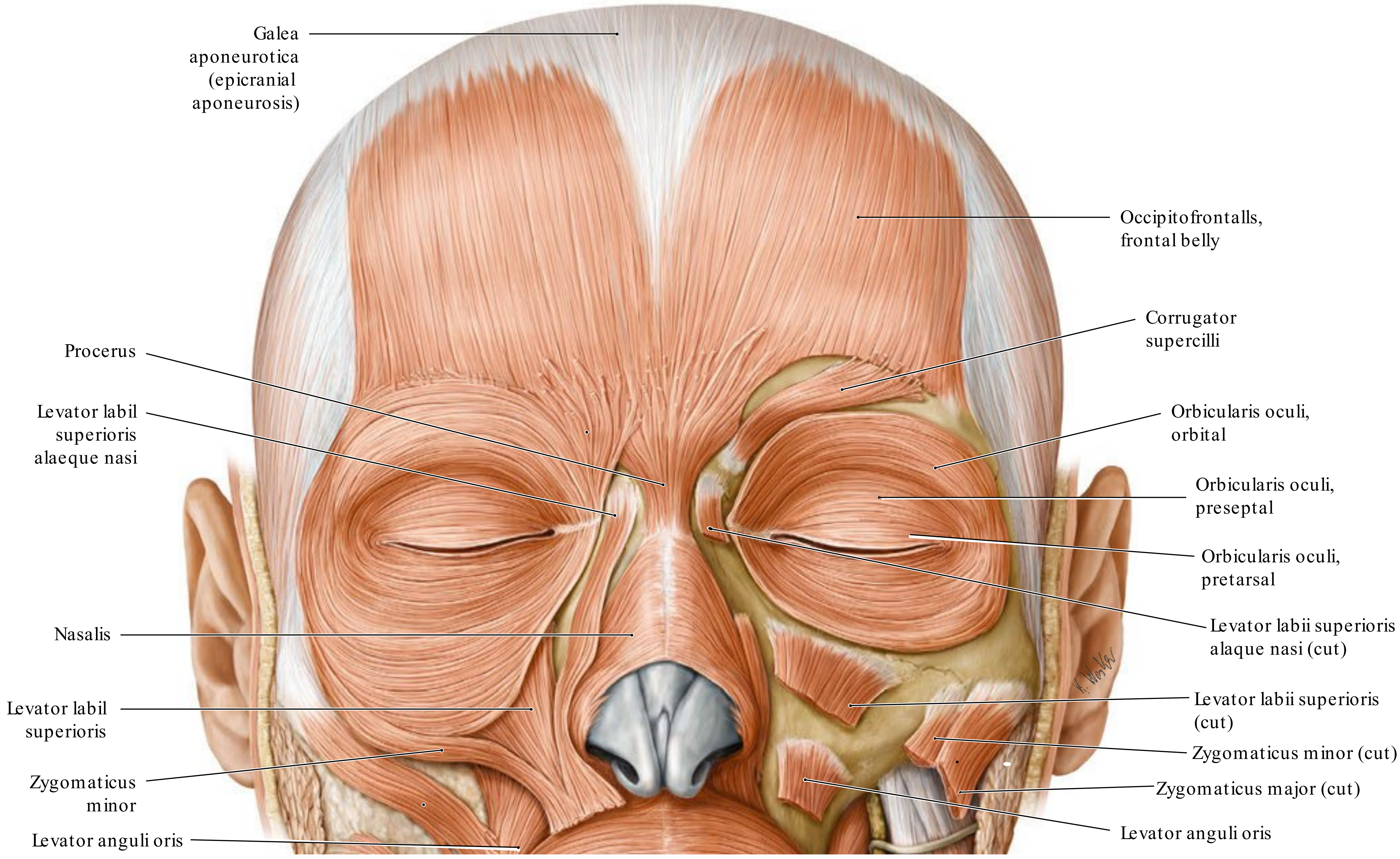


Fig. 15.3 Periorbital facial mimetic muscles. Orbicularis oculi muscle contraction results in eyelid closure. Its fibers are concentric around the eyelids. It is divided into the pretarsal, preseptal, and orbital regions. The pretarsal and preseptal orbicularis are involved in involuntary blink; the orbital portion is involved in voluntary lid closure. (Modified from THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustrations by Karl Wesker.)

head inserts onto the medial canthal tendon and the deep head inserts onto the lacrimal sac fascia. Laterally, the upper and lower fibers join to form the lateral palpebral raphe and connect to the underling lateral canthal tendon.

The orbital orbicularis arises from the medial orbital rim, broadens outward in concentric bands superiorly and inferiorly, and joins at the lateral orbital rim to form a continuous ellipse. It extends beyond the orbital rim.

Lateral and Medial Canthal Tendons

The medial canthal tendon (MCT) splits into anterior and posterior limbs, which attach to the corresponding lacrimal crest encircling the lacrimal sac (**Fig. 15.4**).The anterior limb of the MCT gives the lid structural support whereas the posterior limb keeps the eyelid apposed to the globe. The lateral canthal tendon is formed by superior and inferior limb that fuses to form a common tendon inserting onto Whitnall's tubercle.

Surgical Annotation. Lateral and Medial Canthal Reanchoring

In lateral canthal anchoring (canthoplasty or canthopexy), the lid is sutured to inner aspect of the lateral orbital rim (about 10 mm posterior to the anterior rim) and slightly above the medial canthal angle. Usually the suture is secured to periosteum, but a drill hole may be helpful if the periosteal tissue is inadequate (i.e., scar). In patients with a prominent globe, the lid should be reanchored slightly more anteriorly on the inner aspect of the rim in order to avoid slipping of the lower lid under the globe.

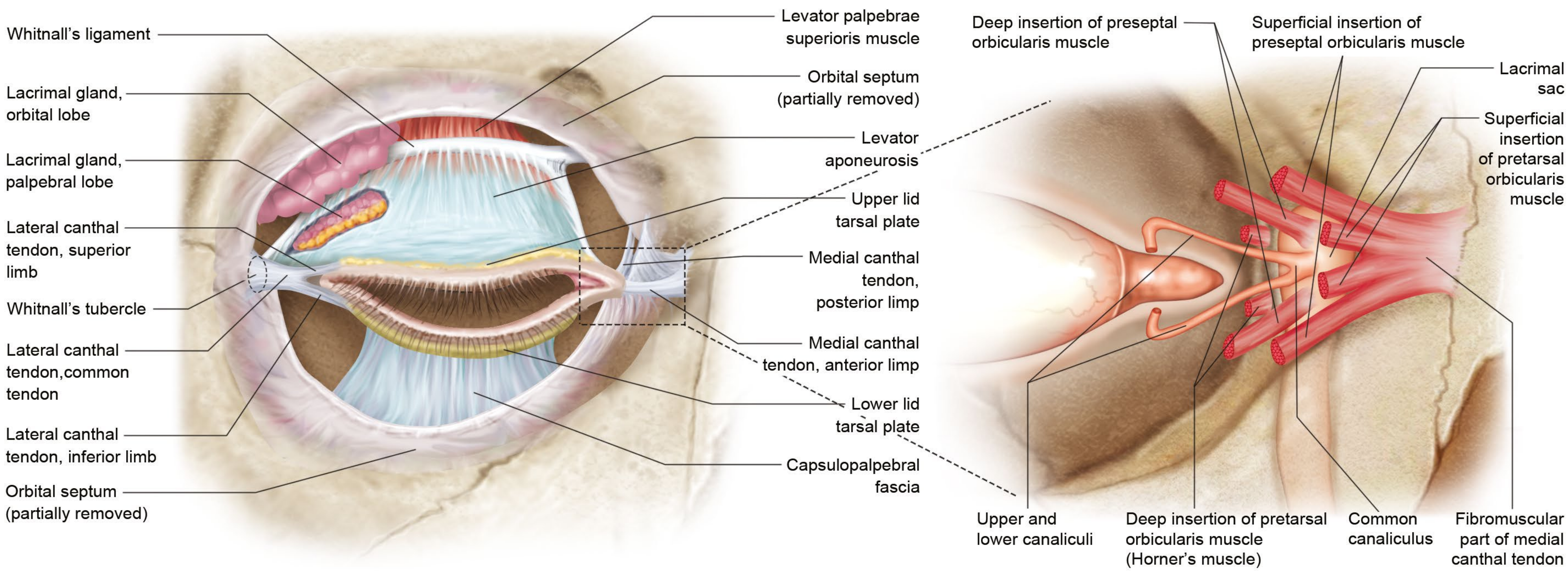
Medial canthal tendon reanchoring or tightening of the anterior limb is to the anterior lacrimal crest. Tightening of the posterior limb presents a greater challenge given the lacrimal sac obscures access to the posterior lacrimal crest.

Orbital Septum

The orbital septum is a connective tissue structure that forms from the periosteum of the orbital rim at the arcus marginalis (**Fig. 15.2a**). It divides the lid into anterior (skin and orbicularis) and posterior (tarsus, conjunctiva, and lid retractors) lamella.

Orbital Fat Pads

Orbital fat, also known as preaponeurotic fat, is sandwiched between the septum and the lid retractors. As discussed in Chapter 14, there is a medial and central fat pad in the upper lid and a medial, central, and lateral fat pad in the lower lid. These fat pads can atrophy with age, creating a hollowed superior or


Whitnall's ligament
Lacrimal gland, orbital lobe
Lacrimal gland, palpebral lobe
Lateral canthal tendon, superior limb
Whitnall's tubercle
Lateral canthal tendon,common tendon
Lateral canthal tendon, inferior limb
Orbital septum (partially removed)
Levator palpebrae superioris muscle
Orbital septum (partially removed)
Levator aponeurosis
Upper lid tarsal plate
Medial canthal tendon, posterior limp
Medial canthal tendon, anterior limp
Lower lid tarsal plate
Capsulopalpebral fascia
Deep insertion of preseptal orbicularis muscle
Superficial insertion of preseptal orbicularis muscle
Lacrimal sac
Superficial insertion of pretarsal orbicularis muscle
Upper and lower canaliculi
Deep insertion of pretarsal orbicularis muscle (Horner's muscle)
Common canaliculus
Fibromuscular part of medial canthal tendon

inferior sulcus or a bulge behind a weakened septum, causing orbital fat prolapse and bulging.

Retractors

Levator Palpebrae Superioris Muscle

The levator palpebrae muscle arises from the lesser wing of the sphenoid bone above the superior rectus attachment. It projects anteriorly toward the globe (**Fig. 15.2a, Fig. 15.4**). Whitnall's ligament is a band of fibrous tissue derived from the muscle itself that attaches medially to the trochlea and laterally to the capsule of the lacrimal gland and lateral orbital wall (**Fig. 15.4**). Near Whitnall's ligament, the levator muscle changes course from anterior-posterior to superior-inferior and also transitions to an aponeurosis. The aponeurosis sends fascial slips posteriorly to attach to the anterior surface of tarsus and anteriorly to the orbicularis muscle and skin to form the lid crease. The lateral and medial levator horns anchor to periosteum. The lateral horn divides the lacrimal gland orbital and palpebral lobes as described in Chapter14. The levator muscle contributes about 10 to 12 mm of upper lid elevation. It is innervated by cranial nerve (CN) III.

Müller's Muscle

Müller's muscle is found posterior to the levator muscle (**Fig. 15.2a**). It is a smooth muscle that is innervated by sympathetic nerves. It contributes about 2 mm of lid elevation. It arises from behind the levator close to the junction where the muscle fibers transition to an aponeurosis. It inserts onto the superior border of the tarsus. Müller's muscle may serve as a coupling mechanism for transmitting levator aponeurosis forces to the tarsus.

Surgical Annotation

External Levator Advancement Ptosis Surgery

With aponeurotic upper lid ptosis, the levator aponeurosis may elongate or disinsert, resulting in ptosis associated with a high lid crease. During external aponeurotic ptosis repair, the levator muscle is reanchored to the tarsus. The orbital septum should be carefully dissected free from the levator. Suturing the septum may tether the eyelid, impair eyelid excursion, and cause lagophthalmos.

Capsulopalpebral Fascia and Inferior Tarsal Muscle

The lower lid retractors contract to depress the lid in down gaze and also help to maintain tarsal position. The capsulopalpebral fascia arises from the inferior rectus muscle sheath, splits to enwrap the inferior oblique muscle, and fuses to form the Lockwood's suspensory ligament (**Fig. 15.2a**). It continues superiorly to fuse with the orbital septum and insert on the inferior tarsal border. The inferior tarsal muscle is poorly developed but lies along the posterior surface of the capsulopalpebral fascia (**Fig. 15.2a, Fig. 15.4**).

During a transconjunctival surgical approach, conjunctiva and lower lid retractors are incised and reapproximated often without compromising lid stability. With lower lid dissection, the lower lid retractors course posteriorly into the orbit, which helps to distinguish them from the orbital septum that arises from the arcus marginalis along the inferior orbital rim.

Tarsus and Conjunctiva

The tarsus is a dense, connective tissue plate that gives structural support to the eyelid (**Fig. 15.2a, Fig. 15.4**). It is about 1 mm thick, and its vertical height measures about 8 to 10 mm in the upper lid and 4 mm in the lower lid but tapers medially and laterally. The tarsus contains meibomian glands, which secrete the sebaceous layer of the tear film. There are about 25 glands in the upper lid and 20 glands in the lower lid. The lateral and medial canthal tendons anchor tarsus to periosteum. Palpebral conjunctiva lines the posterior surface of tarsus and continues superiorly or inferiorly to the fornix then reflects on the globe as bulbar conjunctiva (**Fig. 15.2b**). The conjunctiva contains goblet cells, which provide the mucus layer of the tear film.

Eyelid Margin

The eyelid margin is a confluence of several eyelid structures (**Fig. 15.5**). Starting posteriorly and in contact with the globe is the mucosal surface of the conjunctiva, creating the mucocutaneous junction. Continuing anteriorly, the meibomian gland openings of tarsus are visible. The muscle of Riolan, representing the pretarsal orbicularis muscle, makes up the gray line. Finally, the skin is the most anterior structure with hair follicles emanating. About 100 eyelashes are found in the upper lid and about 50 in the lower lid organized into two or three irregular rows. Glands of Zeis are oil glands associated with hair follicles. Glands of Moll are eccrine, or sweat, glands that are located at the eyelid margin.

The gray line is an important landmark during surgical realignment of the lid margin such as during a marginal laceration repair or wedge lesion excision repair. Without precise align-

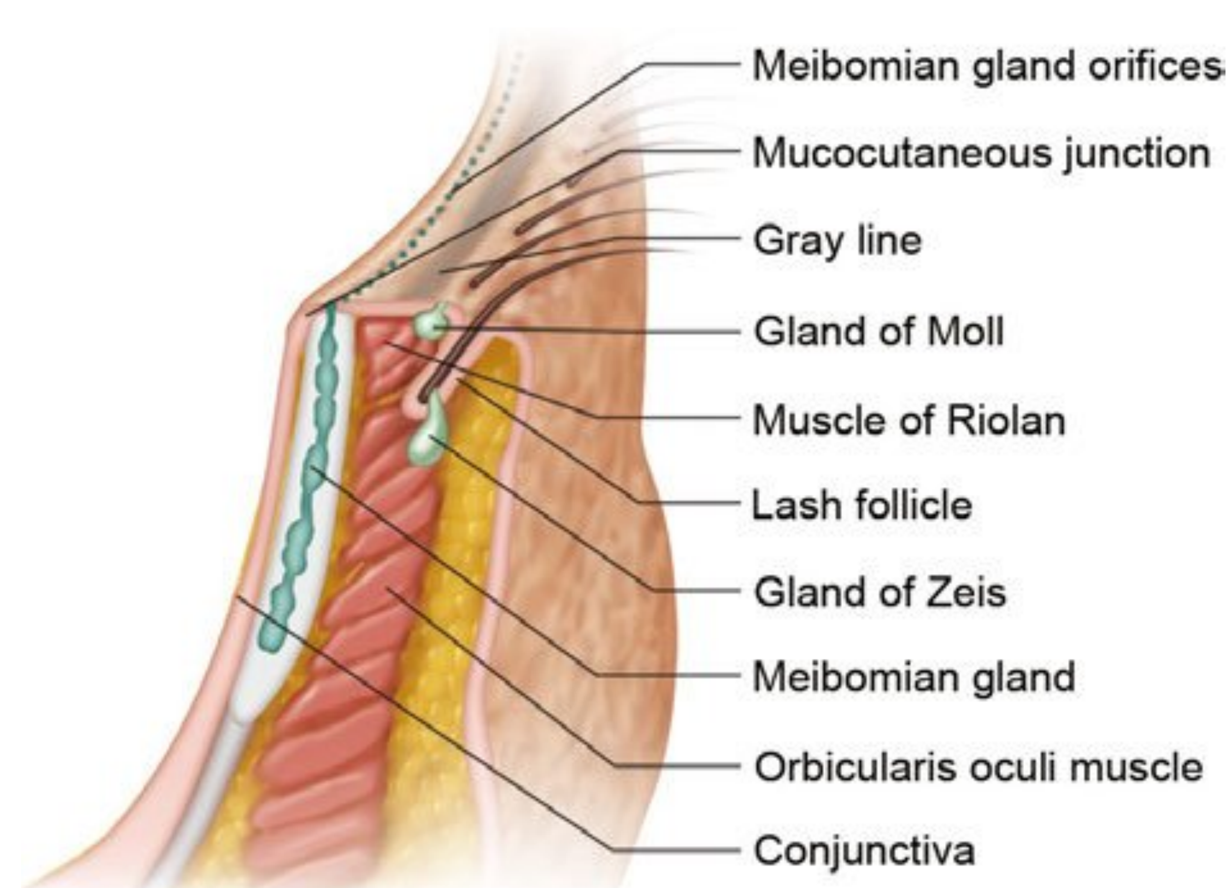


Fig. 15.5 Lower eyelid margin anatomy.

ment, a notch or step-off can result, resulting in ocular surface exposure, poor cosmesis, or both.

