characterized by a variable decrease in strength of the affected muscles. The levator muscle and EOMs are frequently involved, and might be the presenting feature of the disease. A variable ptosis (lids higher at some times than at other times) might be the first presentation. All degrees of ocular motor dysfunction have been observed, from a single muscle weakness to complete external ophthalmoplegia.

### 4–2 ORBITAL COURSE OF THE EXTRAOCULAR MUSCLES

The recti muscles are in close relationship at the orbital apex. For the first 5 to 6 mm of their length, the muscles are buried within the fibrous annulus of Zinn and do not appear as individual structures. By about 8 mm anterior to the optic strut, the rectus muscles separate as individual
The Extraocular Muscles

structures, and the fibrous tissue of the annulus thins and becomes continuous with the muscle sheaths. Once the muscles leave the apex, they sit adjacent to the orbital bones until their insertion onto the globe. The muscles are typically 3 to 5 mm in thickness in the mid-orbit, depending on the position of gaze. Each of the muscles is encased in a thin, fibrous sheath that represents a connective tissue extension of the annulus of Zinn. These muscle sheaths are somewhat interconnected circumferentially by an irregular array of fibrous connective tissue, forming the so-called intermuscular septum. The intermuscular septum is incomplete posteriorly and becomes more defined anteriorly, but nowhere in the orbit is there a single encircling septum in the classic sense except adjacent to the annulus of Zinn and in the superior lateral orbit.

A complex system of fine connective tissue septa extends between the individual muscles, the optic nerve, Tenon’s capsule and periorbita (Figs. 3-2C through 3-2E). This fibrous connective tissue framework (Chapter 3) system helps maintain the positional and functional relationships of these structures during ocular movement. The EOMs have a dynamic relationship with the orbital structures by way of the various connective tissue septa, as well as various check ligaments, as described earlier. The check ligaments also help to restrain the EOM movement. In addition, there might be a dynamic pulley system of some variety to help stabilize the position of the EOMs in the orbit.

At the posterior surface of the globe, the rectus muscles pierce the posterior portion of Tenon’s capsule and are covered by a sleeve-like extension of the capsule. This intracapsular portion of the rectus muscles is 7 to 10 mm in length and has fascial connections to the overlying Tenon’s capsule. The muscles are able to move forward and backward within Tenon’s capsule, thereby preventing restricted ocular motility. As the inferior and superior rectus approach the globe, the relationship with the eyelid retractors becomes more significant. The connective tissue around the inferior rectus and inferior oblique contributes to the formation of the lower lid retractors (capsulopalpebral fascia) and Lockwood’s ligament. The superior rectus also has an intimate relationship with the levator superioris, with numerous fibrous connective tissue strands between the two. Any change in position or injury to the vertically acting muscles can result in a change in lid position.

Clinical Applications

- Recession of the inferior rectus can alter the position of the lower lid, resulting in lid retraction. Similarly, superior rectus traction sutures and recession procedures can result in ptosis or eyelid retraction.
- The recti muscles pass close to the orbital walls in the mid-orbit. This anatomical relationship has numerous clinical implications. For instance, in endoscopic sinus surgery, the medial rectus muscle is particularly vulnerable to injury should the lamina papyracea be removed. In orbital floor fractures, restriction in vertical gaze might be secondary to entrapment of the inferior rectus muscle, the fibrous connective tissue around the muscle, fat, or a combination of these structures.
4–3 INSERTIONS

4–3-1 Rectus Muscles

The rectus muscles insert into the eyeball via their thin, flat tendons, which blend into episclera and superficial sclera (Figs. 4-2A and 4-2B). Some of the tendon fibers might have separate insertions 1 to 5 mm behind the attachments of the main body of the fibers.

The distance from the limbus to the EOM insertion progressively increases from the medial rectus (5.3 to 5.5 mm), inferior rectus (6.5 to 6.8 mm), lateral rectus (6.9 mm), and superior rectus (7.7 to 7.9 mm) and forms the Spiral of Tillaux (Fig. 4-2C). The insertions can vary considerably in infants and children and with age. The medial rectus has been reported to vary from 3.0 to 5.5 mm. This variance in insertion distance might affect recession of the muscle in strabismus repair. The tendon insertion width of the recti muscles ranges from 10.1 to 11.5 mm. The sclera is thinnest just posterior to the insertion of the extraocular muscles (0.3 mm), and a blue discoloration is often present as a result of the underlying uveal tissue’s being seen through the thin sclera.

FIGURE 4-2 Insertions of extraocular muscles. (A) Frontal view. (B) Back view. (C) Spiral of Tillaux.
The transparent and elastic intermuscular septum is present in only fragmented form posteriorly (as discussed earlier), but it becomes better defined at about the equator of the globe. Here the septum exists not as a single membrane but as a series of fascial sheaths irregularly interconnecting the muscles and periorbita. These septa sheets extend forward with the rectus muscles, where they become fused to the sleeve of Tenon’s capsule investing each muscle. Beneath Tenon’s capsule, the fascial sheaths partially coalesce again, and the reformed intermuscular septum continues forward as a separate layer between the sclera and Tenon’s capsule. It finally fuses to the globe about 2 mm from the corneal limbus, just before Tenon’s capsule merges with the superficial sclera. Fine elastic check ligaments extend between the intermuscular septum and Tenon’s capsule near the muscle insertions.

The intraconal fat pocket is contained within the space defined by the rectus muscles and is separated from the sclera by the posterior portion of Tenon’s capsule. The extraconal fat pockets lie outside the rectus muscle cone and continue forward over the rectus muscles external to Tenon’s capsule. These fat pockets extend to within 4 mm of the muscle insertions and end about 10 mm behind the corneal limbus. During strabismus surgery with exposure of the muscle insertion, a cut to the level of the sclera will pass through the conjunctiva, Tenon’s capsule, and intermuscular septum to enter the episcleral space. Tenon’s capsule should not be opened more than 9 to 10 mm posterior to the limbus, as doing so will permit prolapse of the extraconal fat pocket into the wound, with possible scarring and resultant motility restriction.

4–3-2 Oblique Muscles

The tendon of the superior oblique arises from the rounded muscle belly 14 to 15 mm behind the orbital margin. The tendon, like the muscle portion posterior to it, remains invested and supported in a complex suspensory system of fascial septa attached to the adjacent orbital wall. The narrow tendon passes anteriorly through the trochlea, a $4 \times 6$ mm saddle-shaped cartilaginous structure attached to the periosteum of the frontal bone at a small depression, the *fovea trochlearis*, just behind the superomedial orbital rim. The trochlea serves to redirect the pulling vector force of the superior oblique muscle. A bursa-like fibrillovascular connective tissue layer over the cartilaginous saddle allows the oblique tendon to move freely within the trochlea. After passing through the trochlea, the superior oblique tendon turns posterolaterally and travels toward the globe within an extension of Tenon’s capsule for about 8 mm. It pierces Tenon’s capsule 3 to 4 mm nasal to the superior rectus muscle, where it becomes very thin and nearly transparent. It inserts onto the sclera near the superotemporal vortex vein approximately 6.5 mm from the exit of the optic nerve. From the trochlea to the globe, the tendon is about 18 to 20 mm in length.

Clinical Applications

- In order to remember the dimensions of the superior oblique tendon, the reader might find the following mnemonic helpful: The “phone number” of the superior oblique tendon
is 102-108 (10 mm of tendon before the trochlea, 2 mm of tendon within the trochlea, 10 mm of tendon between the trochlea and the globe, and 8 mm of tendon on the globe to insertion).

- During an orbitotomy superiorly and medially (Lynch approach), the superior oblique tendon can be lifted away from the bone in order to provide wider access into the medial orbit. As long as one stays positioned extraperiosteally during this approach, the trochlea usually reattaches without the patient’s developing double vision postoperatively as a result of this dissection.
- Injury to the superior oblique tendon occasionally occurs during ptosis surgery if the surgeon plans on cutting the medial and lateral horns of the levator. If the superior oblique tendon is injured, the patient will complain of diplopia. With the aponeurotic approach to ptosis, the horns of the levator are not cut, and there is no risk of traumatizing the superior oblique tendon.
- Brown’s syndrome is a congenital or acquired motility defect that manifests as an inability to elevate the adducted eye above the mid-horizontal plane. Smaller degrees of elevation deficit are seen in the primary position, and little or none in the abducted positions, of gaze. An associated widening of the palpebral fissure is seen on adduction. This defect appears to have numerous etiologies. In some patients, the superior oblique tendon sheath anterior to the trochlea is unusually taut, resulting in a mechanical restriction. In others, however, the anatomic problem lies more posteriorly, with thickening of or adhesions to the tendon behind the trochlea.
- Several anatomic anomalies of the superior oblique tendon and insertion have been described in congenital superior oblique palsy. This is especially common with facial asymmetry and should be anticipated during any surgery on the superior oblique.
- Trochleitis might present with a nonspecific orbital pain that is difficult for the patient to localize and with few other signs or symptoms. The diagnosis is confirmed by re-creating the patient’s pain by touching the trochlea on the affected side. This problem is occasionally seen in the artificial eye patient and might be secondary to the prosthetic eye edge’s rolling over the trochlea during ocular movements (a form of microtrauma that sets the patient up for irritation and subsequent pain). Anti-inflammatory medications (e.g., ibuprofen) might help, but an injection of triamcinolone is often required to treat it.

The inferior oblique passes from its origin backward and laterally as a flat band inferior to the inferior rectus. The inferior oblique penetrates Tenon’s capsule medial to the inferior rectus muscles and then arcs laterally around the globe. It is firmly attached to the inferior rectus by a fusion of their fascial sheaths, and this combined structure contributes to Lockwood’s suspensory ligament. It inserts on the back of the eyeball over the macula near the horizontal meridian. Its tendon is very short and might be absent, in which case the muscle fibers themselves penetrate the sclera. This can lead to excessive bleeding upon disinsertion from the globe. In nearly 50% of normal individuals, the muscle inserts via 2 or 3 separate slips that divide 5 or 6 mm before the point at which they fuse with the sclera. If not recognized, this might result in incomplete recession during strabismus surgery.
Clinical Application

- The inferior oblique muscle is not uncommonly seen during lower lid blepharoplasty surgery. The ophthalmic surgeon must be on the lookout for this muscle in order to avoid unnecessary bleeding and trauma, especially during removal of the central and medial fat pads. If the muscle is severed, primary repair should be performed. When the inferior oblique muscle is injured, vertical double vision might result that becomes worse on adduction. The primary action of the inferior oblique is excyclotorsion; on exam, the eye might look hypotropic. The patient might adopt a head tilt toward the injured side in order to minimize the double vision. Secondary repair can be performed but is more complicated.

4–4 NERVES AND VESSELS

The motor nerve to each rectus muscle enters at the junction of the posterior one third and anterior two thirds of the muscle. This is important to remember during orbital surgery if the rectus muscles have to be moved to one side. Excess traction or trauma to the posterior half of the muscle might injure the nerve supply.

The lateral rectus is supplied by the abducens nerve (cranial nerve VI). The inferior division of the oculomotor nerve (cranial nerve III) supplies the inferior rectus and the inferior oblique, and usually the medial rectus. The superior division of the oculomotor nerve supplies the levator, the superior rectus, and occasionally the medial rectus. Each of these nerves travels through the fibrous annulus of Zinn en route to their muscles, which they penetrate, on the conal side at the junction of the posterior one third and anterior two thirds, with the exception of the nerve to the inferior oblique. The branch to the inferior oblique is a cord-like structure that runs from the orbital apex to the anterior orbit. It enters the muscle on the intraconal surface at its mid-position. The superior oblique is supplied by the trochlear nerve (cranial nerve IV), which enters the orbit through the superior orbital fissure outside the fibrous annulus of Zinn. The nerve passes forward and medially above the levator and superior rectus, just beneath the periorbita of the roof, to enter the superior oblique as three or four rootlets that penetrate its upper border along the posterior third of the muscle (see Fig. 5-6). The trochlear nerve is the only extraocular nerve that does not penetrate the conal surface of its muscle.

The ophthalmic artery might give off multiple branches to the EOMs, but generally there are two that are more prominent: a medial and a lateral trunk (also called a superior and an inferior trunk). The medial trunk generally supplies the lateral and superior recti, the superior oblique, and the levator. The lateral trunk supplies the medial and inferior recti and the inferior oblique muscles. Additional muscular branches might arise from the lacrimal, supraorbital, anterior/posterior ethmoidal, and infraorbital arteries, or from any large branch of the ophthalmic artery. No definite pattern of the additional muscular branches has been reported. Within the substance of each rectus muscle, branches continue forward and form the anterior ciliary arteries. There are two such anterior ciliary vessels associated with each of the rectus muscles except the lateral rectus, which
usually has just one. As the anterior ciliary arteries run forward, they gradually move to the extraconal surface, where they lie immediately beneath the muscle sheath.

Clinical Application

- Anterior segment ischemia, due to an interruption of the anterior ciliary vascular supply to the globe, is an occasional complication of strabismus surgery. Ocular ischemia generally occurs following the disinsertion of all four recti, but it can also occur following surgery on only three recti muscles. Symptoms and signs of anterior segment ischemia are corneal edema, corneal ulceration, uveitis, iris atrophy, ectopic pupil and posterior synechiae, cataract, hypotony, and phthisis bulbi. Predispositions include multiple muscle procedures, diabetes, other vasculopathies and coagulopathies, and carotid occlusive disorders.

- Duane's retraction syndrome is a condition characterized by a horizontal motility defect in abduction, associated with some degree of restricted adduction and variable retraction of the adducted globe. Although the disorder can be bilateral, it most frequently involves the left eye, and it is more common in females. Electromyographic evidence suggests that the primary cause is paradoxic innervation of the lateral rectus muscle on attempted adduction. This co-contraction of the horizontal rectus muscles on adduction causes retraction of the globe.

4–5 ACTIONS

Synergistic action of the EOMs produces coordinated ocular motility. The basic movements of the eye are abduction, adduction, elevation, depression, extorsion, and intorsion (Table 4-1).

When the various actions of the muscles are discussed, it is important to remember that the eyes are pointed straight ahead and the rectus muscles approach the globe at an angle; for example, the superior rectus approaches the globe at a 23° angle from the medial wall. For this reason, the superior rectus in primary position will cause elevation, but it also causes some adduction and intorsion.

Ocular movements in the horizontal plane are primarily controlled by the medial and lateral recti. Medial rectus contraction causes adduction; lateral rectus contraction causes abduction. A small amount of adduction is produced by the vertical recti in their direction of gaze as a result of the way the muscle fibers are oriented (23° from the medial orbital wall). A small amount of abduction is provided by the contraction of the oblique muscles as a result of the angle at which they insert onto the globe.

Elevation of the eye is provided by the superior rectus and the inferior oblique. As the eye moves into an abducted position, the superior rectus becomes the primary elevator, whereas the inferior oblique becomes the primary elevator of the adducted eye. Because the superior rectus proceeds to the globe from the orbital apex at a 23° angle from the medial wall, the motility induced by its contraction will vary depending on the horizontal position of the eye; for example, if the eye...
is abducted 23°, contraction produces vertical movement. In primary gaze, contraction produces elevation, intorsion, and adduction.

Depression of the eye is provided by the inferior rectus and the superior oblique. The inferior rectus is the primary depressor of the abducted eye, and the superior oblique is the primary depressor of the adducted eye. In primary position, contraction of the inferior rectus produces primarily depression, but also some adduction and extorsion. In adduction, the only movement produced by the inferior rectus is extorsion.

Intorsion is a movement of the globe that rotates the superior pole of the eye nasally. Intorsion is produced by both the superior oblique and the superior rectus. As the eye moves horizontally, the intorsional actions of the muscles vary. The torsional actions of the obliques serve to counteract the torsional movement of the recti muscles. For example, when the superior rectus contracts, intorsion of the globe occurs; this is offset by the inferior oblique, which extorts the globe.

The superior oblique tendon is redirected at the trochlea with an axis directed at a 51° angle from the axis of the globe. Thus, in primary position, superior oblique contraction causes depression, intorsion, and some abduction. In the adducted position, the only movement is depression. At an abduction of 39°, the only movement is intorsion.

Extorsion is a movement of the globe that rotates the superior pole of the eye temporally. This motion is provided by a combined action of the inferior oblique and the inferior rectus. In abduction, the inferior oblique is the primary extorter, whereas the inferior rectus is the primary extorter of the adducted eye.

A 51° angle is produced between the axis of the globe and the inferior oblique. In primary position, inferior oblique contraction produces elevation, extorsion, and abduction. In abduction (approximately 39°), the only movement produced by the inferior oblique is extorsion. In adduction, contraction causes elevation.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Primary Action</th>
<th>Secondary Action</th>
<th>Synergists</th>
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<tbody>
<tr>
<td>MR</td>
<td>Adduction</td>
<td>None</td>
<td>SR and IR</td>
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<tr>
<td>LR</td>
<td>Abduction</td>
<td>None</td>
<td>SO and IO</td>
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<tr>
<td>SR</td>
<td>Elevation</td>
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<td>Intorsion</td>
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<td>LR and SO</td>
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MR = medial rectus; LR = lateral rectus; SR = superior rectus; IR = inferior rectus; SO = superior oblique; IO = inferior oblique.
4–6 ACCESSORY EXTRAOCULAR MUSCLES

In about 8% of individuals, a supernumerary accessory EOM is present in the superomedial orbit. This *levator-trochlear muscle* is thought to differentiate from the levator and is innervated by the superior branch of the oculomotor nerve. It arises from the medial surface of the levator near its origin and runs forward between the levator and the superior oblique muscles. This muscle varies in development from a stout muscle band to an imperceptible condensation of muscle fibers. Anteriorly, it becomes thinner, less well defined, and mostly fibrous. Its major insertion is into the fascia surrounding the trochlea. Other fibers might go to the supratrochlear artery, the intermuscular septum, the levator muscle or medial rectus muscle, the periorbita, and/or the fascia surrounding the superior ophthalmic vein. The function of this anomalous muscle remains unknown.

Another variant is a small accessory muscle in the superolateral orbit, originating from the lateral aspect of superior rectus muscle. This accessory muscle runs in the superotemporal orbit near the periorbita and inserts onto the capsule of the lacrimal gland. It might send some fibers to the lateral horn of the levator aponeurosis as well. Although it is highly variable in development, this muscle might serve in part to retract the lacrimal gland and lateral aponeurosis in upgaze. Although the exact functions of these and other accessory muscles remain unclear, some probably represent developmental anomalies.

**SUGGESTED READINGS**


The Extraocular Muscles


He orbit contains a vast array of motor, sensory, sympathetic, and parasympathetic nerve fibers. Some of these fibers can be seen during eyelid or orbital surgery and are often landmarks of one’s location within the orbit. It is important to know the various nerve pathways, appreciate that there might be some individual variation, and preserve these pathways during orbital surgery.

The discussion of nerves begins with their superficial brainstem origin, proceeds to their intracranial course, and ends with their intraorbital course and eventual termination.

5–1 OVERVIEW OF ORBITAL NERVES

The following nerves enter the orbit:

1. **Optic nerve (cranial nerve II).**
2. **Oculomotor nerve (cranial nerve III).** This motor nerve gives fibers to the levator, inferior oblique, and three of the four rectus muscles. It carries parasympathetic fibers destined for the ciliary ganglion. These fibers will eventually synapse in the ciliary ganglion and then travel to the iris sphincter muscles (sphincter pupillae). Sympathetic fibers have also been recently identified in this nerve.
3. **Trochlear nerve (cranial nerve IV).** This motor nerve distributes fibers to the superior oblique muscle. Sympathetic fibers have recently been identified within this nerve.
4. **Trigeminal nerve (cranial nerve V).**
   a. **Ophthalmic division (V₁).** This sensory division gives fibers to the eyeball (iris, ciliary body, cornea), lacrimal gland, conjunctiva, and eyelids, as well as to the forehead. It also carries sympathetic nerves.
   b. **Maxillary division (V₂).** As it enters the orbit, the maxillary division is known as the infraorbital nerve and lies beneath the periorbita. It gives off the zygomatic nerve, which is an important branch carrying parasympathetic and sympathetic fibers to the lacrimal gland. Within the infraorbital canal, alveolar nerves arise and provide sensation to the incisor and canine teeth. The infraorbital nerve provides sensation to the lower eyelid, nose, cheek area, and upper lip.
5. *Abducens nerve (cranial nerve VI).* This motor nerve goes to the lateral rectus muscle. Sympathetic fibers have recently been identified within this nerve.

6. *Facial nerve (cranial nerve VII).* Parasympathetic fibers traveling in the nervus intermedius alongside the motor component of the seventh cranial nerve eventually get to the lacrimal gland, along with sympathetic nerve fibers, via the nerve of the pterygoid canal and zygomatic nerves to the lacrimal nerve and then the lacrimal gland. The nervus intermedius is considered as a component of the seventh nerve. There are no motor fibers of the seventh nerve traveling within the orbit.

7. *Parasympathetic and sympathetic nerve fibers.* These fibers enter the orbit accompanied by some of the nerves mentioned above, or they travel with various arteries. The ocular sympathetic fibers innervate the dilator muscles of the pupil and the smooth muscles of the eyelids. The parasympathetic fibers innervate the ciliary body and the iris sphincter muscles. Sympathetic and parasympathetic fibers also travel to the lacrimal gland.

As a result of new immunohistochemistry techniques used to label sympathetic nerves in the orbit, it has now been confirmed that sympathetic fibers enter the orbit via the ophthalmic nerve \(V_1\), the maxillary nerve \(V_2\), and a plexus of fibers around the ophthalmic artery. Essentially, sympathetic fibers travel through the optic canal, the superior orbital fissure, and the inferior orbital fissure (via the sphenopalatine ganglion to the zygomatic nerve). Although the extraocular motor nerves (oculomotor, abducens, trochlear) and ophthalmic artery plexus might partially contribute to the orbital sympathetic supply, the major sympathetic route to the orbit is in its sensory branches (long ciliary nerves, short ciliary nerves, nasociliary, lacrimal, and frontal nerves). The sympathetic muscles of the eyelid (e.g., Mueller’s) are supplied by the infratrochlear (direct continuation of the nasociliary) and lacrimal branches of the ophthalmic nerve \(V_1\).

### 5–2 OPTIC NERVE

The optic nerve extends from the globe to the optic chiasm and can be divided into the following parts: intraocular (optic nerve head), intraorbital, intracanalicular, and intracranial. The overall length of the optic nerve is about 50 mm. Each optic nerve contains approximately 0.7 million to 1.4 million axons with a mean axon diameter of 0.85 microns. The highest axonal density is in the temporal inferior segment of the nerve, corresponding with the location of the major portion of the papillomacular bundle.

The intraocular portion of the optic nerve head is 1 mm in length and lies within a sieve-like connective tissue region of posterior sclera known as the lamina cribrosa, through which pass the retinal ganglion cell axons and central retinal vessels. It leaves the globe 4 mm medial to the macula. Immediately posterior to sclera, the intraorbital portions of the nerve axons become myelinated and the nerve becomes surrounded by pia, arachnoid, and dura mater. The dura is continuous with superficial scleral fibers at the posterior globe and with periosteum at the optic canal. The intraorbital portion of the nerve is S-shaped and approximately 25 to 30 mm long. The S-shaped course permits free movement of the globe without compromising the nerve function, which might occur
if the nerve were straight or were stretched into a straight position, as happens sometimes in thyroid eye disease associated with severe proptosis. The optic nerve is surrounded by dura, arachnoid, and pia throughout its orbital course. The subarachnoid space is continuous from the middle cranial fossa along the nerve and into the posterior sclera. Cerebrospinal fluid in the subarachnoid space bathes the optic nerve (Fig. 5-1).

Clinical Application

- The subarachnoid space of the optic nerve is in continuity with the subarachnoid space of the middle cranial fossa. Clinically, this relationship might result in optic nerve compression and papilledema from increased intracranial cerebrospinal fluid pressure (e.g., as occurs in pseudotumor cerebri).
- During optic nerve sheath fenestration surgery (commonly performed for pseudotumor cerebri patients), a window is cut in the dura of the intraorbital portion of the optic nerve. The surgeon watches for a gush of cerebrospinal fluid to help identify the subarachnoid space. Once the window is cut, the surgeon should be able to see the fine nutrient pial blood vessels running on the optic nerve itself.
- In cases of severe proptosis, the optic nerve loses its S-shape redundancy. Stretching of the nerve and compression by its taught sheath might result in visual loss (stretch optic neuropathy).

FIGURE 5-1 The optic nerve has been transected. The dura (outer covering) and subarachnoid space (where cerebrospinal fluid flows) are seen well. The fine fibers in the subarachnoid space are referred to as "arachnoid granulations."
The posterior ciliary arteries and nerves run along the orbital portion of the optic nerve. The ciliary nerves are more numerous laterally, whereas the ciliary arteries are more evenly distributed medially and laterally. The central retinal artery pierces the optic nerve sheath on its inferomedial surface about 10 to 15 mm posterior to the globe, but the point of entry varies among individuals. The central retinal vein usually accompanies the artery, although its position is more variable and it might exit the nerve some distance from the artery.

The intracanalicular portion of the optic nerve is approximately 5 to 6 mm in length. The dura is fused to the periosteum in this area, causing the nerve to be less mobile than in other sections and predisposing it to injury during various head traumas. The ophthalmic artery passes through the optic canal inferior and slightly lateral to the nerve within a longitudinal split within the dura, and thus is separated from the nerve by dural fibers.

Clinical Application

- The intracanalicular portion of the optic nerve is vulnerable to compression from small mass lesions (e.g., optic nerve sheath meningiomas) or from ophthalmic artery aneurysms. Because of the fusion of the dura to the periosteum, this portion of the optic nerve is also vulnerable to contusion injuries. With blunt trauma, the nerve might slide within its sheaths, which can result in the shearing of pial vessels supplying the nerve. Also, the indirect transmission of mechanical forces from the frontal bone to the bones of the canal during severe blunt frontal trauma might result in contusion and edema of the intracanalicular optic nerve, with compression and occasional optic neuropathy from infarction.

The intracranial portion of the optic nerve travels superiorly and posteriorly at an angle of approximately 45 degrees to the horizontal plane. It averages about 10 mm in length (range: 3–16 mm) and extends from the intracranial opening of the optic canal to the optic chiasm. In this area, the optic nerve is very close to the frontal lobe (above), the internal carotid artery (lateral) as it exits the cavernous sinus, the anterior cerebral, middle cerebral, and the anterior communicating arteries. Aneurysms arising from these vessels can compress the optic nerve.

The optic chiasm is a commissure that allows the crossing of the nasal retinal fibers of each optic nerve to the contralateral optic tract. It averages 13 mm in width by 8 mm in length and is approximately 3 to 5 mm thick. The chiasm normally lies above the body of the sphenoid bone and over the diaphragma sella. The chiasm is separated from the diaphragma sellae and the pituitary gland by the basal cistern of the subarachnoid space, with an interval of up to 10 mm. Thus, expanding lesions of the pituitary gland usually become quite large before resulting in chiasmal compression. The afferent pathways diverging from the posterior aspect of the chiasm, termed the optic tracts, will terminate in the lateral geniculate bodies of the thalamus.

Clinical Application

- Optic nerve compression in the anterior or mid-orbit usually results in initial optic disc edema, enlarged blind spot, variable field defects followed by optic atrophy, blindness, and
occasionally optociliary shunt vessels. Compression within the optic canal, however, is usually associated with a normal funduscopic exam initially, but it eventually results in optic atrophy.

- Expanding pituitary lesions or other intracranial masses (e.g., craniopharyngiomas) might disrupt the decussating nerve fibers within the optic chiasm. Visual stimuli from the nasal half of each retina are blocked, resulting in a *bitemporal hemianopia*.
- Lesions of the optic tracts cause a loss of vision in the corresponding halves of each retina (nasal half in one eye, temporal half in the other eye), causing a *homonymous hemianopia*.

### 5–3 Oculomotor Nerve

The *oculomotor nerve* or third cranial nerve innervates the levator palpebrae superioris; the medial, superior, and inferior rectus muscles; and the inferior oblique muscle. It also carries parasympathetic fibers to the globe (via the motor root to the ciliary ganglion), where they innervate the ciliary muscle and the iris sphincter muscles. Recently, sympathetic nerve fibers have been identified within the oculomotor nerve (as well as in the trochlear and abducens nerves).

**Clinical Application**

- The role of the sympathetic nerves traveling with the oculomotor, abducens, and trochlear nerves is not entirely clear. Smooth muscle fibers have been identified within the check ligaments associated with the anterior portion of the extraocular muscles (see Chapter 4). Their innervation might come from these sympathetic fibers and suggests a dynamic role for the check ligaments (extraocular pulleys). One hypothesis suggests that they might help modulate vergence and stabilize ocular alignment in various positions of gaze. The smooth muscle in these pulleys is most prominent in the medial and lateral rectus muscles. Although this suggests a role for sympathetic nerves in the positional regulation of these extraocular muscles, the pathway of the sympathetic nerves to these pulleys is not entirely clear at this time.

#### 5–3-1 Superficial Origin

The oculomotor nuclear complex lies in the periaqueductal midbrain and is made up of paired subnuclei that innervate the extraocular muscles, with the exception that the motor cells that supply the levator originate in a single subnucleus. The fibers arising from the superior rectus subnuclei cross in the midline to join the fibers from the subnuclei of the medial rectus, inferior rectus, and inferior oblique, which arise ipsilateral to the muscle that they will innervate. The third nerve fascicles pass anteriorly through the red nucleus and the cerebral peduncles. The oculomotor nerve emerges from the midbrain as a series of rootlets on the medial surface of the cerebral peduncle, in front of and close to the pons, and from the ventral surface of the peduncle (Fig. 5-2). These rootlets immediately converge to form the oculomotor nerve trunk.
Clinical Application

- A nuclear third nerve palsy will cause bilateral ptosis of the upper eyelids.
- A fascicular third nerve palsy will usually have other neurological signs such as contralateral hemiparesis (Weber’s syndrome) or contralateral tremor (Benedikt’s syndrome).

5–3–2 Intracranial Course

The intracranial course of the oculomotor nerve has a posterior fossa component and a middle fossa component.

1. **Posterior cranial fossa.** The oculomotor nerve passes forward and downward in the subarachnoid space of the cisterna basalis, lying between the posterior cerebral artery and the superior cerebellar artery. Medial, superior, and parallel to it is the posterior communicating artery. The intracranial course of the oculomotor is approximately 25 mm prior to its piercing the dura (Figs. 5-3A and 5-3B).
FIGURE 5-3 Relationship of the brainstem, cranial nerves, and basal structures. (A) The internal carotid extends through the carotid canal and foramen lacerum to enter the cavernous sinus with the abducens nerve at its lateral border. The abducens nerve originates from the brainstem at the medullary–pontine sulcus to travel along the clivus and the petrous portion of the temporal bone. The abducens nerve then bends sharply over the petrous ridge beneath the petrosphenoidal ligament prior to entering the cavernous sinus. (B) The right third nerve (black arrow) is seen leaving the brainstem between the posterior cerebral and superior cerebellar arteries. Medial and parallel to it is the posterior communicating artery (white arrow). The fourth nerve is also evident (blue arrows). Gold arrow: tentorium. Open white arrow: carotid. Star: brainstem.
2. *Middle cranial fossa.* Passing above the attached margin of the tentorium, medial to the free edge of the tentorium and just lateral to the posterior clinoid process, the oculomotor nerve dips below the anterior clinoid process and pierces the dura to lie in the lateral wall of the cavernous sinus. In the sinus, the oculomotor lies in the lateral wall above cranial nerve IV, the ophthalmic and maxillary divisions of cranial nerve V, and cranial nerve VI, with the internal carotid artery below and medial to it in the sinus (Figs. 5-4A through 5-4C). In the anterior part of the sinus, these relationships might become altered, with the trochlear coming to lie above the oculomotor. The oculomotor enters the superior orbital fissure within the annulus of Zinn and divides into a superior and an inferior branch.

**FIGURE 5-4** (A) Cavernous sinus. Sympathetic nerve fibers are seen traveling along the carotid artery (B) at the level of the pituitary fossa and (C) at the level of the anterior clinoid.
Clinical Application

- Within the main nerve trunk, pupillomotor fibers maintain a superomedial position in which they are susceptible to early compression by aneurysms of the adjacent posterior communicating artery.

**5-3-3 Intraorbital Course**

The third nerve leaves the cavernous sinus and enters the orbit, dividing into superior and inferior branches that enter the orbit through the superior orbital fissure. Both branches pass within the annulus of Zinn. Between them are the nasociliary nerve (a branch of the trigeminal) and the abducens. The smaller superior division ascends over the lateral aspect of the optic nerve, lateral to the ophthalmic artery, and enters the undersurface of the superior rectus at about the junction of its middle and posterior thirds. A branch of this nerve also supplies the levator palpebrae superioris, reaching it by passing upward around the medial border of the rectus, or sometimes by piercing the rectus. Occasionally, the superior division also supplies the medial rectus. The inferior division of the oculomotor is the larger. It forms three branches:

1. The first branch passes under the optic nerve and enters the medial rectus on the posterior third of its conal surface.
2. The second branch continues forward and also penetrates the posterior conal surface of the inferior rectus muscle about one-third of the way along its length.
3. The third and slightly larger branch passes forward between the inferior and lateral recti and enters the upper surface of the inferior oblique at about its middle. Along its course (near the orbital apex), this nerve gives off the short, thick motor root of the ciliary ganglion. The motor root courses upward and forward and joins the ciliary ganglion inferolateral to the optic nerve.

Clinical Application

- Injury to the oculomotor nerve results in weakness or paralysis of the extraocular muscles supplied by its motor fibers. The clinical signs depend on the point of injury or axonal disruption. Nuclear lesions might result in unilateral third nerve palsy with contralateral superior rectus weakness and either no ptosis or bilateral ptosis. Complete dysfunction of the peripheral third nerve results in a down and outward deviation of the globe and ipsilateral upper eyelid ptosis. The pupil is dilated without a reaction to light or accommodation. Adduction is absent, and both elevation and depression are impaired. Partial dysfunction of the nerve or its nucleus will produce incomplete portions of this picture. Lesions in the cavernous sinus tend to result in partial third nerve palsies with sparing of pupillary function, and there might also be signs of trochlear or abducens palsy because of their proximity. Sympathetic paresis might accompany cavernous sinus lesions as their fibers enter the orbit from the carotid plexus within the cavernous sinus.
Oculomotor palsy can be the presenting sign of diabetes. Patients generally present with a painful ophthalmoplegia that spares the pupil. Recovery is usually spontaneous within three months of onset. The underlying pathology is ischemia due to occlusion of the intraneural arterioles, producing focal demyelination.

Pupillary involvement with anisocoria greater than 1 mm is an important finding in the evaluation of a painful oculomotor palsy. Involvement of the pupil suggests compression, most often the result of an aneurysm that is actively impinging upon the oculomotor nerve, whereas pupil sparing suggests ischemia, such as in a diabetic etiology. The pupillary fibers are on the superficial superior medial aspect of the oculomotor nerve. Expanding lesions that impinge on the nerve (e.g., aneurysm, tumor) will involve the pupillary fibers; however, localized ischemia, which occurs with diabetic oculomotor palsy, does not affect the pupillary fibers because of their auxiliary vascular supply from the epineurium.

5–4 TROCHLEAR NERVE

The trochlear nerve contains motor fibers for the superior oblique. It also carries sympathetic nerve fibers.

5–4-1 Superficial Origin

The trochlear nerve or fourth cranial nerve emerges from the dorsal surface of the midbrain by two or three rootlets that leave the anterior end of the anterior medullary vellum just behind the inferior corpus quadrigeminum. Although it is the smallest of the cranial nerves, its intracranial course of 40 mm is the longest. It is the only cranial nerve to exit on the dorsal surface of the midbrain and is the only crossed cranial nerve. However, the decussation is incomplete, and about 5% of the motor neurons pass to the ipsilateral trochlear nerve. Remember the “4 points about the 4th”: (1) smallest, (2) longest course, (3) crossed, and (4) arises from the dorsum of the brainstem (midbrain level).

5–4-2 Intracranial Course

Like the oculomotor nerve, the trochlear nerve has an intracranial course with a posterior fossa component and a middle fossa component.

1. *Posterior cranial fossa.* The trochlear nerve passes laterally around the cerebral peduncle, immediately above the pons, between the posterior cerebral and superior cerebellar arteries (Figs. 5-3A, 5-3B, and 5-5). The nerve runs along the free edge of the tentorium cerebelli.
2. *Middle cranial fossa.* The nerve pierces the dura beneath the free edge of the tentorium cerebelli, beneath the posterior clinoid process and inferolateral to the third nerve, and comes to lie in the lateral wall of the cavernous sinus. Initially below and lateral to the third nerve, at the anterior end of the sinus the trochlear nerve might cross the third nerve so that it is then above and finally medial to it.
5–4-3 Intraorbital Course

The fourth nerve enters the orbit through the superior orbital fissure, outside the annulus of Zinn, in company with the frontal and lacrimal branches of the ophthalmic division of the trigeminal nerve. It then passes forward and medially above the levator and the superior rectus, just beneath the periorbita of the roof, and enters the superior oblique as three or four rootlets that penetrate the upper border of the superior oblique along the posterior third of the muscle (9 to 10 mm from the orbital apex) (Fig. 5-6). The trochlear nerve is the only extraocular nerve that does not penetrate the conal surface of its muscle.

Clinical Application

- The trochlear nerve has a long intracranial course and is the smallest cranial nerve. As a result, it is predisposed to injury from blunt head trauma, resulting in isolated unilateral or bilateral superior oblique palsies even after relatively trivial blows.
- Isolated trochlear nerve palsies, other than those traumatically induced, are rare. Localized orbital pathology should be excluded, as should myasthenia gravis and diabetes. In most cases, the etiology of these nontraumatic trochlear palsies cannot be determined, and most are thought to be of vascular origin.
Congenital fourth nerve palsy might not present until adulthood, when fusional control deteriorates. These patients might have a head tilt or large fusional amplitudes, which can help to distinguish the etiology of the vertical diplopia.

- Congenital fourth nerve palsy might not present until adulthood, when fusional control deteriorates. These patients might have a head tilt or large fusional amplitudes, which can help to distinguish the etiology of the vertical diplopia.

**5–5 TRIGEMINAL NERVE**

The *trigeminal nerve* is the largest of the cranial nerves and consists of a small motor root and a larger sensory root. The motor fibers supply muscles of mastication (e.g., the temporalis, masseter, and internal pterygoid muscles) and the sensory component carries fibers for pain, touch, temperature, and proprioception from the eye, face, and scalp. Sympathetic nerve fibers enter the orbit via the first (ophthalmic, V₁) and second (maxillary, V₂) divisions of the trigeminal nerve (as well as a plexus of nerves around the ophthalmic artery and through the inferior orbital fissure via the pterygopalatine ganglion and zygomatic nerve).

**5–5-1 Superficial Origin**

The trigeminal nerve or fifth cranial nerve emerges from the side of the pons as a small motor root and a large sensory root (Figs. 5-2 and 5-3A).
Orbital Nerves

5–5-2 Intracranial Course

Enclosed by a common arachnoid covering, the two roots of the trigeminal nerve pass forward and slightly upward in the posterior cranial fossa to the upper border of the petrous temporal bone, a course of approximately 1 cm. They pierce the dura under the attached margin of the tentorium cerebelli and, leaving the posterior fossa, head toward the semilunar (gasserian) ganglion, which lies in Meckel’s cave over the apex of the petrous temporal bone, in the floor of the middle cranial fossa (Figs. 5-3 and 5-7A). The ganglion is flat, semilunar, and approximately 1 cm × 2 cm. The sensory nerves (ophthalmic, maxillary, mandibular) carrying fibers for pain, touch, temperature, and proprioception from the eye, face, and scalp synapse within the gasserian ganglion. Medial to the ganglion are the cavernous sinus; the third, fourth, and sixth nerves; and the internal carotid artery.