Forehead, Temporal, and Midface Anatomy

The facial planes guide surgical dissection. They vary slightly based on the facial region but they include the following: skin, subcutaneous tissue, superficial musculoaponeurotic system (SMAS) and facial mimetic muscles, loose areolar tissue, and deep facial fascia.

Forehead

The forehead represents the upper third of the face. The layers of the forehead include skin, subcutaneous tissue, frontalis muscle (encompassed in the galea aponeurotica and continuous with SMAS), loose areolar tissue, periosteum, and frontal bone (**Fig. 15.6**). Sensory branches from CN V_1 and vessels can be found coursing on the anterior surface of the frontalis muscle.

Temporal Forehead

The temporal region consists of skin, subcutaneous tissue, superficial temporalis or temporoparietal fascia (continuous with SMAS), loose areolar tissue, deep temporal fascia surrounding the superficial temporal fat pad, and temporalis muscle (**Fig. 15.6**). The superficial temporal artery, which is obtained during a temporal artery biopsy, is found in loose areolar tissue between the superficial and deep temporalis fasciae; however, care must be taken to avoid damaging the facial nerve that courses in the superficial temporal fascia.

Eyebrow

The skin of the brow is thicker than that of the eyelid and thinner than that of the forehead. Elevators and depressors influence brow position, which in turn influences upper lid position. Frontalis muscle contraction elevates the upper lid about 2 mm. The orbicularis, corrugator, and procerus muscles depress the brow (**Fig. 15.3**).

The frontalis muscle interdigitates with the orbicularis oculi muscle above the superior orbital rim. Posterior to the muscle is the brow fat pad, also known as the retro-orbicularis oculi fat pad (ROOF). It is separated from the orbital fat pads by the orbital septum (**Fig. 15.2a**). With aging, the brow pad can contribute to sub-brow fullness and subsequent upper lid droop and fullness. ROOF is continuous with the suborbicularis oculi fat (SOOF) of the lower lid.

Midface

The planes of the midface are especially important to understand for effective treatment of lower lid retraction or midfacial rejuvenation. Sub-orbicularis oculi fat (SOOF) is positioned between the orbicularis oculi muscle and periosteum (**Fig. 15.2a**).The SMAS surrounds the facial mimetic muscles. Ligamentous attachments between SMAS and skin dermis as well as SMAS and the underlying bone contribute to facial expression and support respectively. The orbitomalar ligament attaches the orbicularis oculi muscle that is encompassed in the SMAS to the inferior orbital rim.[1] The zygomatic ligament extends from the periosteum of the zygoma and zygomatic arch and through the malar fat pat to the malar skin.

Surgical Annotation

Lower Lid Malposition

In addition to downward vectors of the lower lid, midfacial ptosis and descent can also greatly influence lower lid positioning.[1] When performing surgery of the lower lid or midface, minimal (if any) skin, muscle, or soft tissue should be excised in the zone extending from the lower lid margin to the mouth. The lower lid is susceptible to any inferior vectors such as anterior lamellar shortening (e.g., cicatrix), ligamentous attenuation, or soft tissue debulking. In addition to directing wound closure and tension horizontally or at least obliquely, tissue recruitment and resuspension in the superolateral aspect of the lower lid and lateral canthus increase the likelihood of surgical success and longevity.

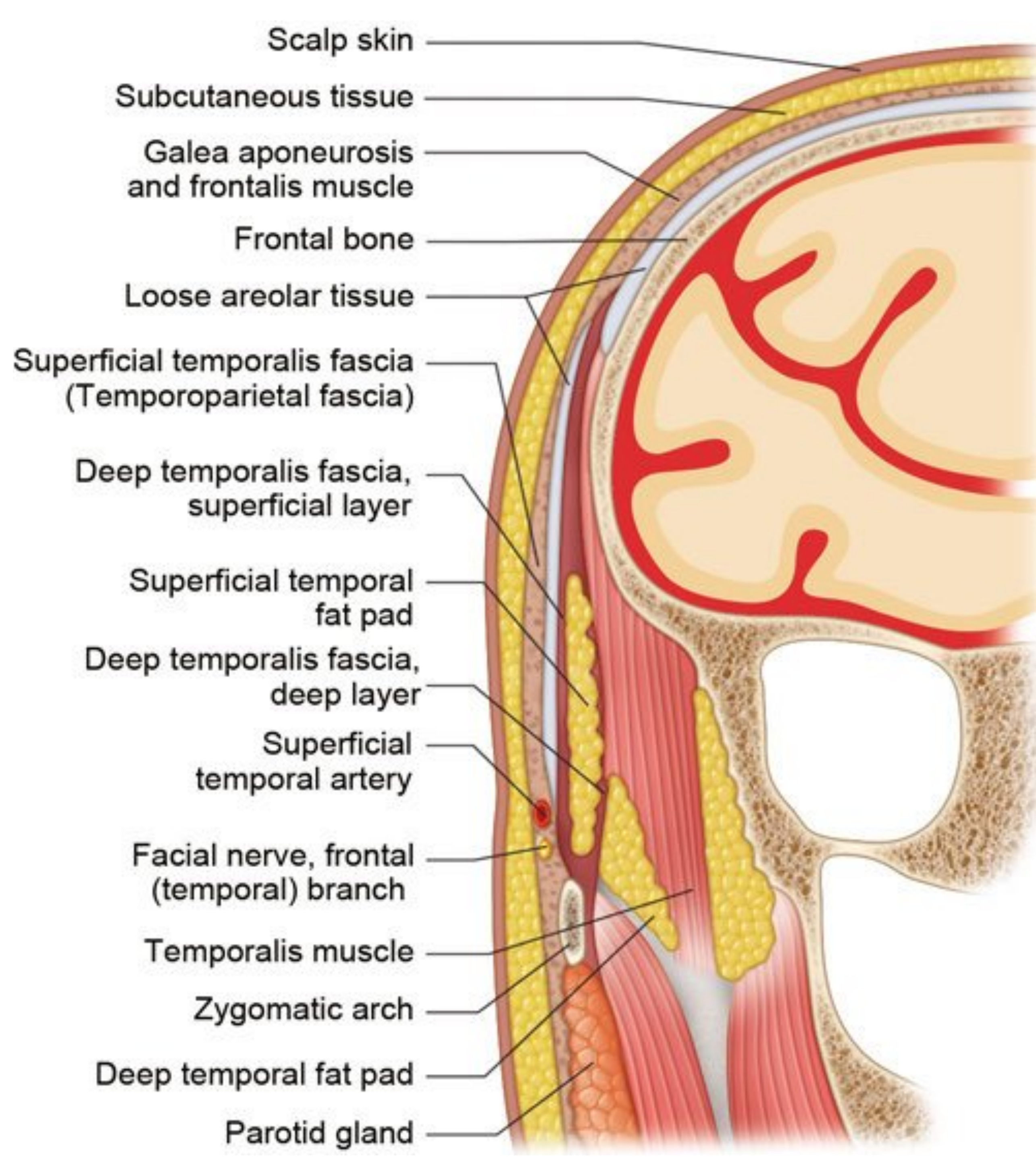


Fig. 15.6 Layers of forehead and temporal forehead regions. The temporal region consists of skin, subcutaneous tissue, superficial temporalis or temporoparietal fascia (continuous with the superficial musculoaponeurotic system [SMAS]), loose areolar tissue, and deep temporal fascia surrounding the superficial temporal fat pad and temporalis muscle.

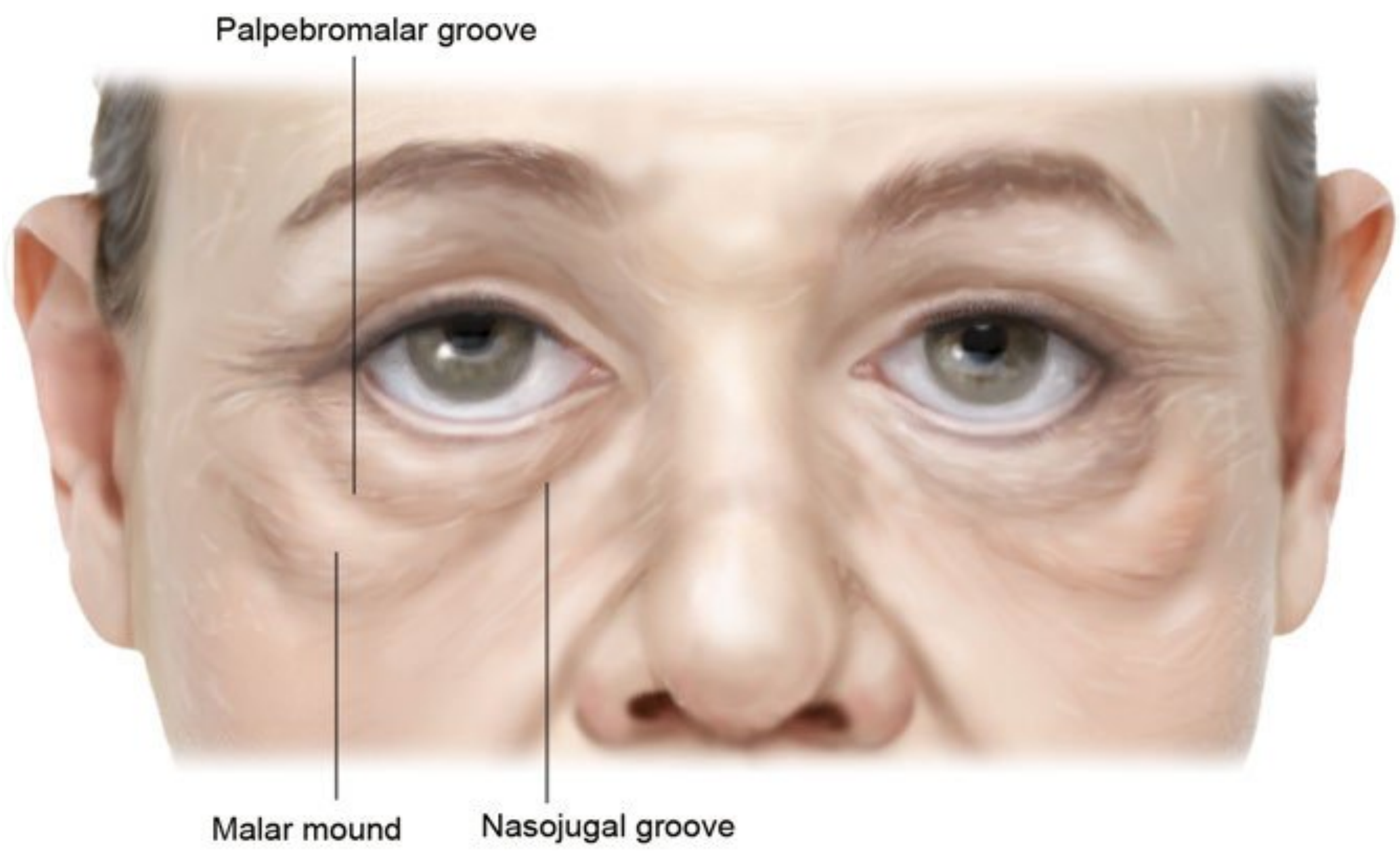


Fig. 15.7 Aging changes of the face. Nasojugal groove (tear trough), palpebromalar groove, and malar mound identified on an aging face.

Addressing the Nasojugal Groove, Palpebromalar Groove, and Malar Region

With age, the midfacial soft tissues descend, ligaments attenuate, and orbital fat herniates. Weakening of the orbital septum and elongation of the orbitomalar ligament results in anterior protrusion of orbital fat with accentuation of the nasojugal groove, or tear trough, and palpebromalar groove (**Fig. 15.7**).[2] Effective surgical management of the tear-trough deformity and palpebromalar grooves requires release of the orbitomalar ligament at the arcus marginalis along with orbital fat pad redistribution and orbicularis muscle tightening.[3]

In the malar region, SOOF descends with age. Zygomatic ligament suspension and SMAS and SOOF dissection, mobilization, and elevation either subperiosteally or preperiosteally improve midface descent.[4,5] Attention to these components addresses the double convexity that occurs with aging. The chief structure that must be preserved with these dissections is the infraorbital nerve that exits the anterior maxilla approximately 1 cm below the rim, centrally. Laterally, the zygomaticofacial and zygomaticotemporal nerves may be encountered. Injury to these smaller sensory nerves may be less consequential than the large infraorbital nerve.

Nerves, Vessels, and Lymphatics

Nerves

In addition to the innervation previously described, the ophthalmic (CN V_1) and maxillary (CN V_2) divisions of the trigeminal nerve carry sensory fibers from the periorbital region. Facial mimetic muscles receive motor innervation from branches of the facial nerve (CN VII). Further details of innervation to periorbital structures are discussed in Chapter 13.

Vessels

The internal and external carotid arteries supply the periorbital region, resulting in rich anastomoses. These anastomoses form two arterial arcades of the upper lid: the marginal and peripheral arcades. The marginal arcade is located about 2 mm away from the lid margin anterior to tarsus. The peripheral arcade is located between the Müller's and levator muscles. During external ptosis repair, the peripheral arcade can be visualized as tortuous vessels on the anterior surface of Müller's muscle and helps distinguish the muscle from levator. Both arcades may significantly bleed during lid surgery. The inferior marginal arcade lies at the inferior tarsal border of the lower lid.

Venous drainage of pretarsal tissues is into the angular and superficial temporal veins. Post-tarsal tissue drains into the deeper veins of the orbit, including the orbital veins, pterygoid plexus, and deep branches of the anterior facial vein. Chapter 13 further describes the vascular supply of the periorbital region.

Lymphatics

The medial and central lower lids have been suggested to drain into the submandibular lymph nodes, the upper lid, medial canthus, and lateral lower lid into the preauricular lymph nodes[6]; however, recent studies show that substantial variability exists. Recent evidence suggests that the preauricular lymph node basin may be responsible for most eyelid lymphatic drainage.[7,8]

References

1. Lucarelli MJ, Khwarg SI, Lemke BN, Kozel JS, Dortzbach RK. The anatomy of midfacial ptosis. Ophthal Plast Reconstr Surg 2000; 16(1):7–22 PubMed
2. Kikkawa DO, Lemke BN, Dortzbach RK. Relations of the superficial musculoaponeurotic system to the orbit and characterization of the orbitomalar ligament. Ophthal Plast Reconstr Surg 1996; 12(2):77–88 PubMed
3. Korn BS, Kikkawa DO, Cohen SR. Transcutaneous lower eyelid blepharoplasty with orbitomalar suspension: retrospective review of 212 consecutive cases. Plast Reconstr Surg 2010;125(1):315–323 PubMed
4. Hoenig JA, Shorr N, Shorr J. The suborbicularis oculi fat in aesthetic and reconstructive surgery. Int Ophthalmol Clin 1997; 37(3):179–191 PubMed
5. Aiache AE, Ramirez OH. The suborbicularis oculi fat pads: an anatomic and clinical study. Plast Reconstr Surg 1995;95(1):37–42 PubMed
6. Cook BE Jr, Lucarelli MJ, Lemke BN, et al. Eyelid lymphatics II: a search for drainage patterns in the monkey and correlations with human lymphatics. Ophthal Plast Reconstr Surg 2002;18(2):99–106 PubMed
7. Nijhawan N, Marriott C, Harvey JT. Lymphatic drainage patterns of the human eyelid: assessed by lymphoscintigraphy. Ophthal Plast Reconstr Surg 2010;26(4):281–285 PubMed
8. Echegoyen JC, Hirabayashi KE, Lin KY, Tao JP. Imaging of eyelid lymphatic drainage. Saudi J Ophthalmol 2012;26(4):441–443 PubMed

16 Nasal Cavity and Paranasal Sinuses

Joe Iwanaga, Tsuyoshi Saga, and Koichi Watanabe

Introduction

The nasal cavity is located in the central region of the face and is divided by the nasal septum into a pair of cavities. These two cavities constitute the uppermost portion of the respiratory tract and continue anteriorly to the outer environment via the nares and posteriorly to the nasopharynx via the choanae. The nasal cavity is divided into two regions: the nasal vestibule and the nasal cavity. The nasal vestibule is the initial part of the nasal cavity as entered through the nares; it is lined by epithelium and contains hair (vibrissae) and sebaceous glands. The nasal cavity is the large space following the nasal vestibule and is lined by mucosa. It is divided into four meatuses (the superior, middle, inferior, and common meatus) by three nasal conchae that arise medially from the lateral nasal wall and curve inferiorly. Each meatus with the exception of the common meatus is located inferior to the conchae. The superior meatus is inferior to the superior concha, the middle meatus is inferior to the middle concha, and the inferior meatus is inferior to the inferior concha. The common meatus is the medial portion of the nasal cavity; it is located on both sides of the nasal septum and extends vertically. The nasal cavity is also divided into two regions according to function: the olfactory region and the respiratory region. The olfactory region is located in the upper part of the nasal cavity and is lined by olfactory epithelium, which contains olfactory receptors. The residual part of the nasal cavity has a respiratory function.[1–3]

Roof of the Nasal Cavity

The roof of the nasal cavity comprises the nasal bone, frontal bone, ethmoid bone, and sphenoid bone (**Fig. 16.1**). In the coronal section, it is triangular; the roof is extremely narrow, and the floor is wide. In a sagittal section, its height is greatest in the central region, which contains the cribriform plate of the ethmoid bone; the roof then decreases in height as it progresses in the anterior and posterior directions. The roof is adjacent to three paranasal sinuses: the frontal sinus, sphenoid sinus, and ethmoid sinus.[1–3]

Floor of the Nasal Cavity

The floor of the nasal cavity mainly consists of the superior surface of the maxilla and palatine bone, which together constitute the hard palate (**Fig. 16.2**). The maxilla occupies the anterior two-thirds of the floor, and the palatine bone occupies the posterior one-third. The incisive canal is located in the anterior part of the floor, immediately lateral to the nasal septum. The nasopalatine nerve and terminal end of the greater palatine artery pass through the incisive canal.[1–3]

Medial Wall (Nasal Septum)

The nasal septum forms the medial wall of the nasal cavity and divides the entire nasal cavity into two (**Fig. 16.3**). Histologically, the nasal septum is made up of a cartilaginous part and a bony part. The septal nasal cartilage forms the cartilaginous part and occupies the anterior part of the nasal septum. The posterior part is the bony part and is made up primarily of the vomer in the inferior posterior region and the perpendicular plate of the ethmoid bone in superior region. The most anteroinferior part of the nasal septum, which is positioned more anteroinferior to the edge of the nasal septal cartilage, is called the columella. The nasal septum often curves and shifts to either the right or left and sometimes obstructs the common nasal meatus on one side. The reported frequency of nontraumatic septal deviation is 20%to 58%[4–6] Guyuron et al[7] classified septonasal deviation into six types: septal tilt, C-shaped deformity (either anteroposterior or cephalocaudal), S-shaped deformity (either anteroposterior or cephalocaudal), and localized deformity. The most common type of deviation is the septal tilt type, in which the septum has no curve but is tilted toward one side in the coronal section. This type is observed in approximately 40%of patients with septonasal deviation. The second most common type is the C-shaped anteroposterior deviation, which occurs in approximately 32%of patients. In this type, the septum exhibits a C-shaped curve in the coronal section. The C-shaped cephalocaudal deviation, in which the septum forms a C shape in the coronal section, is observed in approximately 4% of patients.

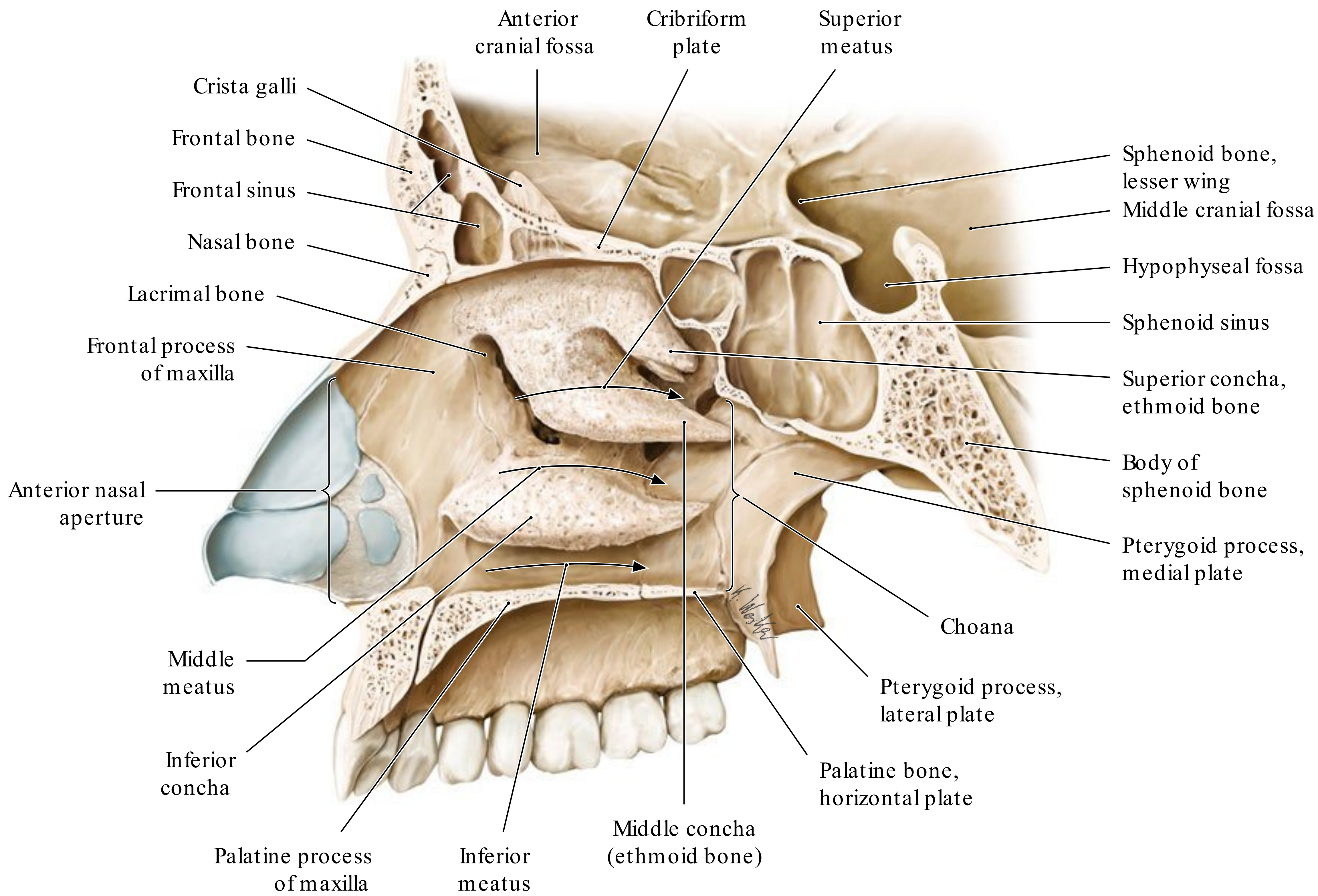


Fig. 16.1 Sagittal section of the nasal cavity (right side). (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

Anteroposterior and cephalocaudal S-shaped deviations are observed in 9% and 1% of patients, respectively. Finally, localized deformities are observed in about 14% of patients with septonasal deviation.[7]

An important region of the nasal septum is Kiesselbach's or Little's area, located in the anterior part of the nasal septum. Five arteries supplying the nasal septum anastomose at this point to create an arterial plexus (**Fig. 16.4**). This area is frequently involved in chronic epistaxis, especially in children.

Lateral Wall of the Nasal Cavity

The lateral wall of the nasal cavity is characterized by three conchae that are long in the anteroposterior direction and protrude medially toward the nasal cavity; their free edge rolls inferiorly (**Fig. 16.4**). These conchae are termed the superior nasal concha, middle nasal concha, and inferior nasal concha, and the meatuses below these conchae are called the superior nasal meatus, middle nasal meatus, and inferior nasal meatus, respectively. At the posterior end of these conchae, the three meatuses conflate and meet at the nasopharynx; this point is termed the nasopharyngeal meatus. An atrophic supreme nasal concha is sometimes found above the superior concha.[8] The posterosuperior part of the nasal cavity, which forms the space between the nasal roof and superior concha, is the sphenoethmoidal recess.

Some important structures are located around the middle meatus. The ethmoid bulla, which contains the ethmoid bulla cells of the ethmoid sinus, projects from the medial wall of the orbit. Part of the ethmoid bulla is exposed on the superior part of the lateral wall of the middle nasal meatus. The uncinate process is the thin, bony projection located above the attachment of the inferior nasal concha. The deep groove between the ethmoid bulla and uncinate process is called the semilunar hiatus.

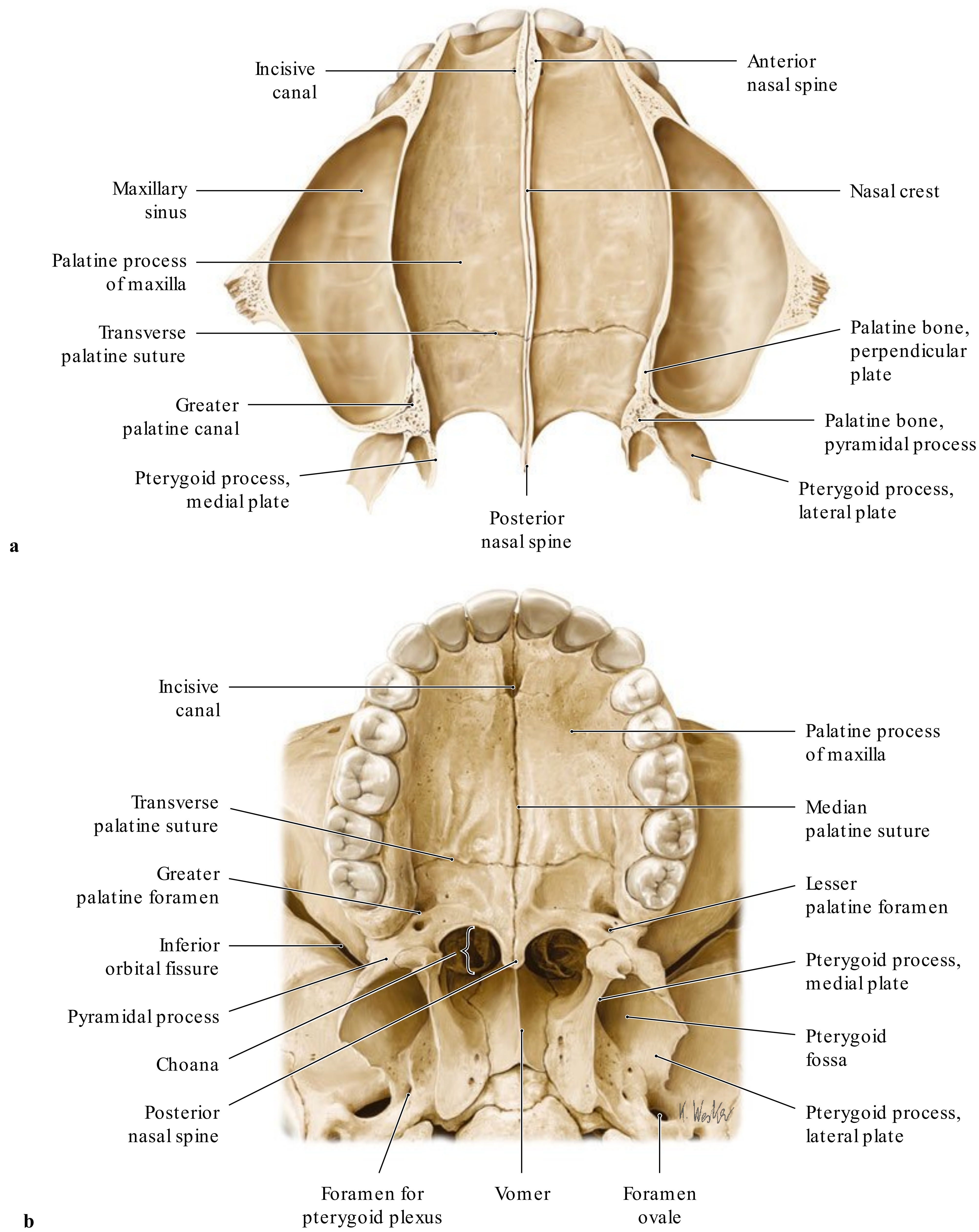


Fig. 16.2 Floor of the nasal cavity. The floor of the nasal cavity comprises mainly the superior surface of the maxilla and palatine bone. In the anterior part of the floor, the incisive canal is observed immediately lateral to the nasal septum. **(a)** Superior view. **(b)** Inferior view. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustrations by Karl Wesker.)

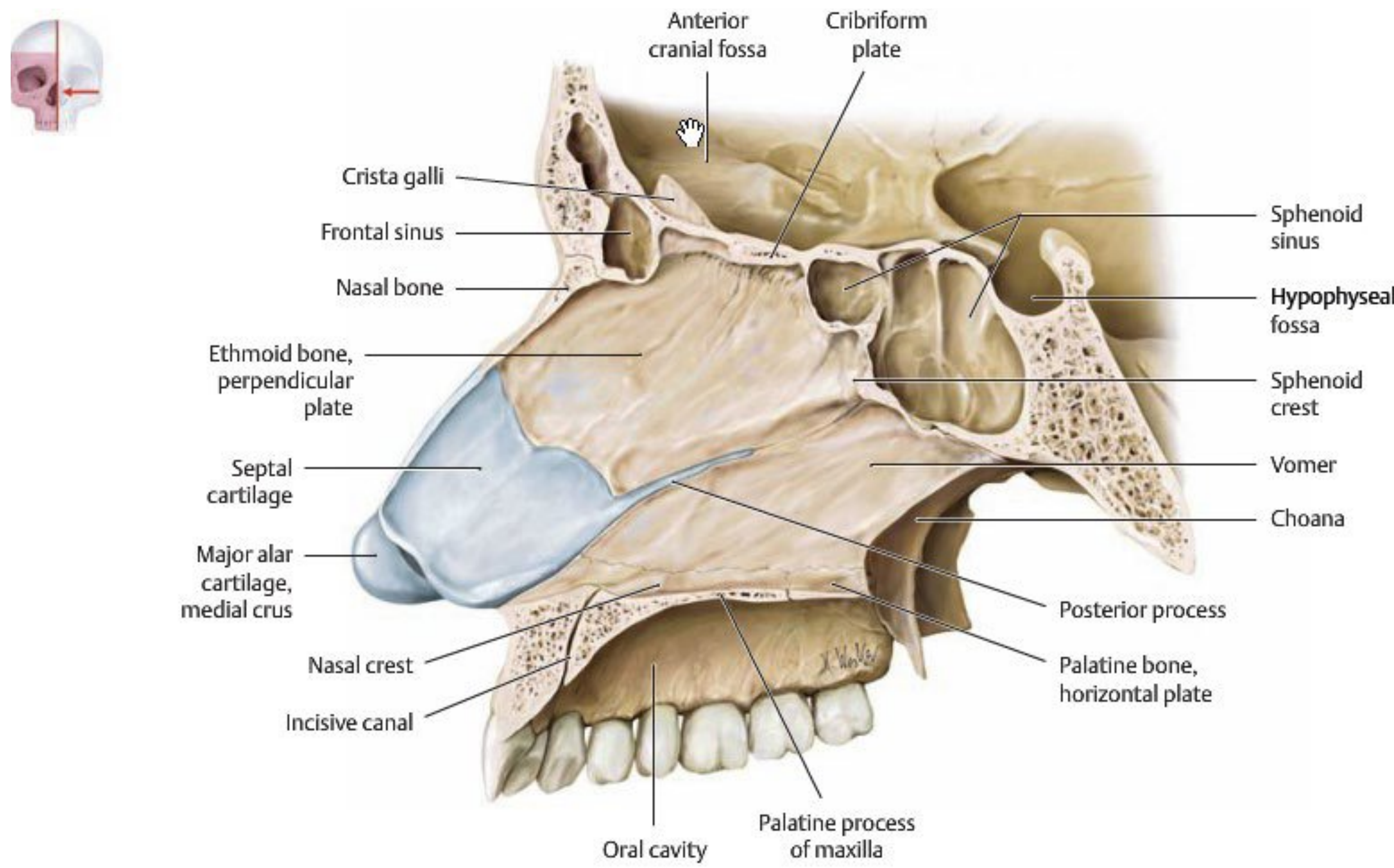


Fig. 16.3 Nasal septum. Parasagittal section viewed from the left side. Histologically, the nasal septum comprises two parts: the cartilaginous part and the bony part. The septal nasal cartilage forms the cartilaginous part and occupies the anterior part of the nasal septum. The posterior part is the bony part and mainly comprises the vomer in the inferior posterior part and the perpendicular plate of the ethmoid bone in the superior part. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

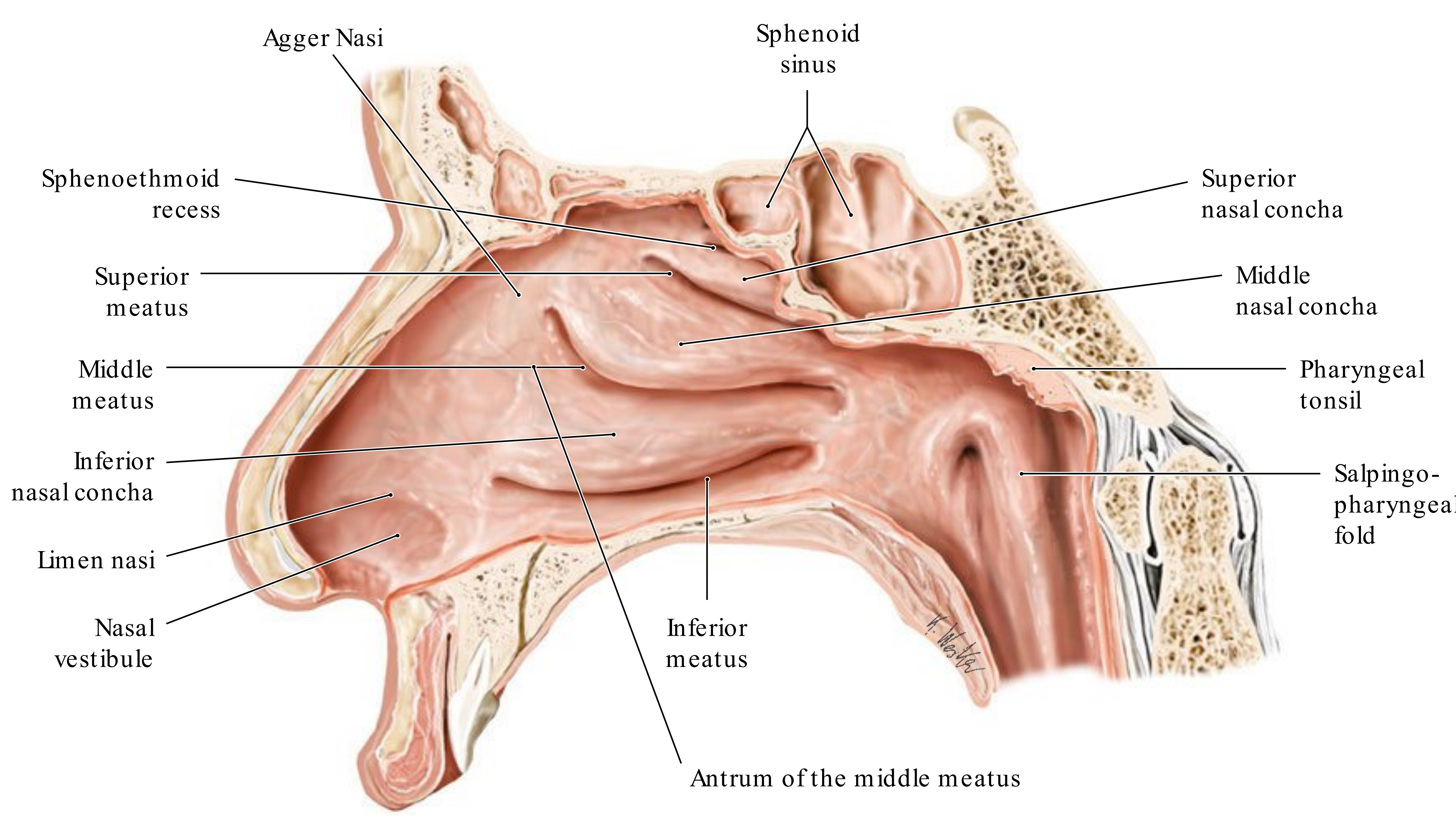


Fig. 16.4 Right lateral wall of the nasal cavity. (Modified from THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme, 2010, Illustration by Karl Wesker.)