From the semilunar (gasserian) ganglion, three large sensory tracts arise: the ophthalmic, maxillary, and mandibular divisions (Figs 5-3 and 5-7B). The ophthalmic division carries the major sensory input from the eyelids and orbit, whereas the maxillary division contributes a small component from the lower eyelid along with other sensory input from the side of nose, upper lip and midface. The ophthalmic and maxillary divisions pass forward toward the orbit in the lateral wall of the cavernous sinus. Within the sinus, the ophthalmic division receives tiny branches from the oculomotor, trochlear, and abducens nerves that carry sensory information from the extracranial muscles they supply. The ophthalmic nerve also receives sensory branches supplying information from the intracranial dura. Sympathetic fibers from the carotid plexus also join the ophthalmic (V1) and mandibular (V2) nerves at this point. The mandibular division travels forward and exits the skull via the foramen ovale. The motor root of the trigeminal nerve passes beneath the semilunar ganglion to join the mandibular division. The mandibular nerve is sensory to the skin below the cheek. The motor root supplies the muscles of mastication (temporals, masseter, and internal pterygoid muscles). It also supplies the tensor tympani, the tensor veli palatine, the omohyoid, and the anterior belly of the digastric muscle.

5–5-3 Intraorbital Course of Ophthalmic Division

As the ophthalmic branch of the trigeminal nerve (V1) exits the cavernous sinus, it divides into three main branches: the lacrimal, the frontal, and the nasociliary (Figs. 5-6, 5-8A, and 5-8B).

The lacrimal nerve is the smallest branch and enters the orbit through the superior orbital fissure, outside the fibrous annulus of Zinn, lateral to the frontal and trochlear nerves. Coursing along the lateral orbital wall, just above the lateral rectus, it is accompanied by the lacrimal artery heading toward the lacrimal gland (Fig. 5-8C).

Just before entering the lacrimal gland, the lacrimal nerve is joined by a branch of the zygomaticotemporal nerve. This nerve provides postganglionic parasympathetic-containing secretomotor fibers to the lacrimal gland, as well as sympathetic fibers (Figs. 5-9A and 5-9B). The parasympathetic fibers originally traveled with the facial nerve, greater superficial petrosal nerve, and vidian nerve, synapsing in the sphenopalatine ganglion. The sympathetic fibers synapsed in the superior cervical ganglion and then traveled up the carotid, exiting as the deep petrosal nerve and traveling with the vidian nerve (or the nerve of the pterygoid canal). Several terminal twigs of
FIGURE 5-7  The left brain stem, with the orbits to the left of the picture and the cerebellum to the right.  
(A) The left trigeminal nerve is seen traveling forward toward the petrous temporal bone, piercing the dura just under the attached margins of the tentorium cerebelli (white arrow). The third (black arrow) and fourth (blue arrow) nerves are also well visualized.  (B) The fifth nerve ganglion is evident on the petrous temporal bone, dividing into its branches: V₁ superiorly, V₂ centrally, and V₃ (arrows). The black material beside the rubber glove is bits of dried blood from the cavernous sinus.
FIGURE 5-8 Superior aspect of a right orbit. (A) The right frontal nerve is well visualized, with the supraorbital artery just medial to it. The superior oblique muscle is seen medially (black arrows). The trochlear nerve is seen as several small white rootlets entering the medial surface of the superior oblique muscle in the posterior one-third of the muscle (green arrows). (B) The right lacrimal nerve is seen laterally (blue arrows); the black arrow denotes the frontal nerve. (C) The right lacrimal nerve (black arrow) and artery (white arrow) are shown heading toward the lacrimal gland (blue arrow).
FIGURE 5-8 (D) The trochlear nerve, frontal nerve, lacrimal nerve, nasociliary nerve, and ciliary ganglion as viewed from above. (E) A lateral view of the frontal nerve, nasociliary nerve, and ciliary ganglion.

the lacrimal nerve also pass through or around the gland and end in the conjunctiva and the skin of the lateral upper eyelid. Innervation to the sympathetic muscles of the upper and lower eyelid is thought to occur via these sympathetic nerve fibers in the lacrimal nerve, as well as through sympathetic fibers recently identified within the infratrochlear nerve (a direct extension of the nasociliary nerve).
The frontal nerve is the largest branch and enters the orbit through the superior orbital fissure, outside the fibrous annulus of Zinn, where it lies between the lacrimal and trochlear nerves. It travels anteriorly, lying between the levator and the periorbita, along the roof of the orbit (Figs. 5-6, 5-8A, 5-8D, 5-8E, and 5-9B). About halfway from the orbital apex to the orbital rim, the frontal nerve usually divides into two branches:
1. The **supratrochlear nerve**, a medial branch, runs forward to pass above the trochlea and leaves the orbit in company with the supratrochlear artery. Piercing the orbital septum, it might divide into one to three branches, and it ascends after passing through the corrugator, frontalis, and orbicularis to terminate by several branches under the skin of the central forehead above the medial eyebrow. The supratrochlear branches supply the lower forehead and medial one-third of the upper eyelid. It also carries sympathetic fibers to the forehead that innervate blood vessels.

2. The **supraorbital nerve**, the larger of the two branches, lies on the levator and, together with the supraorbital artery (which is just medial to it), heads anteriorly to exit at the supraorbital notch (or foramen). The supraorbital nerve might divide into a superficial and a deep branch just prior to or, more commonly, just after leaving the orbit. The superficial branch divides immediately into several smaller branches. A medial (frontal) branch might exit through its own notch. Upon exiting the orbit, the branches of the supraorbital nerve lie in a submuscular plane, deep to the orbicularis, frontalis, and corrugator muscles and in close approximation to the periosteum of the supraorbital ridge. As they ascend on the forehead, these branches become more superficial, passing through the muscle to the subcutaneous plane. The more medial branches penetrate the muscle just below the brow, whereas those more lateral penetrate at higher levels. The supraorbital nerve branches transmit sensory information from the forehead, the scalp, the central two-thirds of the upper eyelid, and the conjunctiva. Sensory fibers are also transmitted from the frontal sinus.

Sympathetic fibers recently identified in the frontal nerve and its branches (supraorbital and supratrochlear) supply blood vessels in the area of the nerve distribution.

The **nasociliary branch** of the ophthalmic division of the fifth cranial nerve enters the superior orbital fissure within the annulus of Zinn (Figs. 5-8D and 5-8E). It crosses over the optic nerve (approximately 8 to 12 mm anterior to the apex) and then has several branches.

As the nasociliary enters the orbit, a small branch (sensory root) extends along the lateral side of the optic nerve and enters the **ciliary ganglion**. The ciliary ganglion is located near the orbital apex, lateral to the optic nerve and medial to the lateral rectus muscle (Figs. 5-8D, 5-8E, and 5-10), situated in loose adipose tissue. The ganglion is about twice the size of a pinhead (approximately 1 × 2 mm). Three roots extend to the ciliary ganglion: the sensory root from the nasociliary nerve, the motor root from the inferior division of the oculomotor nerve (which carries parasympathetic fibers), and the sympathetic root from the carotid cavernous sinus sympathetic plexus (traveling on their own or with the nasociliary nerve).

The nerve fibers in the sensory root to the ciliary ganglion travel through the ganglion without synapsing. These sensory fibers will have already synapsed in the semilunar (gasserian) ganglion. From the ciliary ganglion arise multiple fine, hairlike nerves called short ciliary nerves. There are
generally 5 to 12 short ciliary nerves, and they travel with short ciliary arteries to the back of the eyeball, where they penetrate the sclera near the optic nerve. These fibers carry sensation from the cornea, iris, and ciliary body.

**Parasympathetic and sympathetic nerve fibers** also travel through the ciliary ganglion. The parasympathetic fibers leave the inferior division of the oculomotor nerve (usually from the branch destined for the inferior oblique muscle) and travel toward the ciliary ganglion as the motor root. These fibers will synapse within the ciliary ganglion. As they leave the ganglion, they travel in the short ciliary nerves to the sphincter pupillae and the ciliary muscle. The sympathetic nerve fibers travel through the ciliary ganglion without synapsing en route to the choroidal vasculature and dilator muscle of the eye via the short ciliary nerves. These sympathetic fibers will have already synapsed in the superior cervical ganglion.

Two or three nerves called **long ciliary nerves** extend from the nasociliary nerve as it crosses the optic nerve. These nerves pass by the ciliary ganglion and proceed forward with the short posterior ciliary nerves to the globe (Figs. 5-8D and 5-8E). The long ciliary nerves enter the sclera and extend anteriorly along the medial and lateral aspects of the globe to the iris, ciliary body, and cornea, where they receive sensory input. In addition to afferent sensory fibers, the long ciliary nerves also carry efferent sympathetic fibers from the superior cervical ganglion/cavernous sinus sympathetic plexus to the dilator muscle of the iris.

After the nasociliary crosses over the optic nerve, a branch is given off to the medial orbital wall and exits via the posterior ethmoidal foramen. This nerve is referred to as the **posterior ethmoidal**
nerve or sphenoethmoidal nerve of Luschka. The presence of a posterior ethmoidal nerve varies considerably. As the nasociliary travels anteriorly in the medial orbit, it gives off another branch, called the anterior ethmoidal nerve, which exits through the anterior ethmoidal foramen. The ethmoidal nerves reenter the cranial vault, cross the anterior portion of the cribriform plate beneath the dura of the anterior cranial fossa, and enter the nasal cavity through the anterior nasal canals at the side of the crista galli to become the internal nasal nerve. This nerve divides into three branches: the medial and lateral internal nasal branches, which receive sensory fibers from the nasal and ethmoid sinus mucosa, and the third branch, which continues as the external nasal nerve to the tip of the nose.

After forming the anterior ethmoidal nerve, the nasociliary nerve extends anteriorly as the infratrochlear nerve. This nerve runs along the superior border of the medial rectus and penetrates the orbital septum inferior to the trochlea, above the level of the medial canthal tendon. The infra-trochlear supplies the medial portion of the eyelids, the medial conjunctiva, the caruncle, the nasolacrimal sac, and the side of the nose. It also carries sympathetic fibers. Innervation to the sympathetic muscles of the eyelids is supplied by these fibers, as well as by sympathetic fibers traveling in the lacrimal nerve.

Clinical Application

- The varicella-zoster virus has a tendency to affect the gasserian ganglion and the ophthalmic division of the trigeminal nerve to produce herpes zoster ophthalmicus. Its onset often begins with a severe, unilateral neuralgic pain or paresthesia, followed in several days by vesicular eruption and swelling in the areas of distribution of the ophthalmic nerve. These areas include the upper eyelid, forehead, and tip of the nose. In 1866, Hutchison recognized the association of ocular involvement with zoster affecting the tip of the nose (the Hutchison sign). This association reflects the distribution of the nasociliary nerve. Superficial and deep corneal opacities might occur, associated with an anterior uveitis. When the vesicles rupture, hemorrhagic areas remain; these heal in several weeks, leaving deep-pitted scars. Postherpetic neuralgia with pain, burning, and paresthesia can persist indefinitely in some individuals and might be very resistant to any treatment.

- The oculocardiac reflex is defined as any intraoperative bradycardia exceeding 10% of the preoperative heart rate that occurs during ocular manipulation. It can result in clinically profound bradycardia, nausea, and lightheadedness during ophthalmic surgery. The reflex has also been associated with atrioventricular block, bigeminy, and cardiac arrest. In addition, the reflex increases vagal tone and might cause generalized vasodilation hypoperfusion. It is most commonly associated with traction on the extraocular muscles, but it can also occur with stretching of the eyelid retractors, traction on the medial fat pocket during blepharoplasty surgery, retrobulbar blocks, or enucleation surgery. Sensory fibers forming the afferent limb of this reflex arc run in the ophthalmic division of the trigeminal nerve to the gasserian ganglion and then on to the main sensory nucleus along the fourth ventricle. After descending in the spinal trigeminal tract, sensory stimuli cross via polysynaptic pathways in the reticular formation to the visceral motor nucleus of the vagus nerve. The resulting excessive vagal stimulation produces the clinical symptoms described above and can be blocked with atropine.
• The *oculorespiratory reflex*, like the oculocardiac reflex, can occur with traction on the extraocular muscles. Shallowness of respiratory movement and apnea of up to 20 seconds’ duration have been noted, as have respiratory arrhythmia and irregular respiratory arrest. Although any extraocular muscle can invoke this reflex, the medial rectus appears to be the most sensitive (this is also true for the oculocardiac reflex). However, atropine sulfate has no effect, suggesting that the efferent pathway is different from that in the oculocardiac reflex.

### 5–5-4 Intraorbital Course of Maxillary Division

The *maxillary nerve* is the second division of the trigeminal (*V₂*) and is a pure sensory nerve that also carries some sympathetic and parasympathetic nerve fibers. The nerve provides sensation for the midface, lower eyelid, side of the nose, and upper lip in addition to the mucous membranes of the nasopharynx, maxillary sinus, soft palate, tonsils, roof of the mouth, upper gums, and teeth. Extending from the trigeminal ganglion, it proceeds anteriorly within the inferior lateral wall of the cavernous sinus and leaves the middle cranial fossa via the foramen rotundum. Through this foramen, it reaches the pterygopalatine fossa (also called the sphenomaxillary fossa). Within the pterygopalatine fossa, the maxillary nerve has several branches:

1. **Two or three short sphenopalatine (pterygopalatine) nerves extend to the sphenopalatine (Meckel’s) ganglion.** These branches serve as sensory roots to the sphenopalatine ganglion. In addition, parasympathetic secretomotor fibers from the ganglion extend to the maxillary nerve. These parasympathetic fibers are destined for the lacrimal gland via the zygomaticotemporal nerve.

2. **The zygomatic nerve,** which enters the orbit through the inferior orbital fissure and along the lateral wall of the orbit, divides into zygomaticotemporal and zygomaticofacial branches. The zygomaticotemporal nerve runs along a groove in the zygomatic bone and passes through the zygomaticotemporal canal into the temporal fossa, which it ascends before emerging to supply the skin over the anterior part of the temporal region up to the lateral orbital margin. Just prior to exiting the orbit, the zygomaticotemporal nerve provides secretomotor parasympathetic branches to the lacrimal nerve (Figs. 5-9A and 5-9B). The zygomaticofacial branch emerges on the face through the foramen of the same name and supplies the skin of the cheek.

3. **The posterior superior alveolar nerves** (usually two) arise from the maxillary nerve just before it enters the infraorbital groove; they supply sensory fibers to the upper molar teeth, the gums, and the mucous membrane of the maxillary sinus.

The maxillary nerve enters the orbital space through the middle of the inferior orbital fissure. It becomes the infraorbital nerve once it enters the infraorbital groove (Fig. 5-11). The infraorbital groove is gradually covered with bone and becomes the infraorbital canal. Within the infraorbital canal, the infraorbital nerve gives off the **middle and anterior-superior alveolar nerves.** These nerves run downward in the lateral wall of the antrum to supply the premolar, incisor, and canine teeth, respectively.
The infraorbital nerve exits the maxillary bone approximately 10 mm below the inferior orbital rim. The terminal branches following its exit from the infraorbital foramen are the inferior palpebral, external nasal, and superior labial branches. The inferior palpebral branch supplies the skin and conjunctiva of the lower eyelid. The external nasal branches provide sensation to the nasal skin and nasal septum. The superior labial branch provides sensation to the skin of the upper lip and mucous membranes.

**FIGURE 5-11** Looking from above down at the right orbital floor (globe removed): the infraorbital nerve and unroofed infraorbital artery can be seen, as well as the maxillary antrum mucosa. The small arterial branch seen leaving the infraorbital artery is the “communicating branch” of the infraorbital artery.

The infraorbital nerve exits the maxillary bone approximately 10 mm below the inferior orbital rim. The terminal branches following its exit from the infraorbital foramen are the inferior palpebral, external nasal, and superior labial branches. The inferior palpebral branch supplies the skin and conjunctiva of the lower eyelid. The external nasal branches provide sensation to the nasal skin and nasal septum. The superior labial branch provides sensation to the skin of the upper lip and mucous membranes.

**5–5–5 THE MANDIBULAR BRANCH OF THE TRIGEMINAL**

The mandibular branch of the trigeminal nerve (\(V_3\)) is a mixed cranial nerve with sensory and motor roots. A sensory and motor root of the nerve exits the cranial cavity through the foramen ovale. The sensory fibers supply the skin below the cheek (excluding the upper lip) and the underlying mucous
membranes. The motor root supplies the muscles of mastication (temporalis, masseter, and pterygoid muscles).

Clinical Application

- A blow to the face (e.g., from a tennis ball or a fist) can cause a blowout fracture of the orbital floor. Clinical features, besides soft-tissue ecchymosis, might include enophthalmos, extraocular muscle entrapment with resultant diplopia, and paresthesias in the distribution of the infraorbital nerve. The patient describes numbness in the teeth, cheek, upper lip, and gums as a result of injury to the alveolar nerve fibers branching off the infraorbital nerve.
- Trigeminal neuralgia (tic douloureux) is a disorder characterized by brief attacks of severe pain along the distribution of the trigeminal nerve. This disorder can affect all age groups. The attacks of pain are intense and might start in one area of the trigeminal nerve and then spread to adjacent areas. The mandibular division is most commonly affected, and the ophthalmic division is affected in only 1% to 2% of instances. The attacks are occasionally elicited by the stimulation of trigger points, frequently in the snout area. This being the case, the patients might be unable to speak, brush their teeth, eat, or drink without suffering spasms of pain. Trigeminal neuralgia can be secondary to tumor, trauma, dental problems, multiple sclerosis, or vascular anomalies adjacent to the sensory root or the trigeminal nerve.
- Marcus Gunn jaw winking syndrome, in which the synkinetic elevation of a ptotic lid results from movement of the jaw, occurs because of miswiring or an aberrant connection between the motor nerve branches of cranial nerve III to the pterygoid muscles and the levator muscle.

5–6 ABDCENS NERVE

The abducens nerve or sixth cranial nerve carries motor fibers to the lateral rectus muscle, as well as sympathetic fibers.

5–6-1 Superficial Origin

The nucleus of the sixth cranial nerve is in the dorsal pons, beneath the floor of the fourth ventricle. Interneurons course from the sixth nerve nucleus through the medial longitudinal fasciculus to the contralateral medial rectus subnucleus. This neuroanatomy yokes the muscles of horizontal gaze. The sixth nerve arises via several rootlets near the midline in the sulcus between the pons and the medulla oblongata. It is lateral to the basilar artery (Figs. 5-2 and 5-12).

5–6-2 Intracranial Course

In the posterior cranial fossa, the sixth nerve is closely applied to the surface of the pons, being crossed on its ventral side by the anterior inferior cerebellar artery. The abducens nerve ascends
through the subarachnoid space along the clivus to pierce the dura of the clivus about 1 cm below the crest of the sphenoid bone. Piercing the dura, it passes around or through the inferior petrosal sinus, running forward and outward, and ascends the back of the petrous temporal bone near its apex (Figs. 5-3A, 5-13A, and 5-13B). Here it makes a sharp bend forward (nearly 90 degrees) over the apex of the bone and passes between the apex and the posterior clinoid process under the petrosphenoidal (or petroclinoidal) ligament of Gruber through a tunnel or canal-like structure. This osteofibrous conduit is known as Dorello’s canal and lies lateral to the internal carotid artery and medial to the trigeminal ganglion. As the nerve enters the cavernous sinus, it is closely associated with the lateral side of the internal carotid artery (Figs. 5-4 and 5-14C). As a result, it is usually the first nerve affected by an intracavernous carotid aneurysm. It then lies free within the cavernous sinus and, toward its exit, becomes adherent to the lateral wall of the sinus. The nerve enters the superior orbital fissure within the annulus of Zinn.