Fig. 16.5 Left inferior nasal meatus (cadaver dissection). Anterior part of the inferior nasal concha was cut. Slitlike opening of the naso-lacrimal duct is observed just beneath the attachment of the inferior nasal concha.

The semilunar hiatus is divided into two parts in its anterior region by the projection of the ethmoid bulla: the superior and inferior semilunar hiatus. These structures are involved in connecting the paranasal sinuses. The ethmoidal infundibulum is the funnel-shaped space inside the medial wall of the nasal cavity. It is surrounded by the uncinate process medially and ethmoid bulla laterally and continues to the semilunar hiatus posteriorly. The bony bulge anterior to the anterior end of the middle nasal concha is called the agger nasi. The outward bulge immediately anterior to the middle meatus is called the antrum of the middle meatus.[1–3]

The opening of the nasolacrimal duct is located in the anterosuperior part of the inferior meatus, just below the attachment of the inferior concha (**Fig. 16.5**). The openings of each paranasal sinus and the nasolacrimal duct are described in the section that discusses the paranasal sinuses, nasolacrimal ducts, and their openings into the nasal cavity.

Blood Supply of the Nasal Cavity

The nasal cavity, including both the medial and lateral walls, is supplied by five arteries: the anterior ethmoidal artery, posterior ethmoidal artery, sphenopalatine artery, greater palatine artery, and superior labial artery (**Fig. 16.6**).[2]

Both the anterior ethmoidal artery and posterior ethmoidal artery are branches of the ophthalmic artery. They branch within the orbital cavity, enter the nasal cavity through the ethmoidal bone, and mainly supply the upper region of the cavity. A branch of the anterior ethmoidal artery runs anteriorly,

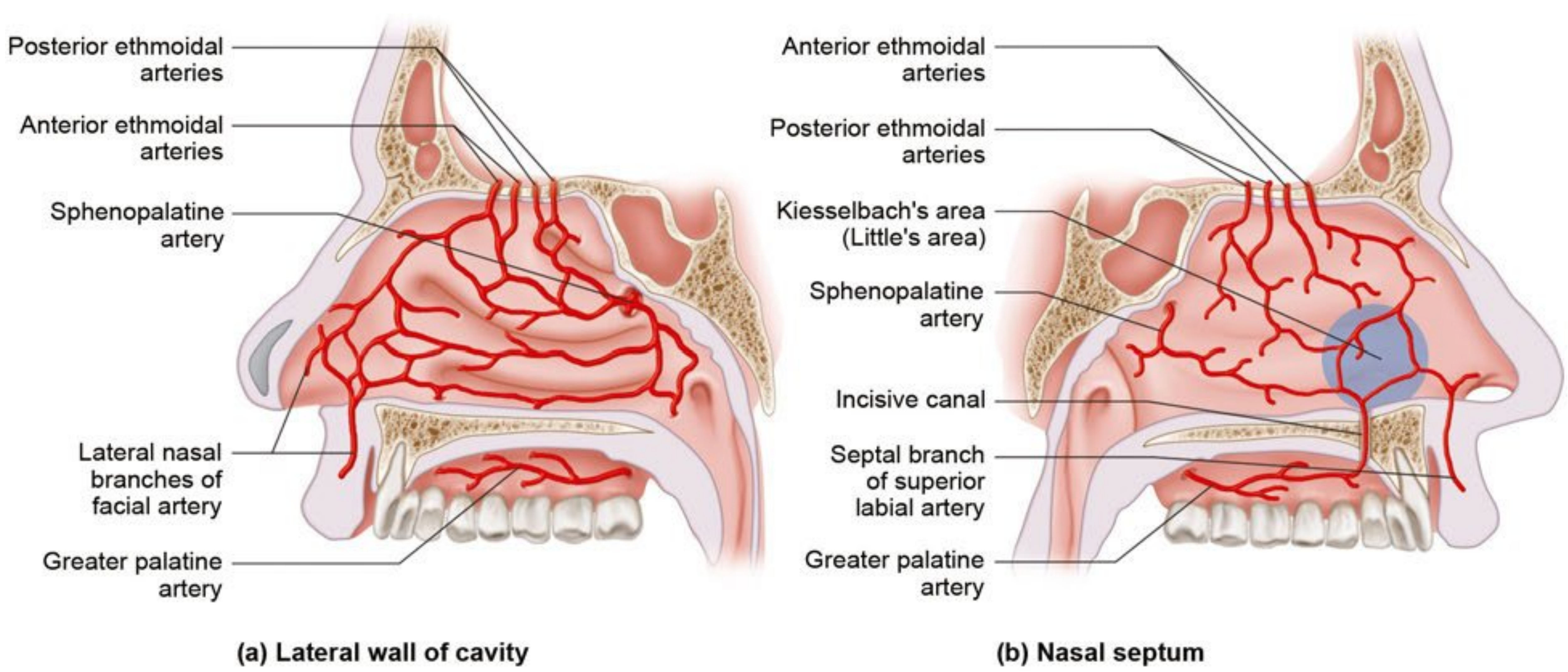


Fig. 16.6 Arterial blood supply of the nasal cavity. **(a)** Arterial blood supply of the nasal septum. Kiesselbach's area is located in the anterior part of the nasal septum. Five arteries supplying the nasal septum anastomose in this region and form the arterial plexus. **(b)** Arterial blood supply of the lateral nasal wall.

pierces the nasal bone, and distributes its blood supply to the nasal epithelium. The main artery supplying the nasal cavity is the sphenopalatine artery. This artery arises from the maxillary artery in the pterygopalatine fossa and enters the nasal cavity through the sphenopalatine foramen, which is located on the lateral wall posterior to the superior nasal meatus. After entering the nasal cavity, the artery gives off various branches. The two main branches course to the posterior part of the nasal septum and posterior part of the lateral nasal wall. The greater palatine artery, which is the terminal branch of the descending palatine artery, enters the nasal cavity through the incisive canal and distributes its blood supply to the lower part of the nasal cavity. The superior labial artery, which is a branch of the facial artery, also enters the nasal cavity through the soft tissue in the upper lip and distributes its blood supply to the anterior and lower parts of the nasal cavity. These arteries anastomose with one another on both the lateral nasal wall and the nasal septum. The region in which these five arteries meet and anastomose at the anterior part of the nasal septum is called Kiesselbach's area (**Fig. 16.6b**).[1–3,9]

Sensory Innervation of the Nasal Cavity

The sensory innervation of the nasal cavity is separated into two areas by the line connecting the anterior nasal spine and the sphenoethmoidal recess (**Fig. 16.7**). The upper area of the nasal cavity contains the anterior ethmoidal nerve, which is a branch of the ophthalmic nerve (first division of the trigeminal nerve). This nerve, accompanied by the anterior ethmoidal artery, enters the nasal cavity through the ethmoid bone and

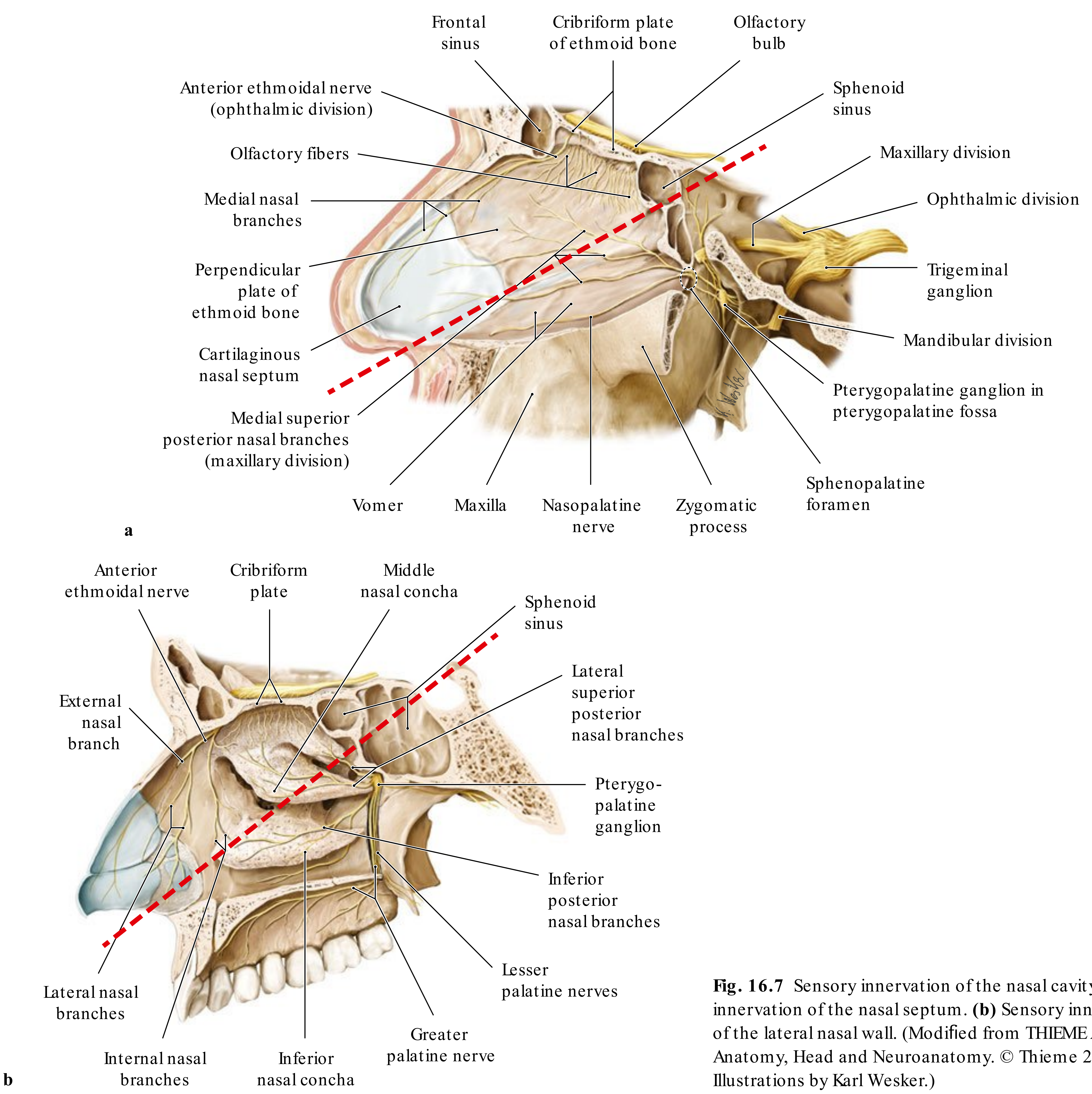


Fig. 16.7 Sensory innervation of the nasal cavity **(a)** Sensory innervation of the nasal septum. **(b)** Sensory innervation of the lateral nasal wall. (Modified from THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustrations by Karl Wesker.)

courses through the anterior and superior parts of the nasal cavity. The lower area of the nasal cavity is innervated by a branch derived from the maxillary nerve (second division of the trigeminal nerve). The nasopalatine nerve and medial superior posterior branch of the greater palatine nerve innervate the nasal septum in this region of the nasal cavity. The medial superior posterior branch innervates the upper half of this area, and the nasopalatine nerve innervates the lower half. The lateral superior posterior nasal branch and inferior posterior nasal branch of the greater palatine nerve innervate the lateral nasal wall in this region of the nasal cavity.

Paranasal Sinuses, Nasolacrimal Ducts, and their Opening to the Nasal Cavity

Frontal Sinus

The frontal sinus is usually divided into two parts around the midline (**Table 16.1, Fig. 16.8**). It is sometimes made up of multiple air cells. The bilateral frontal sinuses extend into the frontal bone and are located posterior to the supraciliary arches of the frontal bone. The sinuses are adjacent to the cranial cavity, orbital cavity, ethmoidal cells, and nasal cavity. The sinuses sometimes extend quite widely, spreading posteriorly and covering the entire orbital roof. Cases of aplasia have also been described. In one report, the sinus was 24.3 mm (range, 5.0–66.0 mm) in height, 29.0 mm (range, 17.0–49.0 mm) wide from the midline coursing in the lateral direction, and 20.5 mm (range, 10.0–46.5 mm) long in the anteroposterior direction.[3] The sinus continues downward and passes through the ethmoid bone on the way to their opening of the nasal cavity. The part of the frontal sinus contained within the ethmoid bone is called the frontal recess, which serves as a drainage pathway of the frontal sinus. The sinuses usually open into the semilunar hiatus or the ethmoidal infundibulum. The drainage pattern depends on the location at which the uncinate process attaches anteriorly. If the uncinate process inserts into the lamina orbitalis (lamina papyracea), the ethmoidal infundibulum ends blindly at the superior position and the frontal recess opens to the middle meatus or suprabullar recess. If the uncinate process inserts at the skull base or middle nasal meatus, the frontal recess opens to the middle meatus via the ethmoidal infundibulum. This blind end is called a terminal cell.

Table 16.1 Paranasal sinuses, nasolacrimal ducts, and their opening to the nasal cavity

Paranasal sinus	Opening
Frontal sinus	Semilunar hiatus (middle meatus), or ethmoidal infundibulum (middle meatus)
Anterior ethmoid sinus	Ethmoidal infundibulum (middle meatus), lateral recess (middle meatus)
Posterior ethmoid sinus	Sphenoethmoidal recess
Sphenoid sinus	Sphenoethmoidal recess
Maxillary sinus	Ethmoidal infundibulum (middle meatus), accessory openings (middle meatus)
Nasolacrimal duct	Anterior edge of the attachment of the niferior nasal concha (inferior meatus)

Surgical Annotation (Frontal Sinus Cranialization for Frontal Fractures and Anterior Skull Base Reconstruction)

Frontal sinus cranialization is required to treat severe frontal fractures that have spread to the posterior table of the frontal sinus with cerebrospinal fluid leakage, as well as to perform

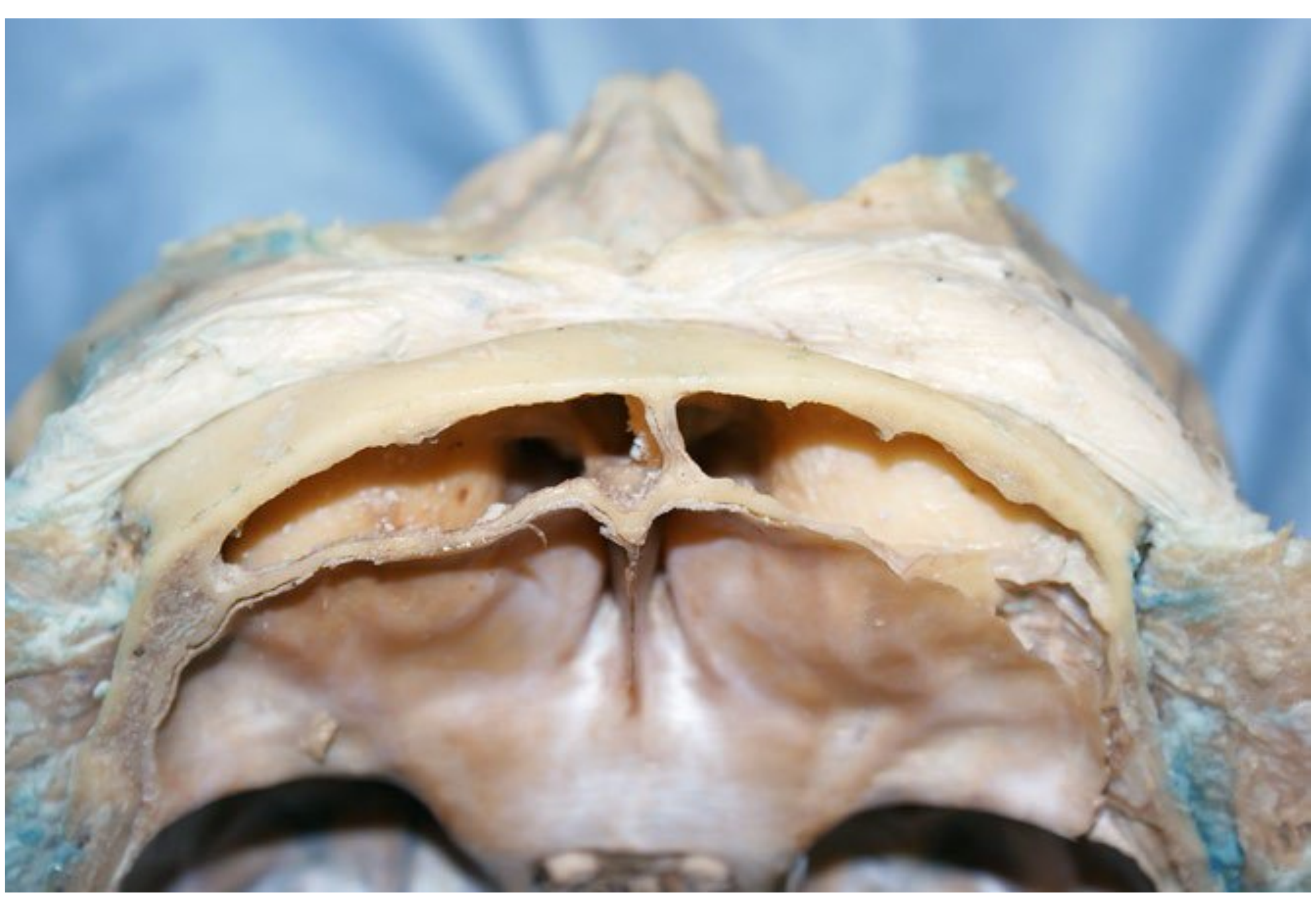


Fig. 16.8 Frontal sinus (cadaver dissection). Calvaria vault and brain were removed.