**Clinical Application**

- A “one and a half syndrome” occurs when a lesion involves both the sixth nerve nucleus on one side of the brainstem and the internuclear fibers of the ipsilateral medial longitudinal fasciculus. The patient has a complete horizontal gaze palsy when looking toward the side of the lesion and can abduct the eye only contralateral to the lesion.
Orbital Nerves

FIGURE 5-13 The sixth cranial nerve. (A) Looking down at the right brainstem: the sixth nerve (white arrows) is seen ascending the clivus and then passing beneath the petrosphenoidal ligament of Gruber (blue arrow). It then enters the cavernous sinus, which is medial to the fifth nerve semilunar ganglion (green arrow). (B) In sagittal view: the right sixth nerve (white arrows) is seen ascending the clivus and then passing beneath the petrosphenoidal ligament of Gruber (blue arrow) to enter the cavernous sinus. (C) In sagittal view: the right sixth nerve (white arrows) is seen within the cavernous sinus lateral to the carotid artery (blue arrow), heading toward the superior orbital fissure.
• During their ascent superiorly along the clivus, both abducens nerves lie in close proximity to each other and some distance from other neural structures. Compressive lesions in this region, such as a basilar artery aneurysm or a chordoma, can result in bilateral sixth nerve palsies without associated neurologic deficits.

5–6-3 Intraorbital Course

The sixth nerve enters the orbit through the superior orbital fissure, within the annulus of Zinn and between the optic nerve and the origin of the lateral rectus. It enters the lateral rectus muscle on its inner surface at the junction of its posterior one-third and anterior two-thirds.

Clinical Application

• The abducens nerve is predisposed to injury from head trauma because of its course along the base of the skull and its abrupt angulation over the petrous ridge (under Gruber’s ligament), where it changes direction rather abruptly, sometimes by nearly 90 degrees.

• Tumors, vascular disease, infection, trauma, diabetes, and multiple sclerosis might present with an abducens palsy. The associated neurologic signs help identify the anatomic location of the abducens palsy. For example, as the nerve passes through Dorello’s canal beneath the petrosphenoidal ligament of Gruber, it might be affected by chronic mastoiditis. In the preantibiotic era, abducens nerve palsy was a common result of suppurative otitis media in the adjacent petrous portion of the temporal bone. This was known as Gradenigo’s syndrome and consisted of apical petrositis, hearing loss, sixth nerve palsy, and severe ipsilateral facial pain.

• Horner’s syndrome and an ipsilateral sixth nerve palsy localize the lesion to the cavernous sinus, where the sixth nerve sits adjacent to the sympathetic fibers running along the carotid artery.

FIGURE 5-14  The left cerebellopontine angle. The seventh and eighth nerves are seen going into the internal auditory canal. Another, smaller nerve, separated from the former two by the labyrinthine artery (a branch of the anterior inferior cerebellar artery), is the nervus intermedius (arrow).
Although the facial nerve is not an orbital nerve on its own, it provides parasympathetic fibers to the lacrimal gland that travel through the orbit via the nervus intermedius, the nerve of the pterygoid canal, and the zygomatic nerve. These parasympathetic fibers play an important role in tear secretion.

The facial nerve has two parts: a large motor root that supplies the frontalis and orbicularis muscles as well as the buccinator, platysma, stapedius, and stylohyoid muscles and the posterior belly of the digastric muscles; and a smaller sensory root (the *nervus intermedius*) that carries sensory and parasympathetic fibers. The sensory fibers are responsible for taste sensation on the anterior two-thirds of the tongue and general sensation from the external auditory meatus, soft palate, and adjacent pharynx. The parasympathetic fibers of the nervus intermedius supply secretomotor fibers to the lacrimal, submandibular, sublingual, nasal, and palatine glands. The nervus intermedius has distinct features and is considered a separate cranial nerve by some authors.

The motor nucleus of the facial nerve is located deep within the reticular formation of the pons. Axons from the facial nucleus proceed from its dorsal surface to arch around the abducens nucleus and form the genu of the facial nerve. The nerve then extends ventrally to emerge from the brainstem between the olive and the inferior cerebellar peduncle at the caudal border of the pons. The sensory and parasympathetic fibers of the seventh nerve are not present at the genu but join distally to the pons. Parasympathetic fibers arise from the area of the superior salivatory nucleus alongside the descending limb of the facial nerve within the pons. Some researchers think there is actually a lacrimal nucleus in the pons adjacent to the superior salivatory nucleus. Sensory fibers with diffuse brainstem connections diverge from the facial root shortly after it enters the pons.

The facial nerve exits the ventrolateral portion of the brainstem at the cerebellopontine angle as a motor root and the nervus intermedius. The fine nervus intermedius is sandwiched among the motor root, the acoustic nerve, and the labyrinthine artery, a fine branch of the anterior inferior cerebellar artery (Fig. 5-14). These fibers extend laterally to the internal auditory canal, where the facial nerve separates from the acoustic nerve to enter the facial canal (or fallopian canal) within the petrous portion of the temporal bone. Within the fallopian canal, the facial nerve follows a serpiginous route (Fig. 5-15). The canal is approximately 30 mm long and is divided into four sections: meatal, labyrinthine, tympanic, and mastoid. The *meatal* segment is that portion prior to the separation of the acoustic nerve from the facial nerve and nervus intermedius. The *labyrinthine* segment of the facial nerve begins as the nerve enters the facial or fallopian canal. This segment is 3 to 6 mm long and extends to the geniculate ganglion. Here the motor root and sensory roots temporarily fuse, and the nerve is thickened by the presence of the geniculate ganglion. The labyrinthine segment is located between the cochlea and the semicircular canals. At the geniculate ganglion, the facial nerve makes an abrupt bend posteriorly and forms the *tympanic* or horizontal segment, which measures 8 to 11 mm. This segment is lateral to the semicircular canals. The *mastoid* segment of the facial nerve then extends straight downward for 9 to 12 mm to exit the skull via the stylomastoid canal. The stapedius nerve (which innervates the stapedius muscle of the inner ear) and the chorda tympani nerve (which supplies taste fibers to the anterior two-thirds of the tongue and parasympathetic secretomotor fibers to the submaxillary and sublingual glands) arise from the mastoid segment.
The parasympathetic fibers of the seventh nerve have an important ophthalmic role, as they contribute to the efferent pathway to the lacrimal gland. As mentioned above, these nerve fibers originate in the so-called lacrimal nucleus in the pons, adjacent to the superior salivatory nucleus. These parasympathetic fibers travel in the pons as the nervus intermedius. The nervus intermedius exits the brainstem sandwiched between the motor parts of the seventh and eighth nerves. These fibers travel toward the geniculate ganglion within the internal auditory canal. These parasympathetic fibers do not synapse in the geniculate ganglion. The geniculate ganglion is a sensory ganglion of the facial nerve and is primarily composed of taste fibers from the chorda tympani, which do synapse within the geniculate ganglion. General sensory fibers from the pharyngeal mucosa and external auditory meatus also synapse in the geniculate ganglion.

At the geniculate ganglion, the parasympathetic fibers of ophthalmic interest branch off of the nerve and head on to the petrous temporal bone as the greater superficial petrosal nerve. Sympathetic fibers traveling along the carotid artery leave and form the deep petrosal nerve fibers. These deep petrosal nerve fibers then join the greater superficial petrosal nerve to form the vidian nerve or nerve of the pterygoid canal. This nerve travels within the pterygoid canal toward the sphenopalatine ganglion (also known as the pterygopalatine ganglion or Meckel’s ganglion). The parasympathetic fibers of this nerve synapse in the sphenopalatine ganglion. The sympathetic fibers will have already synapsed in the superior cervical ganglion. Postganglionic parasympathetic and sympathetic fibers join the zygomatic nerve (a branch of the maxillary division of the trigeminal nerve) and enter the orbit through the inferior orbital fissure. The parasympathetic and sympathetic fibers destined for the lacrimal gland either enter the lacrimal gland directly from the zygomatic nerve or branch off of the zygomatic nerve and travel up the lateral wall to join the lacrimal nerve prior to entering the lacrimal gland (Figs. 5-9A and 5-9B).

The facial nerve anatomy from the stylomastoid foramen to the orbicularis and frontalis muscles is described in Chapter 1.
Clinical Application

- Paralysis of the facial nerve is a common problem with potentially severe ophthalmic consequences as a result of decreased blinking and resultant corneal exposure. The origin of the seventh nerve dysfunction can be anywhere from the cerebral cortex to the peripheral branches of the seventh nerve. The pathologic site can usually be localized clinically. That portion of the facial nucleus serving the upper face receives crossed and uncrossed impulses from the precentral motor cortex from both hemispheres, whereas that portion serving the lower face receives mainly crossed fibers from the contralateral hemisphere. Thus, supranuclear lesions affecting the corticopontine pathway (upper motor neurons) to the facial nucleus (e.g., stroke) result in paralysis of the opposite lower facial muscles with sparing of the upper face. Pontine lesions, such as those associated with multiple sclerosis affecting descending fasicular fibers, generally produce complete ipsilateral facial paralysis. Those lesions in the dorsal pons, in the region where the seventh nerve fibers arch over the abducens nucleus, might produce a sixth nerve palsy, conjugate gaze palsy, and internuclear ophthalmoplegia in addition to facial nerve paralysis.

- As the facial nerve leaves the pons in the cerebellopontine angle, it has an intimate relation with the acoustic nerve (cranial nerve VIII). Expanding lesions in this region such as meningioma, neurilemmomas, dermoid cysts, or aneurysms frequently produce facial paralysis associated with ipsilateral hearing loss. The roots of the fifth, ninth, and tenth cranial nerves lie nearby and might also be involved.

- Compression of the facial nerve within the serpiginous facial canal might occur with neurilemmoma, sarcoidosis, or leukemic infiltrates. Inflammatory processes in adjacent structures (e.g., mastoiditis or otitis media) also might result in facial nerve weakness.

- Herpes zoster involving the geniculate ganglion (Ramsay Hunt syndrome) causes pain and vesicles within the external auditory meatus and on the tympanic membrane, as well as facial nerve paralysis.

- The facial nerve is also vulnerable to fractures involving the temporal bone. Bell’s palsy is an idiopathic disorder characterized by acute facial paralysis of the lower motor neuron that is not associated with other neurologic findings. The cause might be viral infection with edema of the facial nerve within the facial canal. Clinically, the condition might be preceded by pain at the stylomastoid foramen, followed by acute facial paralysis. Orbicularis muscle weakness might result in severe lagophthalmos, corneal exposure, and potential visual loss.

- Hemifacial spasm is characterized by intermittent twitching of the muscles involving one half of the face. In most patients, the etiology is felt to be a vascular compression (as a result of aging changes) of the facial nerve root at the cerebellopontine angle. In 0.2% to 0.5% of patients, a posterior fossa tumor is responsible. All patients require neuroimaging as part of their work-up in order to rule out a posterior fossa lesion. Hemifacial spasm can be treated by peripheral chemodenervation with botulinum toxin or surgically by microvascular decompression, with elevation of the abnormal vessel away from the nerve (the Janetta procedure).

- Essential blepharospasm is a segmental cranial dystonia characterized by bilateral involuntary, sustained contractions of the orbicularis muscle. It more commonly affects females in their early 50s, and the excess blinking and sustained contractions of the orbicularis might
result in a severe visual disability and functional blindness. Some individuals progress to lower facial involvement (Meige syndrome). The etiology is unknown, but some experimental evidence suggests a neurotransmitter deficit at the level of the basal ganglia. The most effective treatment is chemodeneration with botulinum toxin every three to four months. For those resistant to botulinum, a myectomy procedure can be carried out. This might involve removing the orbicularis muscle in only the upper eyelids (limited myectomy), or it might involve the corrugator, procerus, and orbicularis muscles in all four eyelids (complete myectomy).

- **Myokymia** is a localized twitch involving just a few muscle fibers in the upper or lower eyelids. It is commonly seen in young, healthy individuals (20 to 40 years of age) for no apparent reason. It can be worsened by stress, lack of sleep, or increased caffeine intake (e.g., coffee, tea, cola). It usually goes away with rest, decreased caffeine intake, and avoidance of any stressful situations that the patient might have been in.

### 5–8 AUTONOMIC NERVES

Parasympathetic and sympathetic fibers enter the orbit to supply various structures.

#### 5–8-1 Parasympathetic Fibers

The parasympathetic supply to the orbit is closely associated with the oculomotor nerve. Preganglionic parasympathetic fibers from cells in the Edinger–Westphal subnucleus of the third nerve nucleus (within the midbrain) travel in the oculomotor nerve by way of the inferior division through the short motor root to the ciliary ganglion. There they terminate and synapse with postganglionic neurons, the axons of which pass by way of the short ciliary nerves to the eyeball. Some of these parasympathetic fibers travel to the sphincter pupillae muscle of the iris, where they participate in pupillary contraction, and others travel to the ciliary muscles, where they contribute to accommodation.

The parasympathetic nerve supply to the lacrimal, submandibular, and sublingual glands is associated with the facial nerve. Parasympathetic fibers originating in the pons from the lacrimal nucleus travel to the lacrimal gland by way of the nervus intermedius, the nerve of the pterygoid canal, the sphenopalatine (pterygopalatine) ganglion, and the zygomatic nerve to serve in tear production, as previously mentioned. These fibers synapse in the sphenopalatine (pterygopalatine) ganglion and are discussed with the seventh nerve anatomy in a preceding section.

### Clinical Application

- Adie’s pupil (or Adie’s tonic pupil) is an isolated internal ophthalmoplegia that is characterized by a tonic pupil with defective accommodation. The patient presents with unequal
pupils that are most pronounced in bright light. The affected pupil fails to respond normally to direct light (the reaction is sluggish or absent), and one often sees sectorial vermiform movements of the pupillary margin (especially when viewing the pupil at the slit lamp). The pupil does, however, slowly constrict to accommodation. If viewed in darkness, the pupil on the involved side is smaller than that on the contralateral side (the sphincter pupillae does not fully relax). The site of pathology in Adie’s pupil is the ciliary ganglion. Pathologically, one sees absent or grossly diminished ganglion cells.

5–8-2 Sympathetic Fibers

The *ocular sympathics* extend from the hypothalamus to the orbit and involve a three-neuron pathway. The first (central) neuron extends from the posterolateral area of the hypothalamus and descends uncrossed in the brainstem and through the lateral column of the cervical spinal cord to terminate in the ciliospinal centre of Budge between C8 and T1. The second-order neurons immediately leave the spinal cord to enter the paravertebral sympathetic chain, passing adjacent to the lower cervical vertebrae. The second-order neurons pass over the pulmonary apex and then run through the inferior and middle cervical ganglia to synapse in the superior cervical ganglion. The postganglionic (third-order) neurons follow the internal and external carotid arteries providing sympathetic innervation to the head and neck. The postganglionic neurons responsible for facial sweating follow the external carotid, whereas those fibers supplying the orbital structures follow the internal carotid artery.

The postganglionic fibers course along the internal carotid artery and, in the cavernous sinus, form the internal carotid plexus and the cavernous plexus. From the cavernous plexus, sympathetic pupillodilator fibers enter the orbit by one of the following routes:

1. Sympathetic fibers leave the cavernous plexus in close relation to the semilunar (or gasserian) ganglion, from which they may pass into the orbit in the nasociliary nerve and, by its long ciliary branches, reach the eyeball and are distributed to the dilator pupillae muscle of the iris.
2. Sympathetic fibers may also enter the orbit on their own through the superior orbital fissure (within the oculomotor foramen) as the sympathetic root of the ciliary ganglion. Passing through the ganglion, they reach the eyeball through the short ciliary nerves and then pass to the dilator pupillae muscle.

Much of the evidence regarding sympathetic innervation to the eye focuses on its function in regulating pupillary diameter. However, accommodation, aqueous humor secretion, trabecular meshwork function, and blood flow in the central retinal artery and choroid in primates are also believed to be regulated by sympathetics. Ocular and adnexal structures such as Müller’s muscle, the inferior tarsal muscle (the lower eyelid sympathetic muscle), and the lacrimal gland are also important targets of sympathetic nerves entering the orbit. The various sympathetic pathways have been difficult to work out. Antibodies to tyrosine hydroxylase (TH), the rate-limiting enzyme in the production of norepinephrine, have recently been used to label sympathetic nerves expanding
our knowledge of the numerous sympathetic fibers within the orbit. Anti-TH antibodies are a specific marker for orbital sympathetic nerves; other types of orbital nerves do not produce this enzyme. With this technique, TH-reactive nerve bundles (i.e., sympathetic nerve fibers) have been observed as follows:

- in the orbital apex (frontal, lacrimal, and nasociliary nerves);
- branching toward the ciliary ganglion, ophthalmic artery, and extraocular motor nerves as the nasociliary nerve proceeds anteriorly;
- as numerous cell bodies within the ciliary ganglion;
- in the long and short ciliary nerves;
- in the posterior ciliary arteries, suprachoidal space, and episcleral arterioles;
- in the zygomatic nerve as it enters the orbit;
- as a plexus of nerves surrounding the ophthalmic artery upon entering the orbit;
- in the mid-orbit nasociliary, anterior, and posterior ethmoidal nerves;
- in the oculomotor, trochlear, and abducens nerves (small clusters of TH-reactive axons);
- in arterioles within the lacrimal gland;
- in the eyelid, where branches of the infratrochlear nerve supply the medial upper and lower eyelids (intense TH immunostaining; innervation of the sympathetic muscles in the upper and lower eyelids is thought to be via this route);
- in the lateral eyelid, where branches of the lacrimal nerve (intense staining) appeared to innervate Müllers muscle;
- in the inferior tarsal muscle (rich TH-reactive nerve supply);
- in the medial and lateral palpebral arteries supplying the upper and lower eyelids (represented by a strong perivascular pattern of TH staining).
- the vascular supply to the Moll and meibomian glands also shows perivascular TH reactivity.
- in contrast to the sensory nerves, the extraocular motor nerves exhibited only mild TH reactivity upon entering the orbit.

As a result of this new technique to identify antibodies to TH (a specific marker for sympathetic nerves), the sympathetic pathways within the orbit have been more clearly outlined. It is now thought that sympathetic nerves enter the orbit via the first (ophthalmic, V₁) and second (maxillary, V₂) divisions of the trigeminal nerve, as well as through a plexus of nerves surrounding the ophthalmic artery. Extraocular motor nerves receive their sympathetic nerve supply from the sensory nerves in the posterior orbit. Sympathetic nerves innervate ocular structures via the long and short posterior ciliary nerves. Sympathetic axons travel anteriorly in the orbit via the nasociliary and lacrimal nerves to innervate the sympathetic eyelid muscles. Sympathetic nerves also travel with the frontal branch of the ophthalmic nerve to innervate the forehead skin and blood vessels in that area. The ophthalmic artery and all of its branches contain a perivascular sympathetic nerve supply that might be involved in the regulation of blood flow to the ocular and orbital structures. Although the extraocular motor nerves and ophthalmic artery plexus might partially contribute to the orbit sympathetic supply, the major sympathetic routes to the orbital structures are with sensory branches.
Clinical Application

- **Horner's syndrome** results from ipsilateral disruption of the sympathetic innervation to the head and neck. It can be caused by a lesion anywhere along the three-neuron oculosympathetic pathway from the brainstem to the eye. The affected pupil is miotic in dim light because of paresis of the dilator muscle. Impaired innervation to sympathetic accessory retractor muscles in both upper and lower eyelids results in mild upper eyelid ptosis and mild elevation of the lower eyelid. A narrowed eyelid fissure results and gives the patient the appearance of having enophthalmos, even though the eye is still in its normal position. It is therefore referred to as an “apparent enophthalmos.” Patients with congenital Horner’s syndrome have hypochromia of the affected iris. In Horner’s resulting from preganglionic sympathetic denervation, there is associated impairment of sweating and vasoconstriction in the ipsilateral face and neck. In postganglionic lesions, these fibers might still be intact. From a practical standpoint, it is important to be able to determine whether an isolated Horner’s syndrome results from the involvement of preganglionic or postganglionic neurons, as the responsible lesions differ considerably. Confirmation and localization of the site of the abnormality is accomplished with pharmacologic testing. Although cocaine will diagnose Horner’s syndrome, it provides no information regarding the localization of the oculosympathetic disruption, and its use is less common because of its status as a controlled substance and because apraclonidine is being used more commonly. Apraclonidine is an α-2 adrenergic agonist used to lower intraocular pressure. Stimulation of the α-2 receptors inhibits the release of norepinephrine. Apraclonidine also has weak α-1 adrenergic agonist activity. When Horner’s is present, the α-1 effect causes mydriasis and the reversal of ptosis in the affected eye; in the normal eye, the α-2 effect causes the normal pupil to become smaller. Apraclonidine should not be used in children younger than six months old and might yield false results in a new Horner’s syndrome. Hydroxyamphetamine (Paradrine) is recognized as the best pharmacologic agent for determining the pre- or postganglionic localization of Horner’s syndrome. In such evaluations, the absence of pupillary dilatation is characteristic of a postganglionic lesion. If a preganglionic lesion is found, further evaluation is required in order to rule out the presence of a serious underlying pathology. Preganglionic (second-order) Horner’s syndrome is related to a malignancy in up to 50% of cases. Isolated postganglionic (third-order) Horner’s is usually due to causes other than malignant tumors and thus has a better prognosis. When postganglionic Horner’s syndrome results from a lesion in the cavernous sinus, there are usually associated cranial palsies.