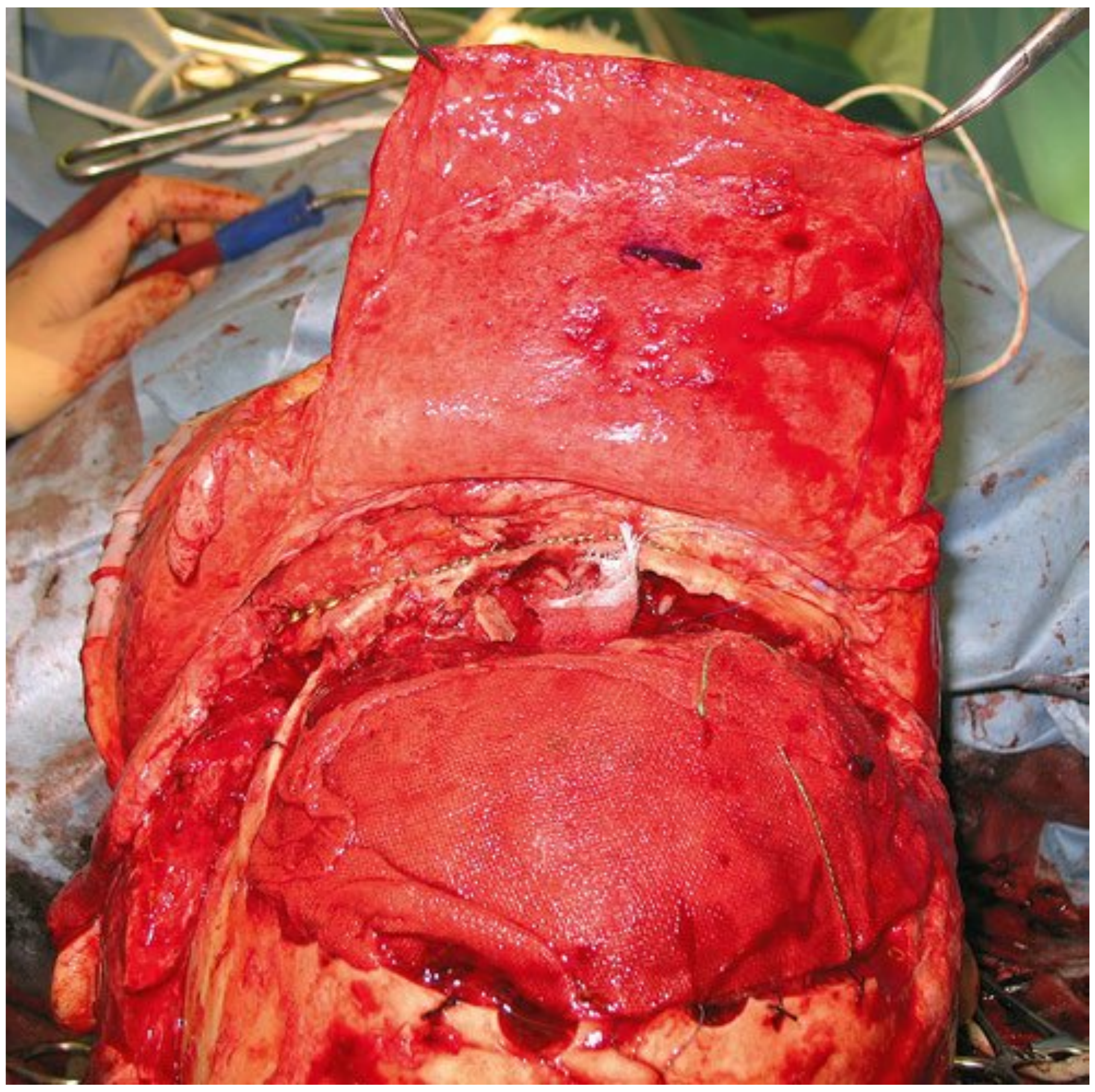


Fig. 16.9 Operative findings of frontal sinus cranialization. Case of a comminuted fracture of the frontal bone. The posterior wall of the frontal sinus and mucosa were removed, and the anterior skull base was reconstructed using a frontal musculoperiosteal flap. In this illustration, the frontal musculoperiosteal flap had just been created.

anterior skull-base tumor resection involving communication between the cranial cavity and nasal cavity (**Fig. 16.9**). Frontal-sinus cranialization allows the frontal sinus to become part of the cranial cavity by removing the posterior table of the frontal sinus. A bicoronal skin incision is usually chosen for the frontal bone approach. A flap for the anterior skull base is then prepared during dissection of the cranial soft tissue. Either a temporal pericranial flap or a frontal pericranial flap is usually selected. On completion of the frontal craniotomy, the posterior table of the frontal sinus and mucosa on the sinus are completely removed. The soft tissue flap is transplanted to the anterior skull base, just above the point at which the frontal sinus meets the frontonasal duct, to disconnect the cranial cavity and nasal cavity.

Frontal sinus cranialization is not needed to treat fractures localized only in the anterior table of the frontal bone. Instead, repositioning and fixation of the fracture is effective. Placement of a drainage tube in the frontonasal duct helps to prevent discharge from pooling in the frontal sinus.[10,11]

Ethmoid Sinus and Sinus around the Frontal Recess

The ethmoid sinus is located in the ethmoidal labyrinth and comprises many small air cells (**Fig. 16.10**). The sinus is adjacent to the medial wall of the orbit, near the orbital plate of the ethmoidal labyrinth laterally and extending to the nasal cavity near the medial wall of the ethmoidal labyrinth medially (**Table 16.2**). The ethmoid sinus usually contains five bony septa called basal lamellae, which separate the sinus in the anteroposterior direction. These lamellae are numbered from anterior to posterior. The first lamella is the septum that continues to the uncinate process. The second lamella arises from the posterior wall of the ethmoidal bulla. The third lamella is the thickest of all five basal lamellae and is uniform in shape. It arises from the middle nasal concha. The fourth lamella continues to the superior nasal concha. Finally, the fifth lamella is the septum supporting the superior nasal concha. The sphenoethmoidal recess is located posterior to the fifth basal lamella (basal lamella of the superior concha).[12] The ethmoid sinus is generally divided by the third basal lamella (basal lamella of the middle turbinate) into two parts: the anterior ethmoid sinus and posterior ethmoid sinus.

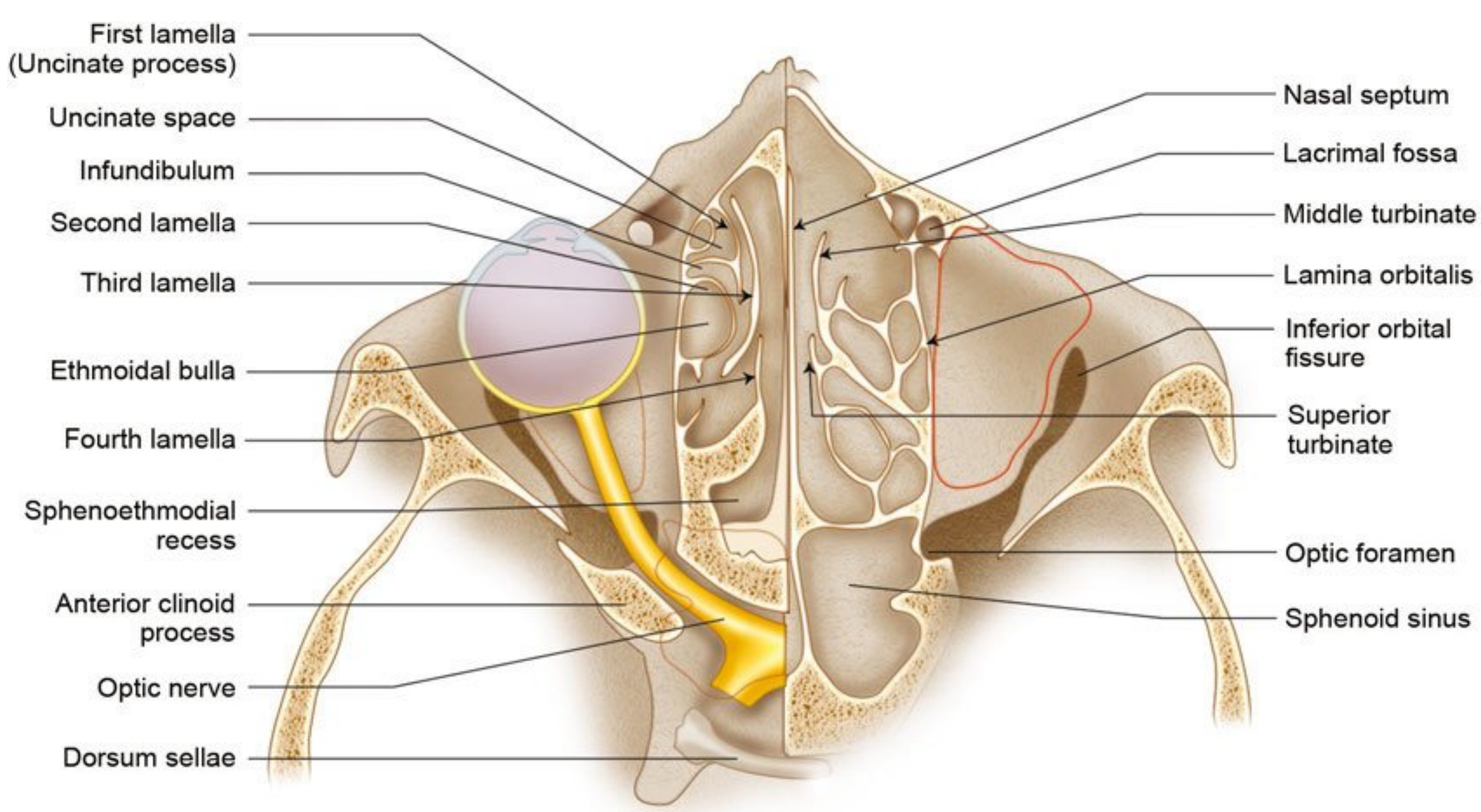


Fig. 16.10 Horizontal section of the right ethmoid sinus.

Table 16.2 Lamellae of the ethmoid sinus

Basal lamellae	Related structure
The first lamella	Uncinate process
The second lamella	Posterior wall of the ethmoidal bulla
The third lamella (basal lamella of the middle turbinate)	Middle nasal concha
The fourth lamella	Superior nasal concha
The fifth lamella	Superior nasal concha

The posterior ethmoid sinus is the air cell that drains to the sphenoethmoidal recess. The posterior sinus sometimes develops within the sphenoid sinus, and the optic nerve and internal carotid artery may thus be exposed within the air cells. These cells constitute the sphenoethmoidal sinus and are sometimes termed Onodi cells.[8] In the anterior ethmoidal sinus, the cells between the second and third basal lamella constitute what is sometimes called the middle ethmoid sinus; however, this term has not been used recently.[9]

The ethmoidal bulla cells, which form the anterior ethmoid sinus, are located relatively posterior to and within the space between the middle nasal concha and uncinate process (i.e., the middle ethmoid sinus). The ethmoidal bulla cells usually open to the lateral recess, which is the space located posterior to the ethmoidal bulla cells. These structures sometimes form the sinus called the lateral recess. The drainage pathway of the frontal sinus passes between the first and second basal lamella and opens to the middle nasal meatus through the ethmoidal infundibulum. The shape of this duct is not a simple tube connecting the frontal sinus and ethmoidal infundibulum but is instead an irregularly shaped cell. Thus, the term *frontonasal duct* is used less frequently today.[9] The air cells located in the superior anterior part of the anterior ethmoidal sinus and surrounding the drainage pathway of the frontal sinus (frontal recess) are called the frontal recess cells. The air cells located around the ethmoidal infundibulum and that open to it are called the infundibular cells.

Anterior to the ethmoidal sinus, some air cells originate from the frontal process of the maxilla. The agger nasi cells, frontal ethmoidal cells, and frontal bulla cells are included in this category. A single agger nasi cell is usually located behind the agger nasi, which is the bulge anterior to the middle nasal concha. By computed tomography, this air cell is detected in more than 90% of cases as the most superficial cell in the coronal section.[13,14] It is an important landmark in the approach to the frontal recess during endoscopic surgery. The air cells facing the lacrimal bone (inferior to the agger nasi cells) are termed the lacrimal cells.

Surgical Annotation

Causes of Bleeding During Ethmoid Sinus Surgery

When performing treatments involving the medial orbital wall, such as fracture repair (medial orbital wall fractures, etc.), tumor resection, or ethmoidal sinus surgery, unexpected massive bleeding sometimes occurs (**Fig. 16.11**). This bleeding is usually caused by damage to the anterior ethmoidal artery or posterior ethmoidal artery. These arteries are branches of the ophthalmic artery, which enters the orbital cavity along with the optic nerve through the optic canal. The artery and nerve then penetrate the medial orbital wall through the anterior and posterior ethmoidal foramens, respectively, which are located on the su-

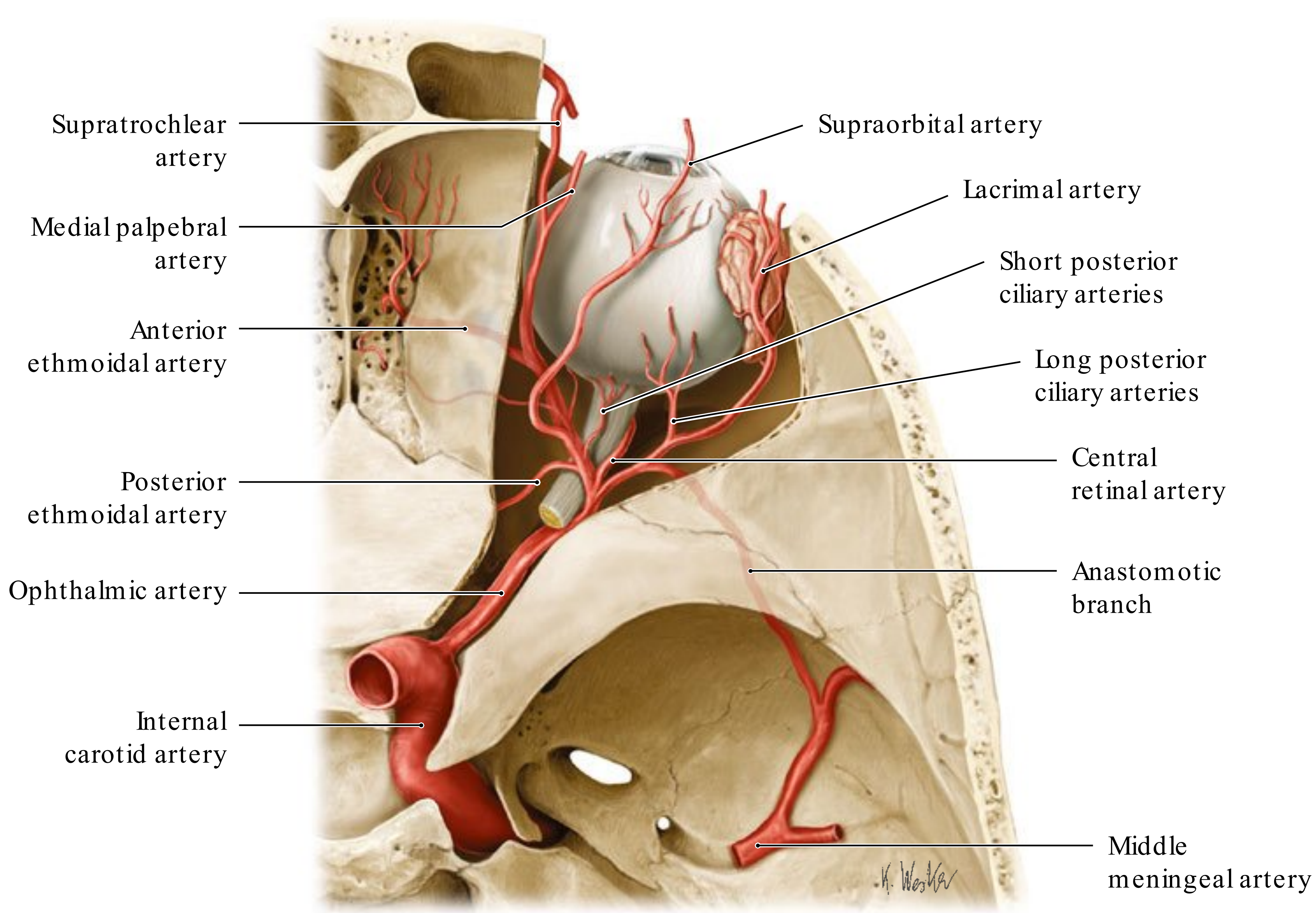


Fig. 16.11 Anterior and posterior ethmoidal arteries. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker).