**SUGGESTED READINGS**


Surgical Anatomy of the Ocular Adnexa


The anatomy of the orbital vascular bed is complex, with tremendous individual variation. The main arterial supply to the orbit is from the ophthalmic artery, a branch of the internal carotid artery. The external carotid artery normally contributes only to a small extent. However, there are a number of orbital branches of the ophthalmic artery that anastomose with adjacent branches from the external carotid artery, creating important anastomotic communications between the internal and external carotid arterial systems. The venous drainage of the orbit occurs mainly via two ophthalmic veins (superior and inferior) that extend to the cavernous sinus, but there are also connections with the pterygoid plexus of veins, as well as some more anteriorly through the angular vein and the infraorbital vein to the facial vein.

A working knowledge of the orbital vasculature and lymphatic systems is important during orbital, extraocular, or ocular surgery. Knowing the anatomy of the blood supply helps one avoid injury to the arteries and veins during operative procedures within the orbit or the eyelid. Inadvertent injury to the vasculature not only distorts the anatomy and disrupts a landmark but also prolongs the surgery and might compromise blood flow to an important orbital or ocular structure.

6–1 ARTERIAL SYSTEM

Upon entering the cranium, the internal carotid artery passes through the petrous portion of the temporal bone in the carotid canal and enters the cavernous sinus and middle cranial fossa through the superior part of the foramen lacerum. It proceeds forward in the cavernous sinus with the abducens nerve along its side (see Figs. 5-4A through 5-4C). There it is surrounded by sympathetic nerve fibers (the carotid plexus) derived from the superior cervical ganglion. It then makes an upward S-shaped turn to form the carotid siphon, passing just medial to the oculomotor, trochlear, and ophthalmic nerves (V₂). After turning superiorly in the anterior cavernous sinus, the carotid artery perforates the dura at the medial aspect of the anterior clinoid process and turns...
posteriorly, inferior to the optic nerve. As it does so, it gives off its first major branch, the ophthalmic artery. In a small percentage of individuals, the ophthalmic artery arises within the cavernous sinus before the carotid penetrates the dura of the cavernous sinus roof.

Within the cavernous sinus, the carotid artery gives off several small but important arterial branches. The most important of these is the meningohypophyseal artery, which sends branches to supply the intracavernous portion of the oculomotor, trochlear, and abducens nerves and the ophthalmic division of the trigeminal nerves, gasserian ganglion, pituitary gland, clival area, and lateral tentorium. These cavernous branches are important because of their potential involvement in carotid-cavernous sinus fistulas and aneurysm formation.

Clinical Application

- Carotid-cavernous sinus fistulas can develop spontaneously or as a result of head trauma and are of either the high flow or the low flow type. Low flow fistulas usually form in the small branch vessels of the posterior cavernous sinus and commonly shunt relatively low volumes of blood to the inferior petrosal sinus. Clinical features of these low flow fistulas (also known as a red-eye shunt) include mild episcleral venous congestion, slightly elevated intraocular pressure, and mild exophthalmos. Carotid bruits are rarely present, and pulsatile proptosis is not encountered. High flow fistulas, in contrast, are typically found in the anterior cavernous sinus and directly affect the carotid artery. With a much higher blood flow, these cause increased venous pressure within the cavernous sinus and a reversal of flow in the ophthalmic veins, leading to severe orbital congestion. Clinically, the patient presents with sudden proptosis, arterialization of the episcleral vessels, limitation of ocular motility, raised intraocular pressure, decreased vision (secondary to retinal ischemia and stretch optic neuropathy), and an orbital bruit. Pulsatile proptosis might be present.
- Intracavernous carotid artery aneurysms have a tendency to occur in middle-aged to older women, who might or might not have headaches. Occasionally, these aneurysms will invade the sphenoid sinus and produce intractable nosebleeds. If they rupture, they produce the characteristic signs and symptoms of a high flow carotid-cavernous fistula.

The principal arteries of the orbit are the ophthalmic, lacrimal, supraorbital, ethmoidal, palpebral, supratrochlear, and dorsal nasal.

6-1-1 Ophthalmic Artery

The ophthalmic artery originates as a branch of the internal carotid artery (Figs. 6-1 and 6-2A). It is responsible for most of the arterial supply to the orbit, with some contributions from branches of the external carotid artery. It can be divided into intracranial, intracanalicular, and intraorbital portions. The intracranial portion of the ophthalmic artery emerges from the carotid trunk just below the optic nerve within the subdural space and is approximately 2.6 mm in length. It enters the optic canal inferomedially. The intracanalicular portion of the artery lies below the optic nerve and
FIGURE 6-1 Looking down at the circle of Willis: anterior cerebral (black arrows), middle cerebral (blue arrows), posterior cerebral (open white arrows), and basilar (white arrow). The third and fifth nerves are seen. The ophthalmic artery (not visible in the photograph) is the first major branch off the internal carotid (green arrows). The anterior communicating (gold arrow) and posterior communicating (purple arrows) vessels are shown.

gradually pierces the dura within the canal. It enters the orbit inferior and lateral to the optic nerve within the annulus of Zinn. Rarely, the ophthalmic artery enters the orbit from the cranial cavity in a separate bony canal (duplicate optic canal) enclosed in a dural covering. Rarely, the ophthalmic artery enters the orbit through the medial part of the superior orbital fissure, medial to the oculomotor nerve. Once in the orbit, there might be a small recurrent artery (the deep recurrent ophthalmic artery) that branches off of the ophthalmic artery and then exits the orbit through the medial aspect of the superior orbital fissure. It travels posteriorly to establish communication with the internal carotid artery.
FIGURE 6-2 Branching pattern of the ophthalmic artery. (A) From above, the ophthalmic artery traveling over the optic nerve. (B) Frontal view.
The ophthalmic artery carries the major blood supply to the orbit in 96% of individuals. In approximately 3%, the middle meningeal artery (of external carotid origin) shares equally through a recurrent meningeal branch (also called an accessory ophthalmic artery) traveling through the superior orbital fissure or a foramen adjacent to the superior orbital fissure in the greater wing of sphenoid, termed the meningeal foramen or foramen of Hyrtl (see Figs. 2-7A and 2-7B). In approximately 1% of individuals, the middle meningeal artery is the only source of arterial blood to the orbit via the recurrent meningeal or accessory ophthalmic artery. In this situation, the recurrent meningeal artery is larger than normal and enters the orbit through the meningeal foramen (foramen of Hyrtl) or the lateral aspect of the superior orbital fissure, at which time it begins branching. It gives off the lacrimal artery first, followed by the ophthalmic artery, which continues toward the medial orbit, giving off other arterial branches as it moves more anteriorly within the orbit.

Clinical Application

- Interventional neuroradiology is a rapidly expanding field of medicine. Detailed high-resolution vascular imaging has helped us to rediscover the complexity of the craniocervical arterial network under normal and pathologic conditions. The concept of dangerous collaterals or dangerous anastomoses was born with the advent of endovascular therapy. Until that time, the arterial network of the skull base had been seen as a safety mechanism bringing relief to areas that had lost their primary source of blood supply (e.g., the classic cerebral collateral supply through the ophthalmic artery in the case of proximal carotid occlusion). With the introduction of transarterial embolization, these beneficial pathways have also become a potential source of procedural complications, mostly due to the inadvertent passage of embolic material into branches supplying important structures, such as the eye or brain.
Although dangerous anastomoses of the skull base are well described in the literature, the variations and collateral pathways related to orbital arteries aren’t as well appreciated. The ophthalmic artery, for example, can have at least three different sources of blood contributing to it, depending upon how the primitive embryologic arterial system developed and then involuted. There also might be a deep recurrent ophthalmic artery present. It is important to be aware of these diverse interconnections during embolization procedures in the cavernous sinus area, as there might be visual implications for the patient. As more interventional radiologic investigations are carried out on patients, this complex and variable anatomy of the orbital apex will be further delineated.

The intraorbital course of the ophthalmic artery and its branching pattern are quite variable. There is no single branching pattern that can be considered “normal.” The order of the branches, as well as the site of origin of the branches given off to various structures, varies a great deal even between the two sides of a single individual. There is such a marked degree of variation that it is best to speak of a “usual branching pattern” rather than a “normal branching pattern.” Whether the ophthalmic artery crosses over or under the ophthalmic artery makes a difference in the order of the branches.

The ophthalmic artery crosses over the optic nerve to head toward the medial wall in approximately 83% of patients and under the optic nerve in approximately 17% of patients (Fig. 6-2A). The central retinal artery is usually the first branch of the ophthalmic artery when the artery crosses over the optic nerve. However, when the ophthalmic artery crosses under the optic nerve, the lateral posterior ciliary is the first branch and the central retinal artery is the second (Table 6-1). The central retinal artery measures approximately 0.3 to 0.4 mm diameter and runs forward, inferior or lateral to the optic nerve, to pierce the dural sheath of the optic nerve 5 to 15 mm posterior to the globe (Fig. 6-3). It then enters the optic nerve and runs toward the optic nerve head in company with the central retinal vein. At the optic disc, it branches into several arterioles that supply the retina.

The ophthalmic artery gives off medial and lateral posterior ciliary arteries (there might be one or up to five in some individuals). The posterior ciliary arteries run forward and divide into multiple smaller, short ciliary branches (Figs. 6-2A and 6-4). At the posterior portion of the globe, approximately 15 to 20 of these short ciliary arteries penetrate the sclera close to the optic nerve, supplying the choroid and the optic nerve head. Two branches of the posterior ciliary artery system pierce the sclera in the horizontal meridian and extend forward within the choroid as the long posterior ciliary arteries to supply the ciliary muscle, the iris, and part of the choroid.

The ophthalmic artery gives rise to a number of collateral branches to the optic nerve during its course. These run along the dural sheath of the optic nerve and then pierce the sheath to form a fine anastomosing plexus on the pia mater. These vessels provide the main arterial supply to the optic nerve itself. They are potentially susceptible to compression from increased intraorbital and subarachnoid pressure.

The ophthalmic artery also gives off multiple muscular branches, but generally two of these are more prominent (the medial and lateral trunk, also called the superior and inferior trunk) and supply most of the extracocular muscles on the intraconal surface of the muscle belly (muscle branches can be seen going to the superior rectus in Figure 6-4). Within the substance of each rectus muscle, branches continue forward and form the anterior ciliary arteries. There are two such anterior ciliary vessels associated with each of the rectus muscles except the lateral rectus, which
TABLE 6-1 “Usual Branching Pattern” of the Ophthalmic Artery

Order of the Arterial Branches when the Ophthalmic Artery Travels “Over” the Optic Nerve
1  Central retinal artery
2  Lateral posterior ciliary artery
3  Lacrimal artery
4  Muscular branch
5  Posterior ethmoidal artery
6  Supraorbital artery
7  Medial posterior ciliary artery
8  Muscular branch
9  Anterior ethmoidal artery
10  Palpebral artery
11  Dorsal nasal artery
12  Supratrochlear artery

Order of the Arterial Branches when the Ophthalmic Artery Travels “Under” the Optic Nerve
1  Lateral posterior ciliary artery
2  Central retinal artery
3  Muscular branch
4  Medial posterior ciliary artery
5  Lacrimal artery
6  Muscular branch
7  Posterior ethmoidal
8  Supraorbital artery
9  Anterior ethmoidal
10  Palpebral artery
11  Dorsal nasal artery
12  Supratrochlear artery

usually has just one. As the anterior ciliary arteries run forward, they gradually move to the extraconal surface, where they lie immediately beneath the muscle sheath.

6-1-2 Lacrimal Artery

The lacrimal artery arises from the ophthalmic artery close to the origin of the central retinal artery (Figs. 6-2A through 6-2C). Occasionally, it arises from the recurrent meningeal branch of the middle meningeal artery (of external carotid origin). Along with the lacrimal nerve, it extends along the lateral wall of the orbit, above the superior border of the lateral rectus near the periorbita. The arterial branches off the lacrimal artery are as follows:

1. recurrent meningeal,
2. extraocular muscle branches,
3. zygomatic (zygomaticotemporal, zygomaticofacial),
4. glandular (to the lacrimal gland), and
5. lateral palpebral.
The recurrent meningeal artery (or accessory ophthalmic artery) passes through the lateral portion of the superior orbital fissure or the meningeal foramen (foramen of Hyrtl) just lateral to the superior orbital fissure, and it anastomoses with the anterior branch of the middle meningeal artery in approximately 70% of individuals (Figs. 6-2A, 2-7A, and 2-7B). As the lacrimal artery (and nerve) continues forward, branches are given to the lateral rectus, medial rectus, superior rectus, levator, and inferior oblique muscles. Further along the course of the lacrimal artery, another branch descends along the lateral wall and then divides into two vessels: the zygomaticotemporal and zygomaticofacial arteries. These branches, with their associated nerves, pass through foramina of the same names in the lateral orbital wall (zygomaticotemporal foramen, zygomaticofacial foramen) and anastomose with the anterior deep temporal and transverse facial arteries (of external carotid origin), respectively. As the lacrimal artery reaches the lacrimal gland, it divides into several branches to supply the lacrimal gland. A terminal branch continues through the gland or inferiorly around it, pierces the orbital septum, and divides to form the superior and
inferior palpebral arteries, which anastomose with the corresponding medial palpebral arteries to form the arterial arcades of the upper and lower eyelid.

6–1-3 Supraorbital Artery

The supraorbital artery arises from the ophthalmic artery as it crosses the optic nerve and is absent in 10% to 20% of normal individuals (Figs. 6-2A through 6-2C). It travels in the extraconal space along the medial border of the superior rectus and levator in company with the supraorbital nerve. The supraorbital artery and its accompanying nerve exit the orbit through the supraorbital foramen or notch, where the artery might divide, giving rise to a smaller medial frontal branch. Small accessory muscular branches from the orbital portion of the artery might help supply the superior rectus, superior oblique, and levator muscles. The supraorbital artery (as well as the nearby supratrochlear artery) helps supply the skin of the forehead, eyebrows, and medial upper eyelid.

6–1-4 Ethmoidal Arteries (Posterior and Anterior)

The posterior ethmoidal branch of the ophthalmic artery extends across the orbit medially, usually passing over the superior oblique muscle toward the posterior ethmoidal foramen (approximately 5 to 6 mm anterior to the optic canal) (Fig. 6-2A). It is absent in 15% to 20% of the population.
The artery extends through the posterior ethmoidal foramen to supply the mucosa of the posterior ethmoidal air cells. Before entering the ethmoidal foramen, it often gives off one or more accessory muscular branches to the superior oblique, superior rectus, or levator muscles.

The anterior ethmoidal artery is larger than the posterior ethmoidal artery and is more consistently present. It is absent in less than 2% of cases and, rarely, might be multiple. The anterior ethmoidal artery passes under the superior oblique muscle en route to the medial wall in company with the anterior ethmoidal nerve to exit through the anterior ethmoidal foramen. The anterior ethmoidal artery supplies the mucosa of the anterior and middle ethmoidal air cells, the frontal sinus, and the lateral wall of the nose and septum. A small meningeal branch from this vessel penetrates the roof of the ethmoidal sinus to supply the dura of the anterior cranial fossa near the cribriform plate.

Clinical Application

- The anterior and posterior ethmoidal arteries and their foramina are important landmarks during orbital surgery. The anterior ethmoidal foramen and vessels are approximately 24 mm from the anterior orbital rim. The posterior ethmoidal foramen is 12 mm from the anterior ethmoidal foramen. The optic canal is 6 mm posterior to the posterior ethmoidal foramen. The mnemonic “24-12-6” is helpful to the physician doing orbital surgery along the medial wall. For example, during a thyroid decompression through an anterior medial orbital incision (Lynch-type approach) or using a transcaruncular approach, it is important to identify the anterior and posterior ethmoidal vessels. Not only is it crucial to cauterize these key landmarks in order to avoid bleeding but, because they are at the level of the cribriform plate, removing bone above this level carries a serious risk of intracranial cerebrospinal fluid leakage.

6–1–5 Supratrochlear Artery (Frontal Artery)

Beyond the anterior ethmoidal artery, the ophthalmic artery continues forward in the superomedial extraconal space and divides into two branches: the supratrochlear artery and the dorsal nasal artery (Figs. 6-2B, 6-2C, 6-4, and 6-5). The supratrochlear artery (sometimes called the frontal artery) is one of the terminal branches of the ophthalmic artery. It pierces the orbital septum above the trochlea and proceeds superiorly to supply the medial forehead and scalp.

6–1–6 Dorsonasal Artery

The dorsonasal (or infratrochlear) artery is another terminal branch of the ophthalmic artery (Fig. 6-5). It pierces the orbital septum between the trochlea and medial canthal tendon and anastomoses with the angular artery (a continuation of the facial artery), thereby establishing an important connection between the internal and external carotid artery systems. The dorsal nasal artery supplies the nasal bridge and the forehead near the midline, and it anastomoses with the dorsal nasal artery on the other side. It might also supply the lacrimal sac.
6–1–7 Palpebral Arteries

The medial palpebral artery either branches off the dorsal nasal artery or is a terminal branch of the ophthalmic artery. It further divides into the medial superior and medial inferior palpebral arteries, which enter the eyelids above and below the medial canthal tendon, respectively (Fig. 6–5). The medial palpebral arteries enter the upper and lower eyelids and eventually anastomose with the lateral palpebral vessels (terminal branches of the lacrimal arteries). Marginal and peripheral arcade vessels are formed in the eyelids once this anastomosis takes place. In the upper eyelid, a marginal arcade vessel runs within or just anterior to the tarsal plate about 2 to 3 mm from the lid margin. A peripheral arcade, generally appearing as one or two vessels, is located along the superior border of the tarsal plate between the levator aponeurosis and Müller’s muscle. In the lower eyelid, usually only the marginal arcade is present, and it is located about 2 mm from the lid margin. A peripheral arcade might occasionally be seen but might exist in only part of the eyelid.

6–1–8 Anastomotic Channels between External and Internal Carotid Systems

Extensive anastomotic connections occur between the internal and external carotid systems around the orbital rim, bringing collateral blood supply to the orbit.

The middle meningeal artery connection is discussed at the beginning of this chapter. As mentioned, in approximately 3% of individuals, the middle meningeal artery (external carotid system) shares the blood supply to the orbit equally with the ophthalmic artery (internal carotid system).
through an enlarged “recurrent meningeal” or “accessory ophthalmic” branch. In 1% of individuals, the middle meningeal artery is the only source of arterial blood to the orbit.