Fig. 16.12 Sagittal section of the right sphenoid sinus. The black string indicates the opening of the sphenoid sinus.

perior part of the medial orbital wall. The anterior ethmoidal artery supplies the anterior and middle ethmoidal air cells and the frontal sinus. After entering the cranium, this artery branches into the meningeal branch and finally enters the nasal cavity through the ethmoidal foramen to supply the nasal cavity. The terminal branch of this artery emerges from the dorsum of the nose between the nasal bone and the lateral cartilage. The posterior ethmoidal artery supplies the posterior ethmoidal air cell after leaving the orbit through the posterior ethmoidal canal and then branches into the meningeal branch after entering the cranium; it finally enters and supplies the nasal cavity.[15]

Sphenoid Sinus

The sphenoid sinus is located posterior to the ethmoidal air cells and is positioned within the body of the sphenoid, forming the posterior roof of the nasal cavity (**Fig. 16.12**). It contains a bony septum that divides the bilateral sinuses. In most cases, the bony septum deviates from the midline. The sinus opens to the sphenoethmoidal recess (the space superior and posterior to the superior nasal concha) through the ostium opening on the anterior wall of the sphenoid sinus. It lies adjacent to important structures in the cranial cavity, including the optic nerve, optic chasm, pituitary gland, internal carotid artery, and cavernous sinus.[3,16]

Maxillary Sinus

The maxillary sinuses are located within the maxilla and have the largest capacity of all the paranasal sinuses (**Fig. 16.13**). They mainly open to the middle nasal meatus at the ethmoidal infundibulum. This opening is called the natural ostium. The maxillary sinuses have one or more accessory openings at their fontanelle in the middle nasal meatus. The shape of these sinuses

Fig. 16.13 Maxillary sinus (left maxillary sinus, inferior view). The white string indicates the natural ostium of the left maxillary sinus (posterolateral view, after removal of the floor of the maxilla and nasal floor).

is pyramidal, their base is the lateral wall of the nasal cavity, and their apex extends to the zygomatic process. Their roof forms the orbital floor and extends medially to the inferior orbital canal.[1,2] The maxillary sinuses may have septa that divide the sinuses into intercommunicating spaces. The size of these sinuses varies from 9.5 to 20.0 ml; the average is about 15.0 ml.[3] Some important structures are located in the maxillary sinuses. The nasolacrimal duct is located in the anterior part of the medial wall of this sinus. The infraorbital nerve, a branch of the maxillary nerve, passes through a bony wall (the infraorbital canal) in the roof of the maxillary sinus to the maxillary skin. The maxillary nerve gives off three branches: the posterior superior; middle superior; and anterior superior alveolar nerves, which innervate the maxillary teeth. The posterior superior alveolar nerve arises just before the maxillary nerve that enters the infraorbital canal, the middle superior alveolar nerve from the posterior part of the infraorbital canal, and the anterior superior alveolar nerve from just before the nerve coming out from the canal. These alveolar nerves run in the bony wall of the maxillary sinus; infratemporal surface (posterior superior), lateral (middle superior), and anterior surface (anterior superior), respectively; communicate with each other; and innervate the teeth. In the posterior region, the maxilla is contiguous with the lateral pterygoid plate and forms the pterygomaxillary fissure. The pterygopalatine fossa is located inside the fissure and gives off the terminal branches of the maxillary nerve and maxillary artery. The descending palatine artery and greater palatine nerve, which course to the palate, pass through the greater palatine canal in the inferior part of the fossa.[1] This neurovascular complex is extremely important in Le Fort I osteotomy.

Surgical Annotation (Le Fort I Osteotomy and Maxillary Fracture)

The opportunity to treat the inferior meatus surgically (e.g., by LeFort I osteotomy or maxillary sinus drainage for maxillary fractures) sometimes arises in the field of plastic surgery. In such cases, the surgeon must pay attention to two important structures in the inferior nasal meatus. One is the opening of the nasolacrimal duct, which is located at the anterior end of the inferior nasal meatus just below the inferior nasal concha, and the other is the descending palatine artery, which is located within the greater palatine canal, inferior to the maxillary sinus. Obstruction of the nasolacrimal duct may rarely occur after maxillary surgery, usually because of secondary inflammation or sometimes direct injury of the valve of Hasner.[17,18] To open the maxillary sinus, drainage to the inferior meatus also should make enough rearward to the valve of Hasner. The descending palatine artery (**Fig. 16.14**) poses a potential risk of massive

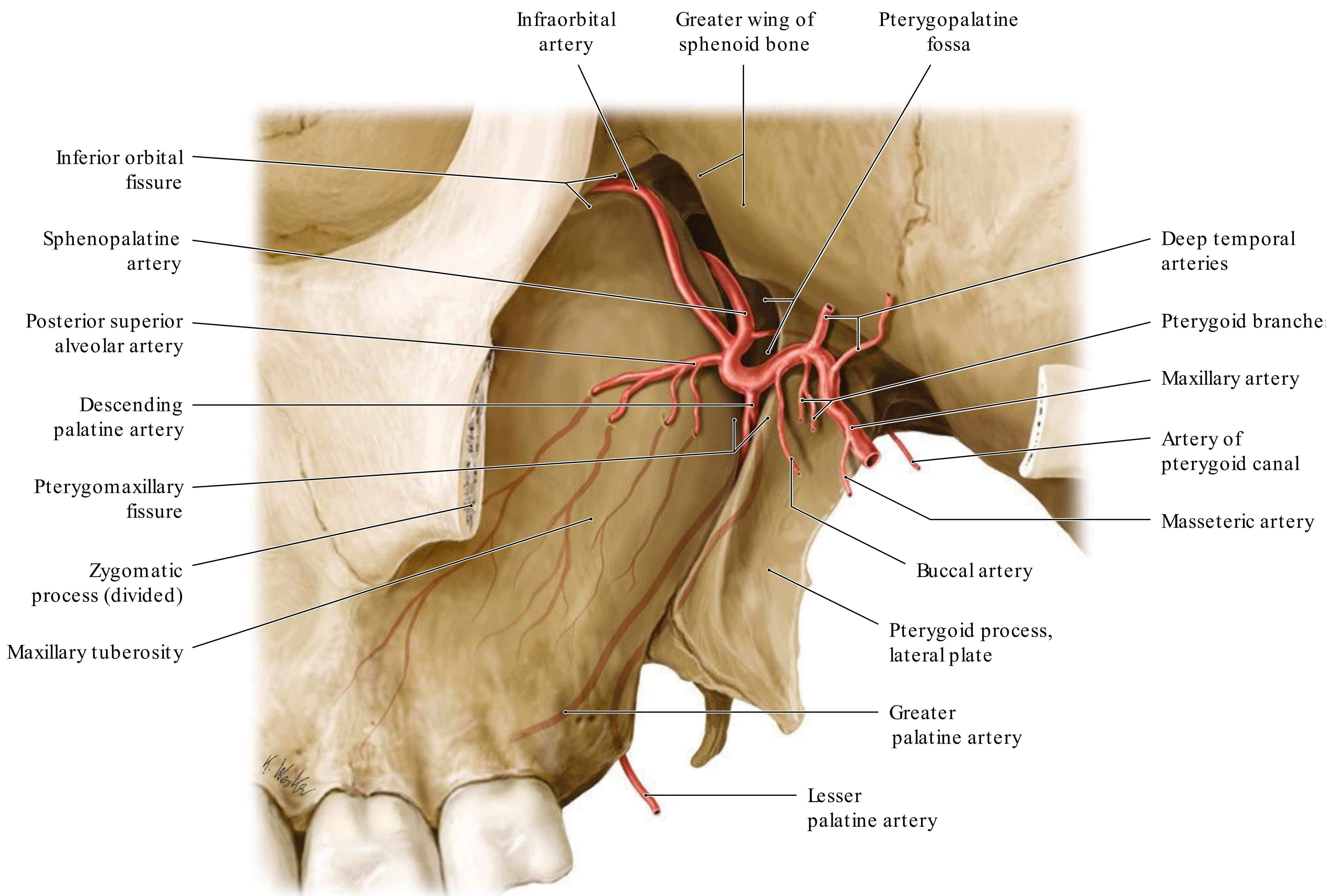


Fig. 16.14 Descending palatine artery. Left lateral view. The descending palatine artery arises from the maxillary artery in the pterygopalatine fossa and descends in the greater palatine canal. The descending palatine artery becomes the greater palatine artery after emerging from the greater palatine foramen at the palate. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

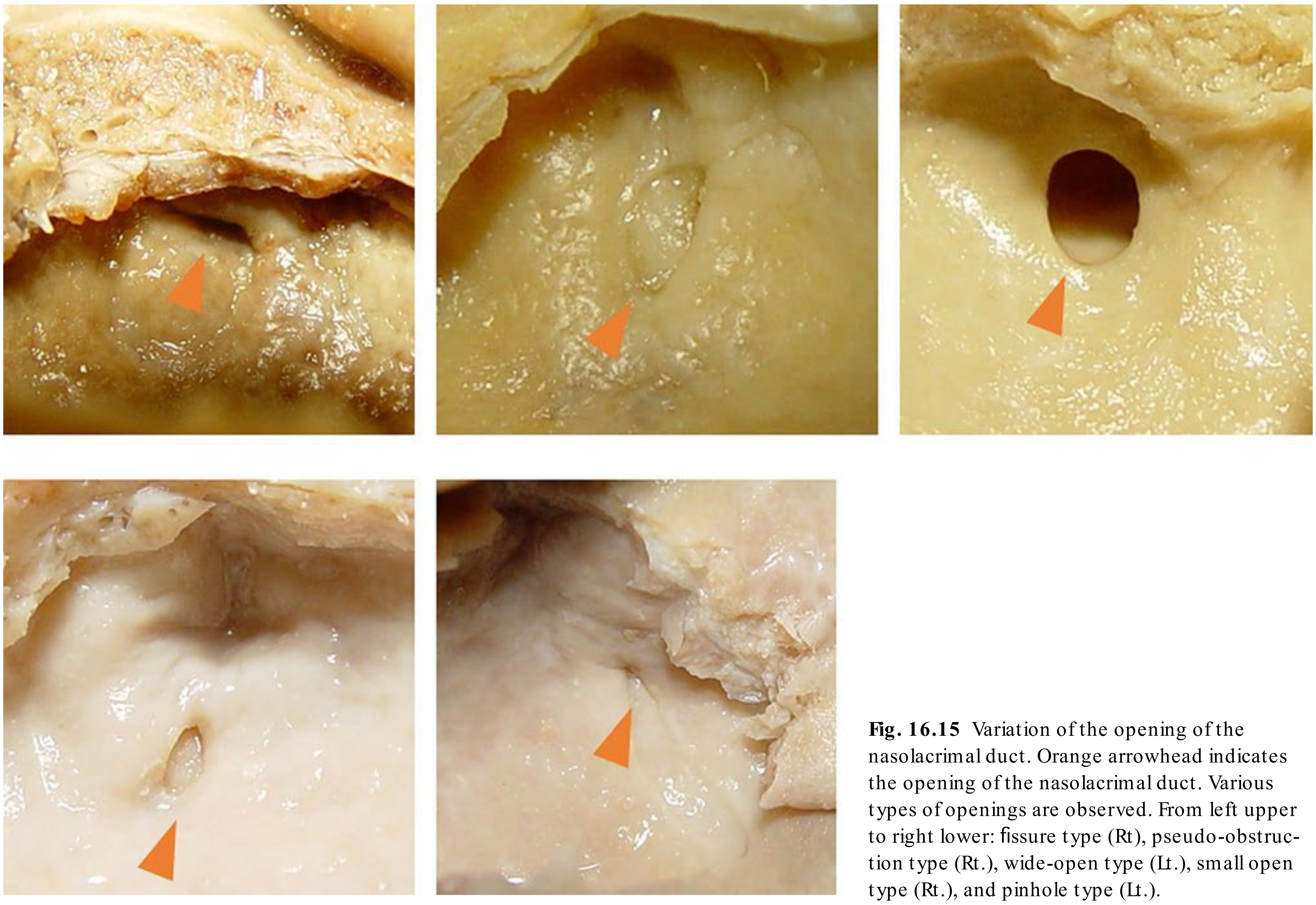


Fig. 16.15 Variation of the opening of the nasolacrimal duct. Orange arrowhead indicates the opening of the nasolacrimal duct. Various types of openings are observed. From left upper to right lower: fissure type (Rt), pseudo-obstruction type (Rt.), wide-open type (Lt.), small open type (Rt.), and pinhole type (Lt.).

bleeding during Le Fort I osteotomy. To avoid damage to the descending palatine artery, osteotomy performed using a chisel or bone saw should be stopped before reaching the artery, and blunt down fracture to the residual posterior part of the maxilla should be performed. Li et al[19] reported that the average distance from the piriform rim to the descending artery was 35.4 mm (range, 31.0–42.0 mm). They found that the greater palatine foramen was located between the second and third molars and that the average distance between the pterygomaxillary fissure and greater palatine foramen was 6.6 mm (range. 2.0–10.0 mm).[19]

Opening of Nasolacrimal Duct (Valve of Hasner)

The nasolacrimal duct opens obliquely on the lateral nasal wall of the inferior nasal meatus, around the anterior edge of the attachment of the inferior nasal concha (**Fig. 16.15**). In our cadaver dissection study,[20] the opening of the nasolacrimal duct was located 36.60 ± 3.92 mm from the anterior edge of the nostril, 19.20 ± 3.21 mm horizontally from the anterior edge of the nostril, and 14.10 ± 3.76 mm vertically from the nasal floor. The shape of the valve reportedly ranges from a round to slit shape, and the frequency of the shape varies among reports. Schaeffer[21] reported that an oval shape was most frequent among Europeans. In contrast, Orhan et al[22] reported a high frequency of the vertical sulcus type. In our study, the fissure type was observed most frequently (**Table 16.3**).[20]

Table 16.3 Variations of the opening of the nasolacrimal duct

Opening of the nasolacrimal duct	Frequency (%)
Wide opening type	17
Small opening type	15
Pinhole type	14
Fissure type	32
Pseudo-obstruction type	22
Obstruction type	0

Source: Tanaka K. An anatomical study of the inferior nasal meatus region of the human nasolacrimal duct. Kurume Igakkai Zasshi 2008;71:38–52.

References

1. Clemente CD, ed. Gray's Anatomy. Philadelphia: Lea & Febiger; 1985
2. Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy. Philadelphia: Lippincott Williams & Wilkins; 2013
3. Lang J. Clinical Anatomy of the Nose, Nasal Cavity and Paranasal Sinuses. New York: Thieme; 1989
4. Blaugrund SM. Nasal obstruction: The nasal septum and concha bullosa. Otolaryngol Clin North Am 1989;22(2):291–306 PubMed
5. Earwaker J. Anatomic variants in sinonasal CT. Radiographics 1993;13(2):381–415 PubMed
6. Pérez-Piñas I, Sabaté J, Carmona A, Catalina-Herrera CJ, Jiménez-Castellanos J. Anatomical variations in the human paranasal sinus region studied by CT. J Anat 2000;197(Pt 2):221–227 PubMed
7. Guyuron B, Uzzo CD, Scull H. A practical classification of septonasal deviation and an effective guide to septal surgery. Plast Reconstr Surg 1999;104(7):2202–2209, discussion 2210–2212 PubMed
8. Janfaza P, Nadol JB, Galla RJ, Fabian RL, Montgomery WW, eds. Surgical Anatomy of the Head and Neck. Cambridge, MA: Harvard University Press; 2011
9. Stammberger HR, Kennedy DW; Anatomic Terminology Group. Paranasal sinuses:anatomic terminology and nomenclature. Ann Otol Rhinol Laryngol Suppl 1995;167:7–16 PubMed
10. Ruggiero FP, Zender CA. Frontal sinus cranialization. Oper Tech Otolaryngol—Head Neck Surg 2010;21(2):143–146
11. Strong EB, Pahlavan N, Saito D. Frontal sinus fractures: a 28-year retrospective review. Otolaryngol Head Neck Surg 2006;135(5):774–779 PubMed
12. Kim SS, Lee JG, Kim KS, Kim HU, Chung IH, Yoon JH. Computed tomographic and anatomical analysis of the basal lamellas in the ethmoid sinus. Laryngoscope 2001;111(3):424–429 PubMed
13. Wormald PJ. Surgery of the frontal recess and frontal sinus. Rhinology 2005;43(2):82–85 PubMed
14. Wormald PJ. Three-dimensional building block approach to understanding the anatomy of the frontal recess and frontal sinus. Oper Tech Otolaryngol—Head Neck Surg 2006;17(1):2–5
15. Erdogmus S, Govsa F. The anatomic landmarks of ethmoidal arteries for the surgical approaches. J Craniofac Surg 2006;17(2):280–285 PubMed
16. Kim HU, Kim SS, Kang SS, Chung IH, Lee JG, Yoon JH. Surgical anatomy of the natural ostium of the sphenoid sinus. Laryngoscope 2001;111(9):1599–1602 PubMed
17. Osguthorpe JD, Calcaterra TC. Nasolacrimal obstruction after maxillary sinus and rhinoplastic surgery. Arch Otolaryngol 1979; 105(5):264–266 PubMed
18. Serdahl CL, Berris CE, Chole RA. Nasolacrimal duct obstruction after endoscopic sinus surgery. Arch Ophthalmol 1990;108(3):391–392 PubMed
19. Li KK, Meara JG, Alexander A Jr. Location of the descending palatine artery in relation to the Le Fort I osteotomy. J Oral Maxillofac Surg 1996;54(7):822–827 PubMed
20. Tanaka K. An anatomical study of the inferior nasal meatus region of the human nasolacrimal duct. Kurume Igakkai Zasshi 2008;71: 38–52(in Japanese)
21. Schaeffer JP. Types of ostia nasolacrimalis in man and their genetic significance. Am J Anat 1912;13:183–192
22. Orhan M, Ikiz ZAA, Saylam CY. Anatomical features of the opening of the nasolacrimal duct and the lacrimal fold (Hasner's valve) for intranasal surgery: a cadaveric study. Clin Anat 2009;22(8):925–931 PubMed

17 External Nose

Hideaki Rikimaru

Introduction

The nose is located in the center of the face and is one of the most impressive features to other people. The shape is a three-dimensionally complex and differs between individual, sex, and race. This complex structure is formed by skin, soft tissue, bone, cartilage, and mucosa, which differ in composition depending on the region of the nose. The vascular supply and innervation of the nose are also intricate. Several vessels and nerves are distributed within the relatively small space of the nose. Thus, it is essential to have a good understanding of the anatomy of the nose for any surgical procedure.

External Anatomy of the Nose

In the lateral view of the skeleton, the uppermost part of the nasal bone connects to the frontal bone by the nasofrontal suture. The midline point on the suture is defined as the *nasion*. The depressed area below the nasion is the nasal root, where the most depressed part is usually located slightly superior to the medial canthal tendon of the eyelid. On the skin, the most depressed point is usually more cranial to the point directly over the bony nasal root because the subcutaneous fat and the mimetic muscles are thick in this area. Heading downward along the nasal ridge, the long straight part protruding anteriorly is the nasal dorsum. The nasal dorsum is narrowest at the intercanthal line, which is the line connecting the bilateral medial canthal tendons that becomes wider as you move down the nose. The junctional point between the upper lateral cartilage and lower lateral cartilage is the supratip breakpoint, which is the inferior border of the nasal dorsum. Below the supratip breakpoint, the highest part of the nose is the nasal tip, and the highest point is the pronasale. The inferior border of the nasal tip is the columellar breakpoint, which is the point corresponding to the angle between the medial crus and middle crus of the lower lateral cartilage. The area superior to the tip defining point in the nasal tip is the supratip lobule and inferior to the point is the infratip lobule. The columella is the inferior margin of the nasal septum, ending in the subnasale (**Fig. 17.1**).

In the inferior view, the shape of the nostril and the length of the columella affect the general shape of the lower nose. In general, the length between the bilateral alar creases and the length from the subnasale to the pronasale are equal. Furthermore, the ratio between the length of the height of the nostril and the length of the infratip lobule is 2:1[1]; however, the shape and proportion of this area vary by race (**Fig. 17.2**).[2,3]

Skin

The characteristics of the nasal skin are distinctly different between its upper and lower parts. The upper part of the skin tends to be thin and mobile. Some wrinkles can be observed during changes in facial expression. Conversely, the skin in the lower part of the nose is thicker and tends to fix to underlying structures. As a result, wrinkles are not observed during changes in facial expression in this area. The skin also plays a role in forming the three-dimensionally complicated nasal structure with the underlying cartilage. The lower part of the skin usually has many exocrine glands, namely, sebaceous and sweat glands. Regarding the thickness of the nasal skin, Lesserd and Daniel reported that it is thickest at the nasofrontal groove at approximately 1.25 mm and thinnest at the rhinion at approximately 0.6 mm.[1,4] This means that the skin is the thinnest in the middle area of the nose (around the rhinion), and becomes thicker above and below this point. The thickness of the skin changes by region with the skin in the columella and along the alar margin usually being thinner.[1] At the nostril apex, there is a soft triangle where the nostril lining skin and lobule skin touch without any subcutaneous structure (**Fig. 17.2**).

Subcutaneous Layer

Lesserd and Daniel also reported that four layers are observed in the soft tissue structures under the skin: the superficial fatty panniculus; the fibromuscular layer; the deep fatty layer; and the periosteum (or perichondrium) (**Fig. 17.3**). The superficial fatty panniculus is the layer consisting of subdermal adipose tissue and interlacing vertical fibrous septa. This layer presents throughout the nose but is concentrated in the glabellar and supratip regions. The fibromuscular layer consists of nasal muscles

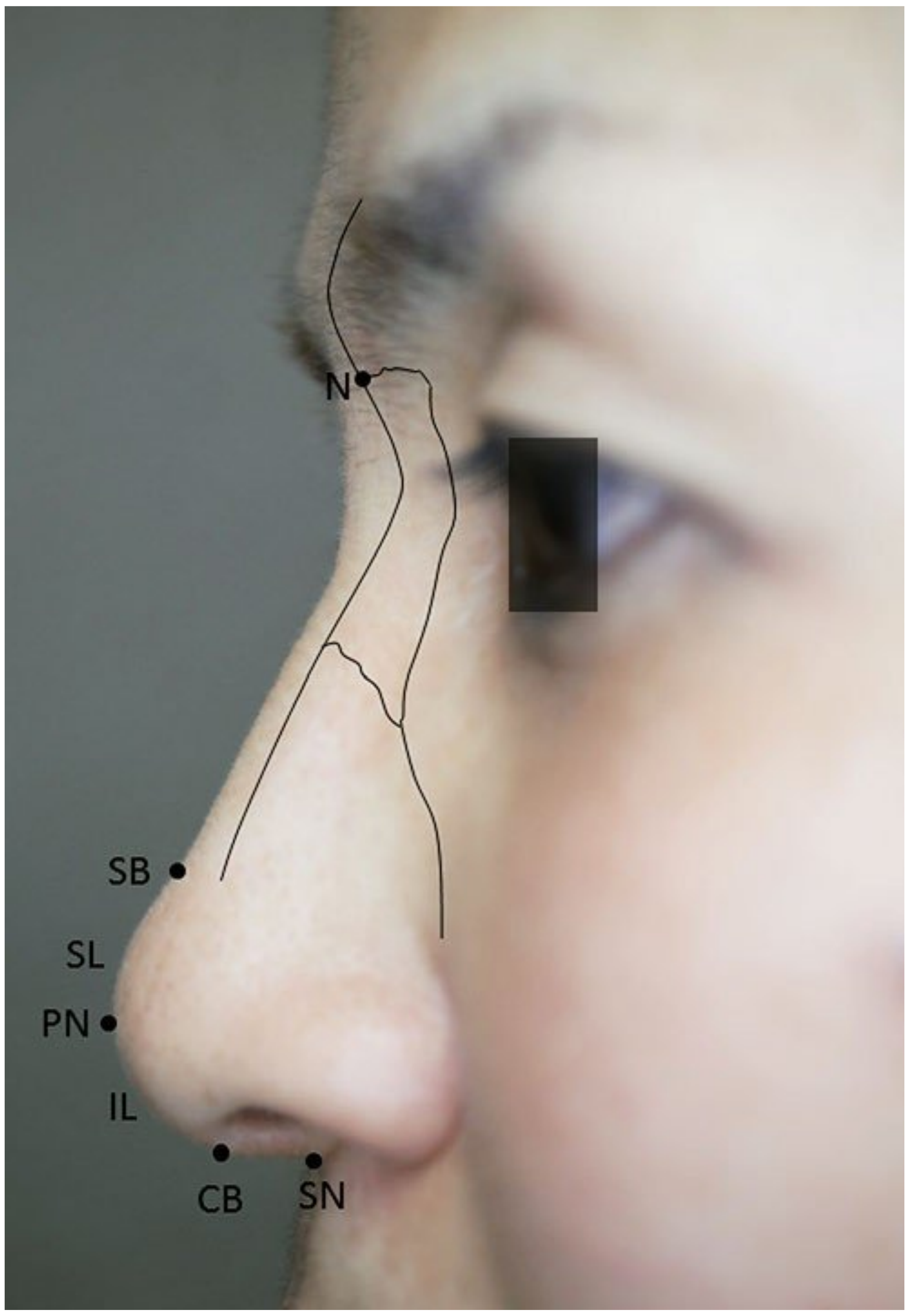


Fig. 17.1 The lateral view of the external nose. CB, Columella breakpoint; IL, infratip lobule; N, nasion; PN, pronasale; SB, supratip breakpoint; SL, supratip lobule; SN, subnasale.

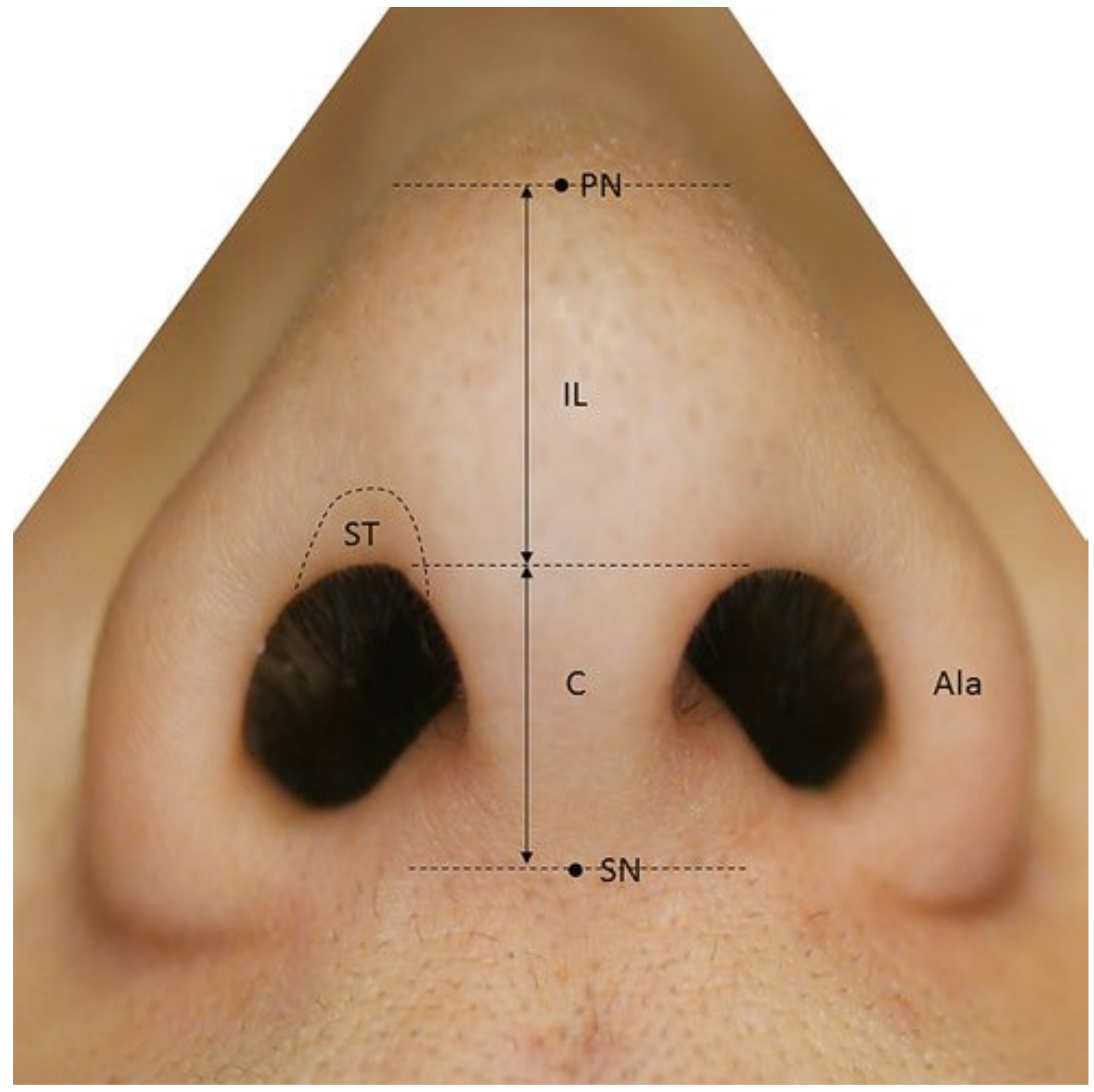


Fig. 17.2 The inferior view of the external nose. C, Columella; IL, infratip lobule; PN, pronasale; SN, subnasale; ST, soft triangle.

and fibrous layers covering the muscles from superficial and deep aspects. This layer is defined as the nasal superficial musculo-aponeurotic system (SMAS) and is continuous with the facial SMAS. The deep fatty layer consists of the loose areolar fat without fibrous septa, which gives mobility to nasal skin.[5]

Muscle Layer of the Nose

The musculature of the nose is categorized functionally into four groups: the elevators; depressors; compressors; and dilators (**Table 17.1**).[1,4,6] The elevators include the procerus, levator labii superioris alaeque nasi, and anomalus nasi muscles. These muscles have a role in lifting and shortening the nose, and also in opening the nasal valve. The depressors include the alar part of the nasalis muscle and depressor septi muscle. These muscles lengthen the nose and dilate the nostril. The compressor includes the transverse part of the nasalis muscle. This muscle also works to lengthen the nose and narrow the nostril. The dilators consist of the dilator naris anterior and posterior muscles and work to dilate the nostril. The zygomatic branch of the facial nerve innervates each of these muscles.

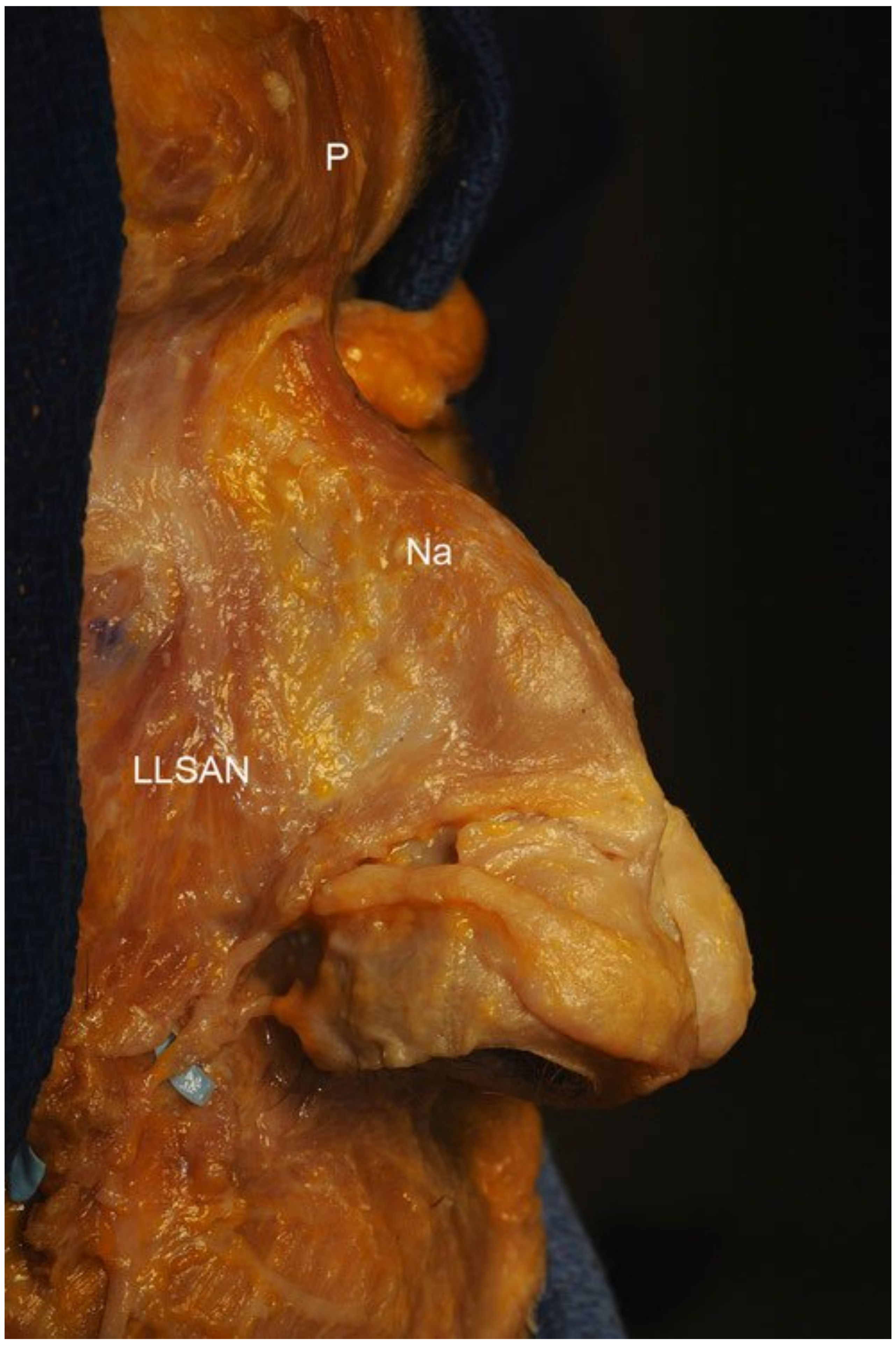
Blood Supply of the Nose

Four arteries originating either from the internal carotid or from the external carotid arteries are the main supply for the external nose (**Table 17.2**). The arteries originating from the internal carotid artery are the dorsal nasal and anterior ethmoidal arteries, both of which are branches of the ophthalmic artery. Two arteries, the angular artery and superior labial artery, originate from the facial artery, one of the main branches of the external carotid artery.