The *external maxillary artery* arises from the external carotid below the angle of the jaw. It courses over the mandible across the cheek to the angle of the mouth as the *facial artery*. It then ascends along the side of the nose as the angular artery toward the medial canthus, where it anastomoses with the *dorsal nasal artery* (of internal carotid origin).

As the external carotid artery continues to ascend, it divides behind the neck of the mandible into two main trunks: the *internal maxillary* and the *superficial temporal arteries*. The internal maxillary artery gives rise to numerous branches that supply deep structures of the face. Of particular importance to the orbit is the infraorbital branch, which arises in the pterygopalatine fossa at the inferior orbital fissure. The *infraorbital artery* enters the orbit and infraorbital groove and then passes forward within the infraorbital canal along with the infraorbital nerve. It emerges on the face at the infraorbital foramen approximately 10 mm below the inferior orbital rim. It supplies the lower eyelid and upper cheek and anastomoses with branches from the palpebral arteries (of internal carotid origin), and angular artery (external carotid origin). Within the infraorbital canal, the infraorbital artery gives rise to one or more communicating vessels. These *communicating branches of the infraorbital artery* penetrate the periorbita midway along the infraorbital canal and head into the orbit. In most individuals, these vessels supply the soft tissue of the orbital floor and the nasolacrimal sac/duct, as well as providing a minor supply to the inferior rectus and inferior oblique muscles, where they anastomose with the inferior muscular branches of the ophthalmic artery (of internal carotid origin). Occasionally the communicating branch of the infraorbital artery vessel is the sole source of blood to the inferior oblique muscle.

Another branch of the internal maxillary artery (external carotid) with orbital connections is the *deep temporal artery*. This vessel ascends between the temporalis muscle and the pericranium to contribute a blood supply to the temporalis muscle. There are anastomotic connections between the deep temporal artery and the lacrimal artery (internal carotid) through the *zygomaticotemporal branch* of the lacrimal artery.

The *superficial temporal artery* originates approximately 1 cm anterior to the bony external auditory canal. As it travels above the zygomatic process, it becomes more superficial and is easily palpated. The superficial temporal artery gives rise to several branches, including the parietal, frontal, zygomatic (or middle temporal), and *transverse facial* arteries. The latter three anastomose with orbital vessels.

The *frontal branch* of the superficial temporal artery crosses the forehead just above the lateral brow. It supplies the frontalis muscle, skin, and pericranium and anastomoses with branches of the *supraorbital artery* (of internal carotid origin). The *zygomatic branch* (or middle temporal branch) runs along the upper border of the zygomatic arch to supply the orbicularis muscle at the lateral canthus. There it anastomoses with the zygomaticofacial and lateral palpebral branches of the lacrimal artery (of internal carotid origin). The *transverse facial branch* arises from the superficial temporal artery just inferior to the zygomatic arch. It courses transversely across the side of the face to supply the parotid gland and masseter muscle, and it anastomoses with branches of the infraorbital artery (which anastomoses with palpebral and angular vessels of internal carotid origin) as well as branches of the facial artery.
The internal-external carotid anastomoses in the orbital region can be summarized as follows:

1. anastomotic connections between the middle meningeal artery (external carotid) and the ophthalmic artery (internal carotid) via the recurrent meningeal artery (accessory ophthalmic artery),
2. anastomotic connections between the angular artery/facial artery (external carotid) and the dorsal nasal artery (internal carotid),
3. anastomotic connections between the infraorbital artery once it exits the infraorbital foramen (external carotid) and branches from the palpebral arteries (internal carotid),
4. anastomotic connections between the infraorbital artery within the infraorbital canal (external carotid) and the inferior orbital muscular arteries to the inferior rectus and inferior oblique muscles (internal carotid) via the “communicating branch of the infraorbital artery;”
5. anastomotic connections between the deep temporal artery (external carotid) and the lacrimal artery through the zygomaticotemporal branch of the lacrimal artery (internal carotid),
6. anastomotic connections between the frontal branch of the superficial temporal artery (external carotid) and branches of the supraorbital artery (internal carotid),
7. anastomotic connections between the zygomatic branch of the superficial temporal artery (external carotid) and the zygomaticofacial and lateral palpebral branches of the lacrimal artery (internal carotid), and
8. anastomotic connections between the transverse facial artery branch of the superficial temporal artery and the infraorbital artery and palpebral and angular arteries (internal carotid).

Clinical Application

- During dissection along the orbital floor, it is very important to be aware of the communicating branch of the infraorbital artery. It might lead to brisk bleeding if not recognized and cauterized.
- Orbital vessels might be involved in the formation of arterial venous shunts. Their effect on orbital structures depends on the site of the shunt and the rate of blood flow volume. Low-flow shunts increase venous pressure, leading to venous dilatation and orbital edema, and might result in thrombosis. High-flow shunts can cause orbital swelling, pulsatile proptosis, chemosis, dilated epibulbar vessels, increased ocular pressure, and ocular ischemia. Arteriovenous (AV) shunts can be congenital but are more commonly acquired either spontaneously or after head trauma. The shunt is usually located outside the orbit near the cavernous sinus, with arterial blood passing directly to the orbital veins via retrograde filling. Distension and increased pressure in the cavernous sinus can result in diplopia from palsies of the cranial nerve, usually the third and sixth. Less frequently, the shunt is located within the orbit and is associated with congenital AV malformation.
Orbital mucormycosis is an aggressive, opportunistic fungal infection of the paranasal sinuses that frequently extends into the orbit. Debilitated and immunosuppressed patients, especially those with uncontrolled diabetes and ketoacidosis, are more susceptible. The patients present with what initially appears to be an early periocular cellulitis, but rapid deterioration ensues. The organism invades blood vessels, leading to vascular occlusion, infarction, and ischemic necrosis. Black eschars might be seen in the oral or nasal mucosa. Rapidly developing proptosis, motility restriction (of the third, fourth, and/or sixth cranial nerve), and sudden visual loss (central retinal artery occlusion) over a matter of hours accompany aggressive orbital infection. The disease might spread intracranially through the superior orbital fissure to the cavernous sinus and be fatal if heroic measures are not taken to debride the necrotic facial/orbital tissues involved, in conjunction with high-dose antifungal medication.

6–2 VENOUS SYSTEM

The orbital venous system has a complex structural organization that involves two major vessels (the superior and inferior ophthalmic veins) and a diffuse network of interconnected branches. In contrast to the more or less orderly topographic arrangement of the arterial system, orbital veins are less well defined and vary considerably more. The veins are valveless and do not generally follow a course parallel to the arteries, as do veins in other parts of the body. Instead, they form a separate morphologic system. The only exceptions are the first part of the superior ophthalmic vein, the lacrimal and ethmoidal veins, which do follow their respective arterial channels.

Blood is drained from the orbit through three major systems: the cavernous sinus, the pterygoid plexus, and the anterior venous system via the angular vein and infraorbital vein. The major drainage occurs posteriorly via the superior and inferior ophthalmic veins to the cavernous sinus. The inferior ophthalmic vein either enters the cavernous sinus directly or fuses with the superior ophthalmic vein prior to entering the cavernous sinus, in addition to sending a branch to the pterygoid plexus. The pterygoid plexus also receives venous drainage from the inferior orbit (through the infraorbital vein) via communicating venous channels along the path of the infraorbital vein. Venous drainage from the orbit also occurs anteriorly through communication of the superior ophthalmic vein (superior and inferior roots) with the angular vein of the facial venous system or via the infraorbital vein to the facial venous system. The direction of blood flow throughout the valveless venous system within the orbit depends largely on local pressure gradients.

6–2-1 Superior Ophthalmic Vein

The superior ophthalmic vein (SOV) is the principal vein in the orbit and has a rather constant course (Figs. 6-6A through 6-6C, 6-7A, and 6-7B). Two roots form this vein: the superior and the inferior. The superior root is a branch off the supraorbital vein just before it anastomoses...
FIGURE 6-6  The orbital venous system (A) from above, (B) in frontal view.
with the nasofrontal veins (also called the frontal or supratrochlear) from the forehead and scalp. The superior root extends from the superior nasal aspect of the orbital rim along the roof of the orbit to the medial aspect of the levator muscle. There it unites with the inferior root. The inferior root is the orbital extension of the angular vein, which is a direct extension of the facial vein. It pierces the orbital septum and then extends in a posterosuperior direction to join the superior root of the SOV (Fig. 6-7). The superior and inferior palpebral veins carry blood from the eyelids and join the inferior root near its junction with the angular vein, or they might join the angular vein directly. The SOV is supported by a hammock of connective tissue. It can be divided into three sections; the first part arises from the union of the two roots in the anterior orbit and ends at the medial border of the superior rectus muscle. The second part, which is usually the largest in caliber, travels beneath the superior rectus muscle to the mid-orbit. The third part begins at the lateral border of the superior rectus and travels toward the superior orbital fissure and into the cavernous sinus. Numerous branches feed into the SOV as it travels posteriorly toward the superior orbital fissure:

- the lacrimal vein,
- the anterior and posterior ethmoidal veins,
- the superior medial and superior lateral vortex veins,
- collateral veins from the inferior ophthalmic vein, and
- muscular branches.

*Lacrimal vein:* The lacrimal gland is drained by the lacrimal vein. It arises from the gland as one or two branches that join to form the lacrimal vein. It runs along the superior border of the lateral
FIGURE 6-7 Looking from above down: a very large superior ophthalmic vein of a right orbit is seen. (A) Two roots of the right superior ophthalmic vein are visualized. The smaller one (blue arrow) is a continuation of the angular vein; the larger one (white arrow) is a continuation of the supraorbital vein. They will join and form the superior ophthalmic vein. The superior rectus muscle is visible (gold arrow). (B) The same dissection as in (A), except that the superior root has been moved medially and a great deal of fat has been removed. The superior medial vortex vein (white arrow) can be seen leaving the globe and going toward the superior ophthalmic vein. The superior temporal vortex vein (green arrow) is seen entering the lacrimal vein (purple arrows), which will also join the superior ophthalmic vein (blue arrow). The superior rectus muscle is visible (open white arrow).
rectus muscle with the lacrimal nerve and artery and joins the SOV as it approaches the lateral border of the superior rectus muscle (Figs. 6-6A and 6-6B). Before it joins the SOV, it might receive various branches (e.g., the superior lateral vortex vein).

**Ethmoidal veins:** Two ethmoidal veins are usually present (Figs. 6-6A and 6-6B). The anterior ethmoidal vein usually drains into the SOV, whereas the posterior ethmoidal vein often drains into a venous network under the orbital roof that has connections with the SOV.

**Vortex veins:** There are usually four vortex veins, located medially and laterally in the superior and inferior orbit (Figs. 6-6A through 6-6C, 6-7B). They emerge from the episcleral space between the sclera and Tenon’s capsule. The superior medial vortex vein has the shortest course and drains into the first part of the SOV. The superior lateral vortex vein has a longer route. It travels posteriorly for some distance to drain into either the lacrimal vein or, sometimes, the second part of the SOV as it travels beneath the superior rectus muscle.

**Collateral veins:** As the SOV proceeds posteriorly, it is joined by “collateral vessels” from the inferior ophthalmic vein.

**Muscular branches:** The muscular veins are the most variable veins in the superior orbital venous system. Numerous muscular branches drain into the SOV from the medial rectus, superior rectus, and superior oblique.

**Other venous branches:** The orbital venous system is highly variable as compared with other venous systems in the body. However, in the superior orbital venous system, the SOV has a remarkably constant course with only a few variations. Some individuals will also have a medial ophthalmic vein. It has an inconsistent origin, arising from either the angular vein or the anterior portion of the SOV. It runs posteriorly medial to the SOV. Depending on its origin, it rejoins either the second or the third part of the SOV, or might travel directly to the cavernous sinus. It might appear to form a circular venous loop, linking the medial collateral and ethmoidal vein, and sometimes the muscular vein from the medial rectus, to the SOV.

The SOV continues posteriorly along the lateral border of the superior rectus muscle, exits the muscle cone, and passes above the heads of the lateral rectus muscle. It leaves the orbit through the superior orbital fissure outside the fibrous annulus of Zinn to join the cavernous sinus.

**Clinical Application**

- The major venous drainage in the orbit occurs posterior to the cavernous sinus, but secondary flow does occur to the pterygoid plexus and in some cases even anterior to the facial venous system via the angular vein and infraorbital vein. In achondroplastic dwarfs, orbital venous flow is usually anterior, possibly as a result of vascular outflow compression from stenosis of the cranial foramina.
- As the SOV extends posteriorly, it is supported by a hammock-like sling formed by the connective tissue framework in the area. The SOV is layered between the superior rectus and this facial hammock. Thickening of the superior rectus muscle, as in Graves orbitopathy or with inflammatory myositis, can compress the vein against this hammock, resulting in impaired blow flow, orbital venous congestion, and a dilated SOV on computed tomography scanning.
• Any increased venous pressure within the cavernous sinus, as with a carotid-cavernous sinus fistula or dural cavernous sinus fistula, results in dilation of the SOV and its tributaries within the orbit. This becomes clearly evident on computed tomography or magnetic resonance images.

### 6–2-2 Inferior Ophthalmic Vein

The *inferior ophthalmic vein* (IOV) drains a network of venous channels in the inferior orbit and is more variable in its course than the SOV (Figs. 6-6C and 3-2D through 3-2F). It originates anteriorly in the medial orbit between the globe and inferior rectus muscle as a diffuse venous plexus formed by veins with abundant interconnections. These interconnected veins are extremely small in diameter and short in length. This plexus receives branches from the medial and inferior rectus, the inferior oblique muscles, the lower eyelid, and the lacrimal sac. There are also collateral branches to the superior ophthalmic venous system. Directly inferior to the optic nerve, the IOV runs posteriorly, staying just above the inferior rectus muscle. It is joined by branches from the inferior-medial and inferior-lateral vortex veins (which are more tortuous than their counterparts in the superior orbit), muscular branches from the inferior and lateral rectus muscles, and additional collateral branches to the SOV. As it extends into the posterior orbit, it shifts to run along the lateral border of the inferior rectus muscle. A net of small vessels located outside the muscle cone along the orbital floor communicates with the inferior ophthalmic venous system via one or more branches passing around the lateral aspect of the inferior rectus muscle. In the posterior orbit, the IOV gives off a branch inferiorly that passes through the substance of Müller’s orbital muscle within the inferior orbital fissure to connect with the pterygoid venous plexus. Here they anastomose with branches from the infraorbital vein, through which blood once again communicates with the facial venous system. The main trunk of the IOV passes out of the muscle cone, inferior to the annulus of Zinn, and travels posteriorly to join the cavernous sinus. In some individuals the IOV passes superiorly to join the SOV as it empties into the cavernous sinus.

### 6–2-3 Central Retinal Vein

The *central retinal vein* travels in close relation with the central retinal artery. The vein emerges from the optic nerve 8 to 15 mm from the posterior portion of the globe. It drains into the SOV near the orbital apex. Occasionally, the central vein continues directly to the cavernous sinus, but it always has at least some anastomotic connections with the SOV.

### 6–2-4 Anterior Venous Pathways

Although orbital venous drainage occurs primarily posterior to the cavernous sinus, anterior drainage also occurs. The most prominent anterior drainage vessel is the *angular vein* in the medial
canthal region, which is continuous with the facial vein medially. Medial palpebral veins will anastomose with the angular vein. Laterally, palpebral veins anastomose with branches of the superficial temporal vein. In addition, diffuse anastomotic channels arise from the IOV and cross over the inferior orbital rim to reach the facial vein to provide anterior venous drainage. These veins are routinely seen during blepharoplasty surgery, passing over the inferior orbital rim in its mid-position. They bleed profusely if not cauterized. The facial vein also receives venous drainage from the inferior orbit through the infraorbital vein via communicating venous channels along the path of the infraorbital vein and pterygoid plexus. The direction of blood flow in the anterior venous system is often determined by pressure gradients.

The superficial temporal vein begins on the side and vertex of the skull in a plexus that communicates with the frontal and supraorbital veins, with the corresponding vein of the opposite side, and with the posterior auricular and occipital veins. From this network, frontal and parietal branches arise and unite above the zygomatic arch to form the trunk of the vein, which is joined by the middle temporal branch from the temporalis muscle. At that point it lies adjacent to the superficial temporal artery. It then crosses the posterior portion of the zygomatic arch, enters the parotid gland, and unites with the internal maxillary vein to form the posterior facial vein, which enters the external jugular vein. The superficial temporal vein receives in its course some parotid veins, articular veins from the temporomandibular joint, anterior auricular veins from the ear, and the transverse facial vein from the side of the face. The middle temporal branch receives the superior palpebral vein running along the superior orbital rim, which also anastomoses with the supraorbital vein. The lateral palpebral vein also sends anastomotic branches over the lateral orbital rim to the superficial temporal vein.

The supraorbital vein (Figs. 6-6B and 6-6C) begins in the forehead, where it communicates with the frontal branch of the superficial temporal vein. It runs downward superficial to the frontalis muscle and has anastomotic connections with the nasofrontal (also called frontal or supratrochlear) vein at the medial angle of the orbit to form the angular vein. Prior to its junction with the nasofrontal vein, it sends a branch through the supraorbital notch into the orbit that communicates with the SOV. This branch is called the superior root of the superior ophthalmic vein.

The angular vein (as discussed above) is formed by the junction of the nasofrontal (or frontal, supratrochlear) vein and the supraorbital vein. It runs downward along the side of the nose (anterior to the medial canthal tendon) to the lower margin of the orbit, where it becomes the anterior facial vein (or simply the facial vein). A branch off the angular vein heading posterior into the orbit is known as the inferior root of the superior ophthalmic vein. The medial superior and inferior palpebral veins join either the angular vein or the inferior root, contributing venous blood from the eyelids.

The anterior facial vein (or facial vein) is a direct continuation of the angular vein and commences at the medial, inferior orbital rim. The facial vein courses lateral to the angular artery across the face toward the anterior border of the masseter muscle and the body of the mandible. It has several important anastomotic connections with the orbit and, therefore, the cavernous sinus. Along its course it receives venous channels originally arising from the IOV that traveled over the inferior orbital rim to reach the inferior palpebral vein, infraorbital vein, and facial vein. The facial vein also receives venous drainage from the inferior orbit directly through the infraorbital vein, which communicates with the pterygoid plexus and cavernous sinus. Further along its course,
the facial vein receives additional connections with the cavernous sinus by way of the deep facial vein, which passes into the infratemporal fossa to join the pterygoid plexus, which in turn communicates with the cavernous sinus. Other venous connections include the superior and inferior labial vein and the buccinator and masseteric veins. The anterior facial vein eventually crosses over the body of the mandible and passes obliquely backward beneath platysma to unite with the posterior facial vein and form the common facial vein, which crosses the external carotid and enters the internal jugular vein below the hyoid bone.

6–2–5 Cavernous Sinus

The cavernous sinuses lie within the middle cranial fossa (adjacent to the temporal lobe), on either side of the body of the sphenoid bone and pituitary gland. They extend from the medial, widest part of the superior orbital fissure to the apex of the petrous portion of the temporal bone. The inferior border of the sinus is contiguous with the gasserian (or semilunar) ganglion of the trigeminal nerve. The two sinuses are interconnected by the anterior and posterior intercavernous sinuses, which cross the midline anterior and posterior to the pituitary hypophysis to form the circular sinus.

The cavernous sinuses represent extradural parasellar spaces between the endosteum of the sphenoid bone and the dura, continuous with the tentorium. They contain the internal carotid arteries; the oculomotor, trochlear, and abducens nerves; branches of the trigeminal nerve (V₁, V₂); and an extensive venous system (see Figs. 5-4A through 5-4C). The exact structure of this venous system is controversial. Currently, most investigators do not believe in the classic view of the cavernous sinus as a space with fibrous trabeculations. Instead, it appears to consist of a plexus of variously sized, diffusely anastomotic venules that receive tributaries from the SOV and IOV, the sphenoid sinus, the middle/inferior cerebral veins, and the middle meningeal veins (see Fig. 5-4). The cavernous sinuses drain into the transverse sinus by way of the superior petrosal sinus and into the internal jugular vein through the inferior petrosal sinus. The cavernous sinus also communicates with the pterygoid plexus via tributaries passing through the foramen lacerum and foramen ovali.

Clinical Application

- Orbital varices are dilated venous channels within the orbit with connections to the orbital venous system (and cavernous sinus). They usually present during the first two decades of life, although the onset can be in middle age or even older age. The varix might present as a bluish or purple palpable mass in the eyelid or anterior orbit that readily distends with a valsala maneuver or on the patient’s bending over. When it is deeper in the orbit, variable proptosis might be the initial presenting symptom. Spontaneous hemorrhage and thrombosis can occur, leading to pain, diplopia, and potentially visual loss. Unless they are causing severe problems, orbital varices are best left alone, as diffuse bleeding that is very difficult to control often complicates surgical removal.
- The cavernous sinus and superior orbital fissure are, rarely, involved with a nonspecific orbital inflammatory syndrome referred to as Tolosa–Hunt syndrome. Patients with this
condition present with a painful ophthalmoplegia that is exquisitely responsive to steroids. The diagnosis of Tolosa–Hunt is one of exclusion and is made only after evaluation has ruled out other causes of painful ophthalmoplegia (e.g., a tumor).

- Cavernous sinus thrombosis can result from the hematogenous extension of infection from the face, nasal cavity, paranasal sinuses, or ear. Cavernous sinus thrombosis can also be a rare complication of orbital cellulitis. The signs of cavernous sinus thrombosis are Bluish-purple eyelid discoloration, proptosis, chemosis, and ocular motor palsies. The absence of ocular pain and decreased sensation in the area supplied by the maxillary division of the trigeminal nerve are other characteristic findings on physical examination. Bilateral involvement is not unusual and is due to the anterior and posterior intercavernous sinus connections.

6–3 LYMPHATIC SYSTEM

The lymphatic system consists of a network of delicate, endothelium-lined vessels with internal valves. Located along their paths are the lymph nodes, through which lymph passes en route to the venous system. The primary function of lymphatic vessels is to return large protein molecules and excess fluid extravasated into tissues (from the arterial side) back into the vascular system (on the venous side).

Lymphatic channels have been extensively described in the eyelids and conjunctiva. In the eyelids, they form a deep system and a superficial system. The deep vessels form a plexus along the tarsal borders and drain the tarsal and conjunctival regions. The superficial system drains the skin of the eyelids and the orbicularis. The lymphatics of the eyelids drain into the preauricular and submandibular nodes (Fig. 6-8). Generally, the drainage of the lateral two-thirds of the upper eyelid, the lateral one-third to one-half of the lower eyelid, and the lateral half of the conjunctiva are thought to go to the preauricular nodes. The medial one-third of the upper and medial one-third to one-half of the lower eyelids, as well as the medial half of the conjunctiva, are thought to drain into the submandibular nodes via channels that follow the angular and facial arteries. However, it is important to appreciate that there is a great deal of variability in the lymphatic drainage pathways from the ocular adnexa among individuals. Thus, lymphatic drainage patterns assessed via lymphoscintigraphy not uncommonly conflict with the previously described classic drainage patterns. For example, the medial conjunctiva and medial lower eyelid might at times drain into the preauricular nodes rather than the submandibular nodes. A recent study by Nijhawan et al. revealed that in 72% of test subjects, the first-order sentinel node was the preauricular node regardless of the location of the injection site in the eyelid.

6–3-1 Orbital Lymphatics

The question of whether lymphatic vessels exist in the human orbit has been controversial over the years. Numerous animal studies have produced evidence for an orbital lymphatic drainage system; however, there is no clear and convincing study that demonstrates the actual pathway
by which fluid leaves the orbit. Sherman and co-workers, using enzyme histochemistry (staining orbital tissue for 5′ nucleotidase activity) and ultrastructure examination of orbital tissues with light and electron microscopy, have produced some interesting findings in a primate model (rhesus monkey). Light microscopic evidence of lymphatics was found in some extraocular muscles, the optic nerve arachnoid, the orbital apex, and the lacrimal gland. Electron microscopic findings confirmed the light microscopic results for some areas: lymphatic vessels were identified in the lacrimal gland, the optic nerve arachnoid, and the orbital apex. Although some examples of lymphatics were found in a number of extraocular muscle specimens, the majority failed to show them by light or electron microscopy. The authors suggested additional studies to define the nature and extent of orbital lymphatics, as well as their connection to the extraorbital lymphatic system. The presence of lymphatic vessels in other parts of the orbit was suspected, but further investigation is required.

### 6–3–2 Lymphatics Within the Eye

Given that the eye was believed to lack lymphatics, there is some excitement over the recent discovery of a rich network of lymphatic channels in the ciliary body of the human eye. Lymphatics distinct from blood vessels drain fluid from the tissues, clear protein, and monitor immune responses. The ocular lymphatic circulation appears to be an active one, as various tracers injected
into the eye find their way to distant regional lymph nodes and are clearly identified within lymphatic channels.

Lymphatics in the eye might be highly relevant to an understanding of aqueous humour outflow. Impaired aqueous humour drainage leads to elevated intraocular pressure, the major risk factor for glaucoma. Pathways for aqueous humour to leave the eye include conventional outflow via the trabecular meshwork and unconventional uveoscleral outflow through the ciliary body. In the latter, tracers flow through interstitial spaces of the ciliary muscle into the suprachoroidal space, moving through the sclera. This unconventional or uveoscleral outflow route is less understood. The rich lymphatic network recently discovered has been termed the “uveolymphatic” pathway and very likely contributes to this route. It is possible that prostaglandin agonists, the most widely prescribed glaucoma drug family, lower pressure and also act on the uveolymphatics. Novel therapies to target this pathway might help to reduce intraocular pressure for the treatment of glaucoma.

Lymphatic channels in the ciliary body might also be relevant to an understanding of the development and spread of intraocular melanomas. Rare studies show that uveal melanomas can spread to regional lymph nodes. Ciliary body melanomas with extraocular extension have been found to have lymphatic channels within them in some instances. These channels were believed to be coming from outside of the eye. In view of the findings of lymphatics in the normal ciliary body, an intraocular origin of the tumor lymphatics is a distinct possibility. Further studies of the lymphatic circulation in the eye might elucidate the mechanisms of extraocular tumor spread and the relation between ocular tumors and the immune system.

The eye traditionally has held immune-privileged status. This concept emerged from experimental evidence of a weak delayed immune response to various antigens inoculated into the eye. One of the explanations for this phenomenon is the lack of lymphatics in the eye. Most organs and tissues drain antigens to regional lymph nodes to elicit appropriate responses. In contrast, the eye is thought to drain antigens via outflow pathways directed into the blood stream, where they can be degraded. New insights into the interface between intraocular lymphatics and immune regulation will no doubt provide new understandings of ocular inflammatory diseases and their treatment.

The uveolymphatic pathway in the ciliary body likely plays an important role in the clearance of proteins and interstitial fluid from the eye. Future studies involving topographic mapping and in vivo tracer studies should help characterize the structure and function of these newly discovered lymphatic vessels.

Clinical Application

- Despite the typical absence of lymphatic tissue within the orbit, lymphangiomas are not uncommon orbital tumors in children and young adults. They present as infiltrating masses that might involve the eyelids and deep orbital structures. Imaging reveals them to be poorly delineated, and there might be multiple fluid levels on magnetic resonance imaging. These tumors can spontaneously bleed into one of the cystic spaces, forming a so-called chocolate cyst. Episodes of spontaneous bleeding can lead to sudden proptosis, double vision, and hemorrhagic chemosis. Treatment is difficult, and surgery is hazardous: as the tumor has no defined capsule, it tends to infiltrate everything, and attempts to take it all out risk damaging normal structures.
FIGURE 6-9 Chronic lymphedema of the right upper and lower lid that developed after surgery and radiation for a malignant parotid gland tumor in a 28-year-old man.

- Lymphedema is a form of tissue edema resulting from the accumulation of lymph fluid. Eyelid lymphedema can be seen after various surgical eyelid procedures (for example, ptosis repair or blepharoplasty) but is short-lived and resolves as the tissues heal. Chronic eyelid lymphedema is unusual (Fig. 6-9). It is etiologically related to a loss of lymphatic vessels on either a congenital basis (aplasia or hypoplasia) or an acquired basis (damage to lymphatic vessels from surgery [usually in the temporal region], radiation, trauma, and the like). Chronic lymphedema can be difficult, if not impossible, to eradicate.
- Conjunctival melanoma is a rare tumor of the ocular surface. The regional lymph nodes are thought to be the first site of metastasis. The traditional ways of assessing the regional lymph nodes at the time of initial diagnosis include palpation of the regional nodes, imaging studies such as computerized tomography or magnetic imaging, and ultrasonography with fine needle aspiration. Recently there has been some progress toward better staging of the regional lymph nodes in patients with conjunctival melanoma by adapting sentinel lymph node (SLN) biopsy as a way to discover microscopic (subclinical) metastatic disease. The mapping of SLNs begins with preoperative identification of the afferent lymphatics using radionucleotide imaging (lymphoscintigraphy). Technetium 99m sulfur colloid is injected at two to four spots around the lesion. Multiple images of the ipsilateral head and neck region are obtained in the nuclear medicine department, beginning within a few minutes of injection. Intraoperatively, a short time later a handheld gamma probe is used to transcutaneously localize SLNs that are highly radioactive due to uptake of the technetium-labeled sulfur colloid. These areas are marked on the skin, an excisional biopsy is performed, and the nodes are sent for histological processing.

SUGGESTED READINGS


Surgical Anatomy of the Ocular Adnexa


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CHAPTER 7

THE LACRIMAL SYSTEM

The lacrimal system is made up of both the lacrimal secretory system and the nasolacrimal drainage system (Fig. 7-1). The secretory system consists of the glands that make up the tear film (the lacrimal gland, the accessory glands of Krause and Wolfring, and the meibomian glands). The nasolacrimal drainage system consists of the puncta, canaliculi, lacrimal sac, and nasolacrimal duct. These two systems provide for the production and maintenance of the precorneal tear film as well as the drainage of tears from the eye. The normal functioning of these two systems is essential for proper optical refraction, preservation of corneal integrity, and ocular comfort. The physiology of tear production and distribution requires normal eyelid anatomy and mobility. Blinking spreads the tears vertically over the ocular surface. It also adds two important components to the tear film: lipid from the meibomian glands and mucin from the conjunctival goblet cells. The horizontal flow of tears to the medial canthus is along the tear meniscus at the eyelid margin. This requires normal contour and eyelid apposition to the globe and an adequately functioning orbicularis pump mechanism. Both of these functions can be compromised by horizontal and vertical eyelid laxity or by eyelid margin deformities.

7–1 THE SECRETORY SYSTEM

7–1-1 Lacrimal Gland Anatomy

The lacrimal gland begins in embryologic development as epithelial buds arising from the conjunctiva of the superior temporal fornix. Canalization of the epithelial buds to form ducts begins in utero, but full development of the gland does not occur until three to four years postnatal.

The lacrimal gland provides the principal aqueous secretory component of the tear film. It is located just behind the superolateral orbital rim within a depression in the lateral aspect of the orbital roof (the lacrimal gland fossa). The gland’s convex/concave shape reflects its location between the roof of the orbit and the globe. The gland is divided into a larger orbital lobe and a smaller palpebral lobe by the lateral horn of the levator aponeurosis. The orbital lobe lies behind the orbital septum and immediately above the lateral horn of levator. It measures approximately 20 mm long by 12 mm wide by 5 mm thick. Normally it lies completely behind the superior orbital
rim, but occasionally it prolapses forward and downward, where it presents as a mass in the lateral upper eyelid. The gland can be distinguished from the adjacent preaponeurotic orbital fat by its color, surface texture, and consistency. Unlike the yellow orbital fat, the lacrimal gland is a pale pinkish-tan color with a finely lobulated structure and a firm consistency. The major supportive structures of the lacrimal gland are the lateral horn of the levator and the lateral portion of Whitnall’s ligament. Although the lacrimal gland lacks a true capsule, there is a fine, translucent veil-like envelope of connective tissue around the orbital lobe, continuous with the orbital connective tissue system. This layer divides into septae that pass into the gland between the individual lobules. The fibrous interlobular septa also continue beyond the pseudocapsule of connective tissue around the gland as loose connective tissue strands that attach the gland to the periorbita of the frontal bone. These are known as Sommering’s ligaments and help support the lacrimal gland. One other, minor supportive structure of the posterior portion of the lacrimal gland comes from septa arising from the lateral orbital connective tissue suspensory system. These have become known as the inferior ligament of Schwalbe.

Nearly two-thirds smaller than the orbital lobe, the palpebral lobe lies beneath the levator aponeurosis and can be examined in the superior fornix by elevating or everting the lateral upper eyelid. The palpebral and orbital lobes are continuous posteriorly, where they are joined by an isthmus behind the free edge of the aponeurosis.

The lacrimal gland is composed of epithelial glandular elements, consisting of the numerous acini arranged into lobules that are drained by ductules. There also are myoepithelial cells and plasma cells. Immunohistochemistry studies have shown that lacrimal gland tissue belongs to the mucosa-associated lymphoid tissue. Ductules from the orbital lobe of the lacrimal gland pass through its substance and around the lateral horn of the aponeurosis. They are joined by additional ductules that run separately from the palpebral lobe. Six to twelve ductules empty into the superolateral temporal fornix approximately 4 to 5 mm above the tarsus.
Clinical Application

- A prolapsed lacrimal gland is not uncommonly identified at the time of ptosis or blepharoplasty surgery. It can be easily repositioned into the lacrimal gland fossa by gently removing the septum over its surface. A double arm 5-0 Mersilene or Dacron suture on a spatula needle can be passed right through the peripheral edge of the lacrimal gland lobules and then into the periorbita just inside the orbital rim. As the suture is tied, the lacrimal gland goes back into the orbit.

- The lacrimal gland is invested in a thin pseudocapsule of connective tissue that is continuous with the interlobular septa. This layer is surgically distinct and important in the management of lacrimal gland tumors. Resection of a pleomorphic adenoma (a benign mixed lacrimal gland tumor) should maintain this fascial layer as intact, as well as a layer of fat around it wherever possible, as small pseudopod extensions from the lacrimal gland tumor often protrude through this layer and can be responsible for recurrence.

- Dacryoadenitis is an inflammation of the lacrimal gland and can be either infectious or noninfectious. With an infectious process, patients present with upper eyelid swelling, pain, and discharge. They feel unwell and might be febrile. The upper eyelid is typically ptotic and has an S-shaped curve to it as a result of the inflamed lacrimal gland. The eyelid skin is red and swollen, and the superior temporal conjunctiva is very chemotic and has discharge present. The gland might be tender to the touch, and there might be an enlarged preauricular lymph node. In the noninfectious variety ("nonspecific inflammation of the lacrimal gland"), patients might present in a similar fashion, but there is usually more pain, and systemically they feel well and are afebrile. Sometimes it is hard to tell. Therapy is usually initiated with oral antibiotics as a first step. If no improvement is seen within 48 hours, biopsy and placement of steroids are recommended. It is always best to perform a biopsy, as some malignant processes (e.g., lymphoma) might present with acute inflammation and will also respond to steroids. However, a course of steroids would be an inappropriate treatment.

- Resection of the conjunctiva in the superior temporal fornix or excision of a prolapsed palpebral lobe might result in a loss of the secretory function of the lacrimal gland as a result of trauma or destruction to the lacrimal ductules.

The secretion of tears is modulated by the autonomic nervous system (parasympathetic and sympathetic innervation; see Chapter 5). The salient features are as follows: the parasympathetic fibers exit the brainstem at the cerebellopontine angle as the *nervus intermedius* in company with the motor division of the seventh and eighth cranial nerves. The nervus intermedius enters the auditory canal and runs toward the *geniculate ganglion*. There the parasympathetic fibers leave the facial nerve and enter the middle cranial fossa as the *greater superficial petrosal nerve*. It continues forward beneath the dura. In the area of the internal carotid artery, the greater superficial petrosal nerve unites with the *deep petrosal nerve* carrying postganglionic sympathetic fibers from the superior cervical ganglion. Together they form the *nerve of the pterygoid canal* or *vidian nerve*. The vidian nerve passes through the pterygoid canal to the pterygopalatine fossa. There the parasympathetic fibers *synapse in the pterygopalatine ganglion* (also called the sphenopalatine ganglion or Meckel’s ganglion). Postganglionic parasympathetic and sympathetic fibers join the *zygomatic nerve*.
(a branch of the maxillary division of the trigeminal nerve) and enter the orbit through the inferior orbital fissure. The parasympathetic and sympathetic fibers destined for the lacrimal gland either enter the lacrimal gland directly from the zygomatic nerve or branch off the zygomatic nerve and travel up the lateral wall to join the lacrimal nerve (see Fig. 5-9B) prior to entering the lacrimal gland. Along with the afferent sensory arc from the cornea (supplied by the trigeminal nerve), the parasympathetic efferent pathways are responsible for reflex tearing.

Blood is supplied to the lacrimal gland via the lacrimal artery, a terminal branch of the ophthalmic artery. The lacrimal artery also has an anastomotic connection to the middle meningeal artery and serves as one of the many connections between the internal and external carotid artery blood supplies.

7–1–2 The Accessory Lacrimal Glands

In addition to the main lacrimal gland, there are accessory lacrimal glands in the substantia propria of the palpebral conjunctiva. Although these have been widely believed to be responsible for basic tear secretion, there is evidence suggesting that they respond to reflex stimulation as well. The accessory lacrimal glands consist of 20 to 30 glands of Krause in the superior fornix and 6 to 8 in the lower fornix. These glands are more common in the lateral portions of the eyelid. Three to four accessory glands of Wolfring are also found in and around the upper tarsal border and, to a lesser extent, in the lower tarsal border. Their ducts pass through the outer border of the tarsus then onto the conjunctival surface. The accessory lacrimal glands are tubular glands rather than the acini lobular arrangement of the main lacrimal gland.

The caruncle, in addition to sweat glands and sebaceous glands, might also have some accessory lacrimal glands within it—the accessory glands of Popoff.

Clinical Application

- During upper eyelid levator recession surgery, the various accessory lacrimal glands are often visualized along the superior edge of the tarsus as Müller’s muscle is dissected away from the conjunctiva. Posterior tarsalconjunctival resection or posterior levator recession/advancement might traumatize or destroy these glands. Fortunately, there is enough reserve compensation in tear production that most people undergoing these operations do not develop dry eyes.

7–1–3 The Tear Film

The ocular surface is maintained by the complex tear film. This tear film provides lubrication and nutrients to the anterior globe and the anterior refractive surface of the eye, and it serves as a protective barrier against pathogens. The normal tear film is composed of an anterior lipid layer,
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a middle aqueous layer, and a posterior mucin layer. The superficial lipid layer is added to the tear film by the meibomian glands. The meibomian glands are sebaceous glands located within the tarsal plate. There are approximately 25 to 30 in each upper eyelid and 15 to 20 in each lower eyelid. The lacrimal and accessory lacrimal glands of Krause and Wolfring add the aqueous layer. The mucin layer of the tear film is provided by the goblet cells, which are also more concentrated in the conjunctival fornices. An abnormality in any one of the three layers can lead to tear film dysfunction and tearing due to excess lacrimation or tear film instability.

The only other glands that discharge along the eyelid margin are the glands of Zeis and glands of Moll associated with the lash follicle (see Chapter 1). Their secretions lubricate the lashes but do not contribute to the tear film that we know of.

Clinical Application

• Blepharitis refers to inflammation of the eyelid margin. It is common and can lead to an unstable tear film as a result of inflammation and altered lipid production from the meibomian glands. Bacteria reside on the surface of everyone's skin, but in certain individuals they thrive at the base of the eyelashes. The resulting irritation sometimes associated with overactivity of the nearby oil glands causes dandruff-like scales and particles of discharge to form along the lashes and the eyelid margin. For some people, the discharge associated with blepharitis produces only minor irritation and itching, but in others it can cause redness, stinging, burning, and tearing.

7–2 THE LACRIMAL DRAINAGE SYSTEM

The lacrimal drainage system consists of the puncta, canaliculi, lacrimal sac, and nasolacrimal duct (Fig. 7-1). Normal tear outflow depends on both the pump function of the eyelids and the patency of the nasolacrimal drainage system. Tight apposition of the eyelids to the globe and placement of the puncta against the globe, as well as an open and patent drainage system, are critical to normal tear flow and visual function. Pathology in any part of the outflow system leads to tearing due to insufficient drainage. Knowledge of the anatomy of the outflow system is critical when assessing any tearing problem.

Clinical Application

• When assessing any patient with tearing, both history and physical examination are important. As an example, intermittent bilateral tearing in a 60-year-old female that is exacerbated in windy conditions is often due to dry eyes with reflex tearing. A Schirmer study, decreased tear meniscus, and rapid tear break-up time with Rose Bengal or Lissamine Green staining
of the conjunctiva would substantiate this. In contrast, intermittent tearing in a 30-year-old female with episodes of tearing lasting one to two weeks with associated medial discomfort, swelling, and discharge and then clearing is often due to a dacryolith. A partial or complete block of the nasolacrimal outflow with Jones testing would help confirm this. Sometimes there are few, if any, clues in the history, and the physical exam provides the answers. Clinically it is important to assess the tear production (Schirmer study), tear stability (tear break-up time, signs of meibomian gland dysfunction), tear distribution system (signs of lid laxity: lid distraction test, lid snap back test, lash position, punctal position), and nasolacrimal patency (e.g., Jones I and Jones II testing, lacrimal scintigraphy, dacryocystogram).

- Tearing related to a tear film abnormality will often be associated with burning and itching, whereas tearing from an outflow abnormality will more often be constant or exacerbated by situations that overwhelm an already compromised drainage system, such as eye irritation from a chemical or physical insult that causes increased tear production.

### 7–2-1 Lacrimal Puncta

The lacrimal papillae are pale, elevated mounds located along the mucocutaneous junction of the medial eyelid. In the center of each papilla is a punctum that opens into the canalicular system. The punctal openings should not be seen unless the eyelids are slightly everted. If they are easily seen, a degree of punctal ectropion exists and might readily explain a patient’s tearing complaints. On average, the puncta are about 0.3 mm in diameter, whereas the canaliculi are about 1 to 2 mm in diameter. The lacrimal puncta of the lower lid rest slightly more lateral than the puncta of the upper eyelid.

**Clinical Application**

- Incomplete embryological development explains many of the congenital nasolacrimal outflow system anomalies commonly seen in clinical practice. During embryonic development, a cord of ectodermal cells is buried beneath the skin by the migration and fusion of the maxillary mesodermal processes with the frontal nasal mesodermal process. Buds extend from the ectodermal cord toward the medial canthus and the nose to form the nasolacrimal duct. A number of congenital anomalies can occur as a result of a failure of the budding. A persistence of the embryologic tract that the ectodermal cells followed beneath the mesodermal processes is referred to as a “persistent nasolacrimal anlage.” If this is patent, a small “peep hole” is seen just below the medial canthal tendon in the infant’s skin that episodically discharges tears. If the canalicular buds do not complete their migration, there will be no identifiable punctal opening on the lower, upper, or both eyelids. If the migration is almost complete, a persistent “cellophane-like membrane” might be seen over the opening of the puncta. If more than one canalicular bud grows toward the medial lid, there might be a duplicate puncta on one eyelid. If the nasolacrimal duct buds fail to migrate toward the inferior meatus, the child will present with tearing and mattering. Approximately 50% to
70% of newborns have an imperforate nasolacrimal duct opening at birth that often opens within the first few months of life.

- With aging, the puncta often lose elasticity and become somewhat oval or slit-shaped.

### 7-2-2 Lacrimal Canaliculi

The upper and lower canaliculi are each about 10 mm long (Fig. 7-1). They are lined with a nonkeratinizing, stratified squamous epithelium. Each canaliculus has an initial vertical portion that is approximately 2 mm long. At the base of this vertical section, the canaliculus dilates slightly and forms a small **ampulla** where tears collect. The canaliculus then turns horizontally and runs toward the medial canthus for about 8 mm. The horizontal portions of the canaliculi in most individuals unite prior to their entering the lacrimal sac, forming a **common canaliculus**. Occasionally, the canaliculi enter the sac without forming a common canaliculus. Once having formed, the common canaliculus enters the lateral wall of the lacrimal sac, beneath the medial canthal tendon, via a common internal punctum.

The opening of the common canaliculus into the sac might be preceded by a small dilation called the **sinus of Maier**. The canaliculus opens into the sac at an angle, producing the **valve of Rosenmüller**. This mucous membrane valve prevents reflux from the lacrimal sac into the canaliculus. Some individuals, during nose blowing, experience a puff of air onto the eye, indicating the presence of an incompetent valve of Rosenmüller.

The canaliculi travel to the lacrimal sac within the fascial tissues between the anterior and posterior arms of the canthal tendons. This connective tissue helps prevent their collapse. Along their course, the canaliculi are also covered anteriorly and posteriorly by pretarsal orbicularis muscle. The superficial head of the pretarsal orbicularis fibers lies anterior to the canaliculus and contributes to the formation of the anterior limb of the medial canthal tendon. The deep head of the pretarsal orbicularis lies posterior to the canaliculus; it is referred to as the **pars lacrimalis muscle, tensor tarsi muscle, or Horner’s muscle**; and contributes to the formation of the posterior limb of the medial canthal tendon (see Figs. 1-14 and 1-16C). It attaches to the posterior lacrimal crest and lacrimal fascia (lacrimal diaphragm). These deep fibers play an important role in the lacrimal pump mechanism by shortening the canaliculus and moving the punctum medially (see Chapter 1).

### Clinical Application

- In the presence of a lower nasolacrimal duct obstruction, the competency of the valve of Rosenmüller due to edema or inflammation will prevent the reflux of mucopurulent material out the punctal openings. This results in a palpable nasolacrimal sac that might be associated with a chronic dacryocystitis and/or a fistula tract onto the skin in the medial canthal area.
- Infections involving the canaliculus (canaliculitis), although uncommon, are often overlooked as a cause of recurrent unilateral conjunctivitis. Canaliculitis patients usually have a history of unilateral conjunctival inflammation and discharge despite numerous antibiotics
and several visits to more than one physician. Examination reveals some typical changes: the patient’s redness is usually just medial in location, involving the bulbar conjunctiva, the caruncle area, and possibly the medial eyelid. There is usually swelling in the area of the canaliculus, and the puncta is erythematous and raised (the so-called pouting punctum sign). Posteriorly directed pressure over the swollen canaliculus produces a milky yellow discharge, often with concretions from the punctal orifice. The organism most commonly responsible for this is Actinomyces, an anaerobic bacterium. The primary treatment is opening the canaliculus and removing the concretions. This is done with a longer-than-normal three-snip punctoplasty, gently milking out the concretions, irrigating with a balanced salt solution, and placing the patient on a broad-spectrum antibiotic-steroid drop. Curetting the walls of the canaliculus risks scarring the delicate canalicular lining and is simply unnecessary. Irrigation with iodine and the preparation of specially formulated drops (penicillin) are also not required.

- If the canaliculi are obstructed (e.g., following herpetic infections, trauma, or some medications), canalicular reconstruction can be attempted during dacryocystorhinostomy surgery with dilation and the placement of silicone tubing through the canalicular system and the osteotomy and into the nose. However, in most patients a conjunctivo-dacryocystorhinostomy with placement of a Jones tube will be required in order to provide relief from the tearing. The Jones tube is made of Pyrex and runs from the caruncle area to the middle meatus of the nose.

- Successful repair of a lacerated canalicular system is improved by carrying out the repair within the first few days of injury, stenting the severed ends of the canaliculus over a silicone tube, anastomosing the canalicular walls or pericanalicular tissue with one to three fine sutures (7-0 polglactin or chromic), and leaving the stent in place for at least 12 weeks (preferably 24 to 52 weeks).

### 7-2-3 Lacrimal Sac

The *lacrimal sac* lies within the *lacrimal fossa*, which is created by the frontal process of the maxillary bone and the lacrimal bone. The anterior lacrimal crest makes up the anterior border of the lacrimal fossa, and the posterior lacrimal crest of the lacrimal bone makes up the posterior border. The bony wall of the fossa is relatively thick anteriorly (maxillary bone) but paper-thin posteriorly (lacrimal bone). The lacrimal fossa continues inferiorly as the *nasolacrimal duct*. Medial to the position of the lacrimal fossa is the middle meatus of the nasal cavity. The lacrimal sac extends 3 to 5 mm above the superior margin of the medial canthal tendon, forming the fundus of the sac. The body of the lacrimal sac extends from the level of the medial canthal angle to the osseous nasolacrimal canal. In the lacrimal fossa, the fundus of the lacrimal sac is surrounded by connective tissue (the lacrimal fascia or lacrimal diaphragm). The lacrimal sac and the nasolacrimal duct are a continuous tube lined with modified respiratory epithelium (*pseudostratified* columnar epithelium). The epithelial cells of the sac and the duct are lined with microvilli that might play a role in tear reabsorption. Goblet cells produce mucins that facilitate tear drainage and protection against pathogens. This type of epithelial lining may also be referred to as *transitional epithelium*. 
Clinical Application

- Acute dacryocystitis (bacterial infection of the nasolacrimal sac) is a result of an obstruction within the nasolacrimal duct. When it occurs, the lacrimal sac swells at its weakest point, which is below the medial canthal tendon. This causes erythematous swelling of the medial lower eyelid. It can begin very quickly during the course of a day and might be associated with intense pain as discharge builds up and distends the nasolacrimal sac. Prompt diagnosis and initiation of antibiotics are important. The responsible organisms are usually upper respiratory tract organisms (B-hemolytic Streptococcus, Staphylococcus). Antibiotic treatment is often initiated with oral clxicillin or a cephalosporin in addition to warm compresses and treatments for pain relief.

- Chronic infection of the nasolacrimal sac tends to be indolent, producing symptoms of tearing and mild to moderate recurrent unilateral discharge. The patient may apply pressure over the sac, producing a reflux of a mucoid or mucopurulent discharge from the punctum recurrently. A dacryocystorhinostomy is required in order to treat this situation, as the outflow system is totally blocked. Topical and/or oral antibiotics are only a temporizing measure.

- A distended, noninfected lacrimal sac can present at birth (congenital dacryocystocele, amniotocele, or amniocele) and is the result of amniotic fluid’s entering the nasolacrimal sac but not getting out due to a blockage at the nasolacrimal-duct level and a ball-valve effect at the common-duct level preventing outflow through the puncta. Some physicians advocate conservative treatment with topical antibiotics and massage, whereas others prefer early surgical intervention. Infants are obligate nasal breathers, and airway obstruction from the dacryocystocele can occur in some patients. If there is any suggestion of infection within the amniotocele or of airway obstruction, we advocate prompt surgical intervention. In such a situation, we probe the nasolacrimal system with endoscopically guided marsupialization of the dacryocystocele on the nasal side and placement of silicone stents within the nasolacrimal system. The baby’s airway should be protected with an endotracheal tube prior to the probe and marsupialization.

- Simple congenital nasolacrimal duct obstruction as a result of incomplete nasolacrimal canilization at the level of the valve of Hasner is a more common condition than congenital amniotocele, and few of the affected infants develop acute infections. Infants with congenital obstructions have a history of tearing with mattering of the eyelids and minimal (if any) dilation of the lacrimal sac. It is important to distinguish this common and benign condition from acute dacryocystitis, which presents in a much more dramatic fashion. In the newborn and young infant, it can be difficult to tell whether one is dealing with dacryocystitis, orbital cellulitis, or both. Newborns and young infants can get into trouble quickly, and it might be preferable to hospitalize them for intravenous antibiotic therapy in order to decrease the chances that orbital abscess or sepsis will occur.

- An appreciation of the nasolacrimal anatomy is essential if one is to perform dacryocystorhinostomy for an obstructed nasolacrimal passageway. The approach used in external dacryocystorhinostomy surgery is commonly through a 10 to 15 mm incision made 10 to 12 mm medial to the medial canthal tendon insertion and directed inferolaterally, tangential to the inferonasal rim of the orbit, in a straight line alongside the nose.
It is essential for the novice surgeon to locate the anterior lacrimal crest and stay inferior to the level of the medial canthal tendon. As the surgeon dissects through skin, orbicularis muscle, and periorbita alongside the nose, anatomic landmarks are used to maintain orientation. The longitudinal suture of Weber, inominate suture, or sutura Notha is an incomplete suture line parallel to the anterior lacrimal crest and located 2 mm anterior to the lacrimal crest. Not uncommonly, a vessel is located along this line that is within 2 mm of the lacrimal crest (Fig. 7-2).

Once the anterior lacrimal crest is identified, the surgeon proceeds into the nasolacrimal fossa and gently moves the lacrimal sac laterally so that the lacrimal bone can be viewed. This bone is very thin and might have perforations within it. It is in this thin lacrimal bone in the lacrimal fossa that the dacryocystorhinostomy is initiated. The remainder of the surgery involves the creation of nasolacrimal sac and nasal mucosal flaps, which are subsequently anastomosed, followed by tissue closure. Silicone stents may be put in place prior to flap closure but are not always necessary. The dacryocystorhinostomy procedure characteristically drains into the middle meatus of the nose.

- Dacryocystorhinostomy surgery can also be performed via the endoscopic route. The limiting factor is the size of the nasal passageway (it must be large enough to allow placement of the endoscope). The surgery can be performed with 2 mm rongeurs or with a laser. The endoscopic route is quicker and involves less downtime for the patient, but the success rate is slightly lower. In addition, the set-up time for the laser equipment may be slightly longer.

7-2-4 Nasolacrimal Duct

The nasolacrimal duct is a continuation of the sac and is lined with modified respiratory epithelium (pseudostratified columnar epithelium). The duct begins at the point where the sac enters the osseous nasolacrimal canal of the maxillary bone. It measures 4 to 5 mm in diameter and is

FIGURE 7-2 The right nasolacrimal crest is viewed from the side as if doing an external dacryocystorhinostomy procedure: the eyelashes (white arrow) and nose (star) are visible. The longitudinal suture of Weber is visualized with a vessel running along it (blue arrow). The anterior lacrimal crest is approximately 2 mm from this line (black arrow).
approximately 18 mm in length. It continues through the maxillary bone along the medial wall of the maxillary antrum into the nose. The nasolacrimal duct exits into the nose, beneath the inferior turbinate, into the space referred to as the inferior meatus (Fig. 7-3). The inferior opening of the nasolacrimal duct is the ostium lacrimale. At this level is a fold of nasal mucosa termed the valve of Hasner. It is this mucosal area that is imperforate in children with congenital nasolacrimal duct obstruction.

Clinical Application

- Approximately 50% to 70% of newborns have an imperforate valve of Hasner, which leads to tearing and mattering of the young infant. This valve might open spontaneously or with the help of massage. If it does not open by one year of age, probing might be required in order to reestablish normal tear flow.

- Aging individuals (>65 years of age) not uncommonly demonstrate increasing narrowing of the nasolacrimal duct as they age. This primary acquired nasolacrimal duct obstruction, or PANDO, is most commonly the result of inflammatory fibrosis of the nasolacrimal duct walls. As nasolacrimal duct narrowing develops, the patient develops tearing. Clinically there is intermittent or continuous tearing and occasionally a dacryocystitis. In most cases, a dacryocystorhinostomy procedure (via an external or endoscopic approach) will be curative.

- In the young-adult age group, the most common cause of a nasolacrimal duct obstruction is trauma or the presence of a nasolacrimal stone (dacryolith). Individuals with a dacryolith

![FIGURE 7-3](image_url) Lateral wall of the nose.
have a characteristic history: females are more commonly affected than males, and patients are usually in their early 30s. Patients complain of a sensation of pressure in the medial canthal region, followed by tearing discharge and the development of a lump in the nasolacrimal sac area. This is the result of the dacryolith that has blocked the tear outflow, causing the retention of tears with resultant distension of the nasolacrimal sac and eventually a full-blown dacryocystitis. The symptoms might resolve before the patient develops dacryocystitis, and he or she will be fine until the same sequence develops again. There is generally a history of similar episodes in the patient’s past, which will have lasted four to seven days and resolved either spontaneously with antibiotic eye drops or, occasionally, with oral antibiotics.

- The nasolacrimal duct in women is smaller in diameter than that in men, which might be a factor in the higher incidence of PANDO in women.

### 7-3 BASIC NASAL ANATOMY

An appreciation of the nasal anatomy is essential for surgeons contemplating dacryocystorhinostomy surgery. The nasal passageway should be examined in any patient presenting with a tearing problem. The nasal examination is performed as part of the basic tearing workup, for example, during a Jones I test or a dye disappearance test. It is important to assess the mucosal health and to detect any disease process that might be responsible for intranasal obstruction of the nasolacrimal duct. At the same time, it can be determined that enough space is available in the nasal passageway for any possible nasolacrimal procedure.

The lateral wall of the nose has three *turbinates, or conchae* (Fig. 7-3). The turbinates have a thin, bony framework and are covered with highly vascular mucosal tissue that is composed of a dense arterial network and venous plexus (lakes), similar to erectile tissue. This covering is most evident on the inferior turbinate. The turbinates (particularly the inferior) periodically swell by means of vascular engorgement and can lead to variation in the size of the nasal airway.

Beneath each turbinate lies a meatus. The inferior meatus receives drainage from the nasolacrimal duct only, at a point about one-third of the way back from its anterior margin. The middle meatus receives drainage from the nasofrontal duct (frontal sinus drainage) and anterior ethmoid cells anteriorly, from the middle ethmoid cells and maxillary sinus ostium medially, and from the posterior ethmoid cells posteriorly. Mucopurulent material might be seen draining from these regions during acute sinus infections. The superior turbinate is very small and is located high and posterior, and it usually cannot be seen on ordinary clinical examination without shrinking the nasal mucosa. The superior meatus receives drainage from the sphenoid sinus and from some of the posterior ethmoid cells.

The nasal septum is formed by cartilage anteriorly and by bone posteriorly. The septum might grow irregularly or be traumatized so that it obstructs breathing on one or both sides of the nose. If the deviation is severe enough, it inhibits proper drainage or obstructs the sinus ostia by putting pressure on the turbinate. A very deviated septum needs to be identified and corrected before the surgeon can consider dacryocystorhinostomy surgery.
The nasal and sinus mucosa is pseudostratified columnar epithelium. Like the skin, the mucosa has free nerve endings that respond to chemicals and to changes in temperature, humidity, and pressure. These receptors serve to alert and protect the lower airway following exposure to pollutants or extremes of temperature. They stimulate vasodilation, mucous production, and bronchial constriction.

Clinical Application

- Explanation and proper patient positioning are the keys to a successful examination of the nasal passage. The patient should be sitting erect and slightly forward, with the back away from the chair. The examiner sits close to one side of the patient, with the patient’s nose at the examiner’s eye level. The basic equipment for an intranasal examination consists of a strong, focused light source (indirect ophthalmoscope or fiberoptic headlight) and a nasal speculum. If an indirect ophthalmoscope is used to illuminate the nose, the examiner does not look through the eyepieces but rather tilts the headpiece up and just uses the light to examine the nasal passage. The speculum is gently inserted into the nasal vestibule and opened in a vertical, not horizontal, fashion so as not to exert pressure on the highly sensitive nasal septum. The examination proceeds with the examiner looking first at the nasal floor, inferior turbinate, and lower septum and finally upward at the middle meatus, middle turbinate, and superior septum.

The mucosa is generally moist and deep pink. Inflammation results in erythema, edema, and ulceration if severe. Areas of crusting might also be noted. The nasal septum is rarely perfectly straight and can be so deviated as to block the proposed area of a dacryocystorhinostomy. Adhesions might be apparent between the septum and the turbinate, indicating previous trauma.

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