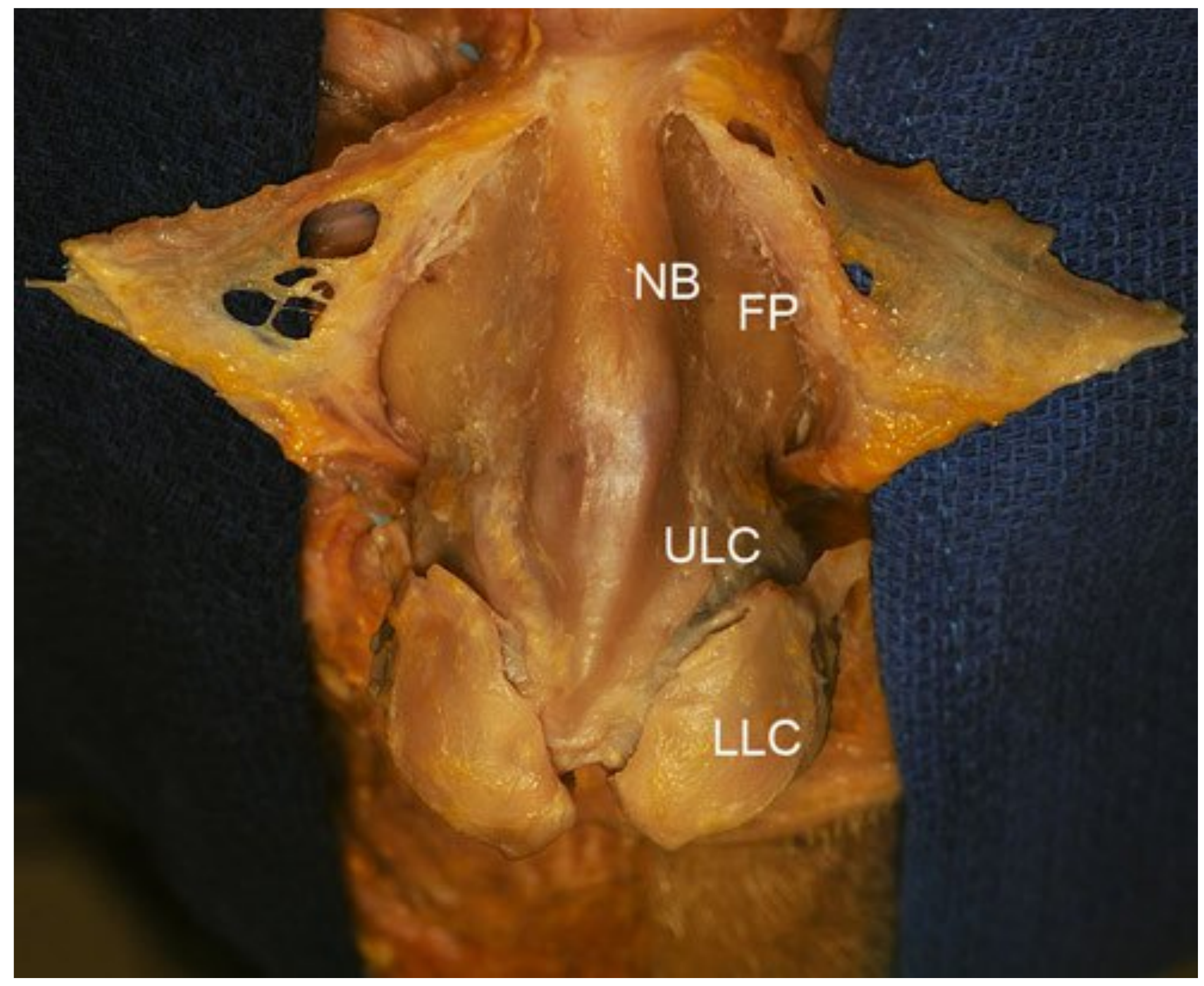
The dorsal nasal artery emerges from the orbital cavity to the subcutaneous layer above the medial canthal tendon, which runs obliquely inferomedially and distributes in the upper dorsal part of the nose. The anterior ethmoidal artery, which is also a branch of the ophthalmic artery, emerges from the base between the nasal bone and the lateral nasal cartilage and runs downward to the nasal tip. The angular artery, which is a continuation of the facial artery, has a number of branches, such as the lateral nasal branch to the lower lateral nose. The superior labial artery primarily supplies the nostril sill and columella.

The venous drainage of the nose is carried out by veins with the same name as the arteries they travel with. These finally drain into the facial vein or the cavernous sinus via the ophthalmic vein.

The arterial and venous networks distribute in or above the mimetic muscle layer (fibromuscular layer; nasal SMAS layer). Then, the desirable layer of dissection of the nose is under the fibromuscular layer to preserve the blood circulation of the nasal skin, prevent bleeding, and to reduce edema after surgery. Especially, open rhinoplasty requires extremely accurate treatment about dissection of the layers.



a



b

Fig 17.3 Soft tissue layers of the external nose. **(a)** The external nose is dissected under the subcutaneous layer. The fibromuscular layer is exposed. LLSAN, Levator labii superioris alaeque nasi, Na, Nasalis; P, Procerus. **(b)** The fibromuscular layer and periosteum are dissected and turned over to the lateral sides. Bony and cartilaginous structures are exposed. FP, Frontal process of the maxilla; LLC, lower lateral cartilage; NB, nasal bone; ULC, upper lateral cartilage.

Table 17.1 Muscles of the nose

Group	Action	Muscles
Elevators	Lifting and shortening the nose	Procerus Levator labii superioris alaeque nasi Anomalous nasi
Depressors	Lengthening the nose and dilating the nostril	Alar part of the nasalis Depressor septi
Compressors	Narrowing the nostril	Transverse part of the nasalis
Dilators	Dilating the nostril	Dilator naris anterior and posterior

Table 17.2 Blood supply of the nose

Artery	Origin	Distribution
Dorsal nasal artery	Ophthalmic artery	Upper dorsal part
Anterior ethmoidal artery	Ophthalmic artery	Nasal tip
Branches of the angular artery	Facial artery	Lower lateral nose
Superior labial artery	Facial artery	Nostril and columella

Table 17.3 Sensory innervation of the nose

Nerve	Origin	Distribution
Supratrochlear nerve	Ophthalmic nerve	Upper part of the nose
Infratrochlear nerve	Ophthalmic nerve	Upper part of the nose
Anterior ethmoidal nerve	Ophthalmic nerve	Distal dorsum and nasal tip
Infraorbital nerve	Maxillary nerve	Distal nose (ala, columella, etc.)

Sensory Innervation of the Nose

Four nerves, the supratrochlear, the infratrochlear, the anterior ethmoidal, and the infraorbital nerves provide sensory innervation to the external nose (**Table 17.3**). The supratrochlear and infratrochlear nerves originate from the ophthalmic division of the trigeminal nerve, emerging from the medial orbital rim and traveling to the subcutaneous layer to be distributed to the upper part of the nose. The anterior ethmoidal nerve emerges from between the nasal bone and lateral nasal cartilage, and is distributed to the distal dorsum and the nasal tip. Injury of the anterior ethmoidal nerve causes sensory disturbance to the nasal tip. The infraorbital nerve is a branch of the maxillary division of the trigeminal nerve that runs inferomedially to the ala after emerging from the infraorbital foramen, and distributes in the distal nose, including the ala and columella.

Bony and Cartilaginous Structures of the Nose

The bony and cartilaginous frame of the nose can be divided into three parts according to structure (**Fig. 17.4**). Pairs of nasal bones form the upper part and frontal processes of the maxilla, the middle part is made of pairs of upper lateral cartilages, and the lower part consists of lower lateral cartilages.

In the upper part, the paired nasal bones and frontal processes of the maxilla form the pyramidal vault in horizontal section. The paired nasal bones are rectangular shaped bone and fuse in the midline. In the lateral view, the nasal bone changes the angle of the ridgeline at approximately the upper one-third point, defined as the nasofrontal groove. The nasal bone is also fused with the frontal bone superiorly by the frontonasal suture and with the frontal process of the maxilla by the nasomaxillary suture. The inferior border joins to the upper lateral cartilage. At the internal surface, the nasal bone connects with the structures forming the nasal septum, such as the nasal spine of the frontal bone, the perpendicular plate of the ethmoid, and the cartilage of the nasal septum. The nasal bone is generally thicker and narrower in the superior region and thinner and wider inferiorly. The bone varies in form and size in different individuals. However, Lessard and Daniel reported that the average length from the nasofrontal suture line to the inferior border is 25.1 mm.[4] The frontal process of the maxilla is the upward projection of the maxilla and fuses with the frontal bone superiorly, with the nasal bone medially, and the lacrimal bone laterally. The levator labii superioris alaeque nasi and orbicularis oculi muscles attach to the process. The medial canthal tendon attaches to the frontal process at the narrowest part of the nose. The line connecting the bilateral medial canthal tendona is the intercanthus line. Taking the inter canthus line as a reference, the nasofrontal suture is ~10.7 mm above, the nasofrontal groove is ~5.8 mm above, and the inferior border of the nasal bone is ~14.4 mm below the line.[4]

In the middle part of the nose, the upper lateral cartilage makes up the hard structure. At the transition zone between the nasal bone and upper lateral cartilage, nasal bone overlaps the cartilage (the nasal bone lies on the upper lateral cartilage), and they connect to each other by dense connective tissue. The overlapping area is called the keystone area, which forms a cres-

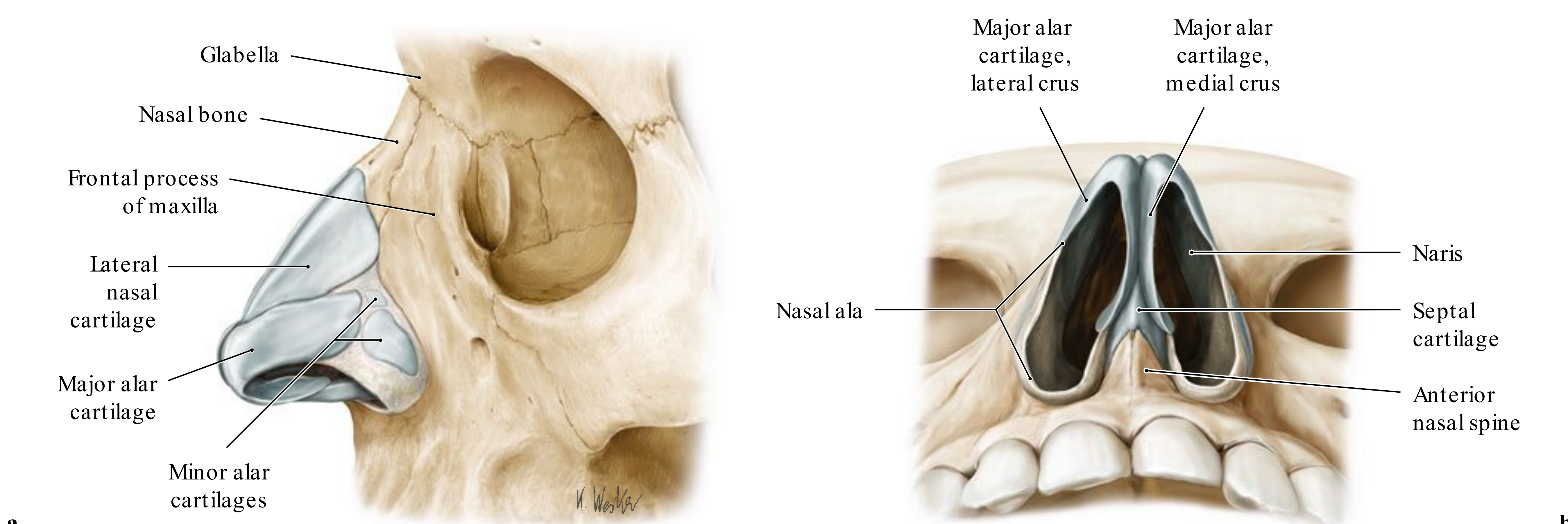


Fig. 17.4 Bony and cartilaginous structures of the external nose. **(a)** Left lateral view. **(b)** Inferior view. (Modified from THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustrations by Karl Wesker.)

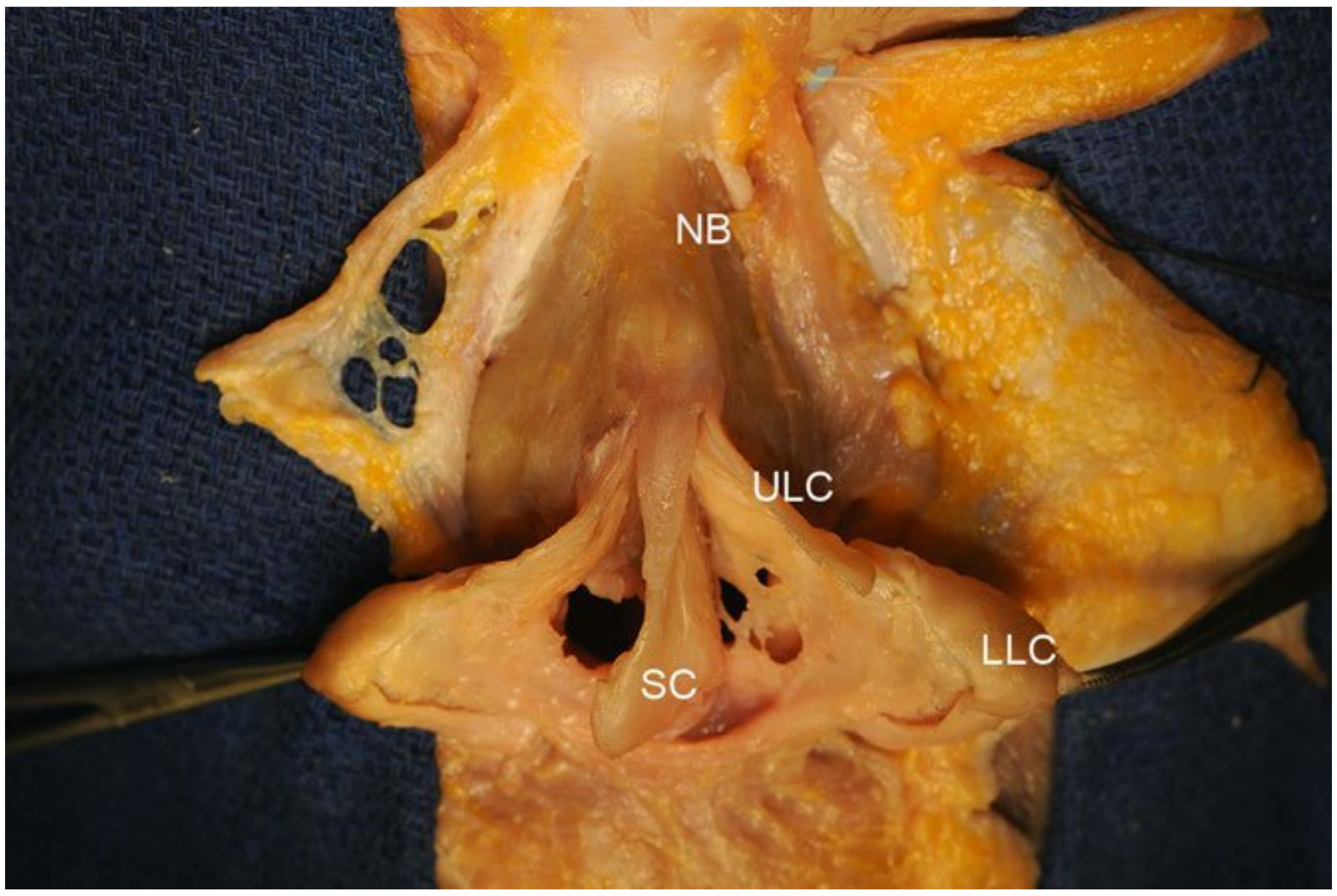


Fig. 17.5 The upper lateral cartilage. Bilateral upper lateral cartilages and cartilaginous regions of the nasal septum integrate as a unified structure, but a linear gap appears between the upper lateral cartilage and the septal cartilage, which is less than two-thirds of the area. LLC, Lower lateral cartilage; NB, Nasal bone; SC, Septal cartilage; ULC, Upper lateral cartilage.

cent shape in a concave upward direction, widest in the midline, decreasing in width laterally.[7] In the upper region of the upper lateral cartilage, including an overlapping area, the bilateral upper lateral cartilages and the cartilaginous part of the nasal septum integrate as a unified structure, but a linear gap appears between the upper lateral cartilage and the septal cartilage that constitutes less than two-thirds of the area (**Fig. 17.5**). Some people consider the upper lateral cartilages to be winglike extensions of the septal cartilage.[8–10] At the lowest part, the upper lateral cartilage connects with the lateral crus of the lower lateral cartilage, which is referred to as the scroll.[9] In most cases, these two cartilages overlap in various shapes, and this connection bears a major tip-supporting mechanism.[11]

In the lower part, a pair of lower lateral cartilages, the alar cartilages, are the supporting structures and affect greatly the shape of the lower nasal structure (**Fig. 17.6**). The lower lateral cartilage can be divided into three crura—the medial, middle, and lateral crura—all three of which intimately correlate to the outer shape of the nose.[12,13] The medial crus consists of the columella and is divided into two segments; the footplate and columella segments. The cartilage is curved convex toward the medial side as a whole, just like a section of cut cylinder, and it curves laterally in the frontal view and posteriorly in the lateral view between the two segments. The footplate segment forms the bulge in the base of the columella, and the columella segment forms the columella. The bilateral cartilages in the columella segment are open in the frontal view. Inappropriate dissection of the columella during open rhinoplasty can cause unexpected bifidity. At the upper border of the columella segment, the columella segment transits to the middle crus, a region known as the columella–lobular junction. In this region, the cartilage is curved posteriorly to some degree in the lateral view, which is referred to as rotation angle.[1,12] The middle crus is the part corresponding to the shape of the surrounding tip area, including the nasal tip and soft triangle. The middle crus is also divided into two segments: the lobular and domal segments. The lobular segment is relatively straight, but bilateral cartilages adjoin the posterior and anterior parts. The domal segment is the region where the cartilage curves drastically in the inferolateral direction on the frontal view and posteriorly on the lateral view.

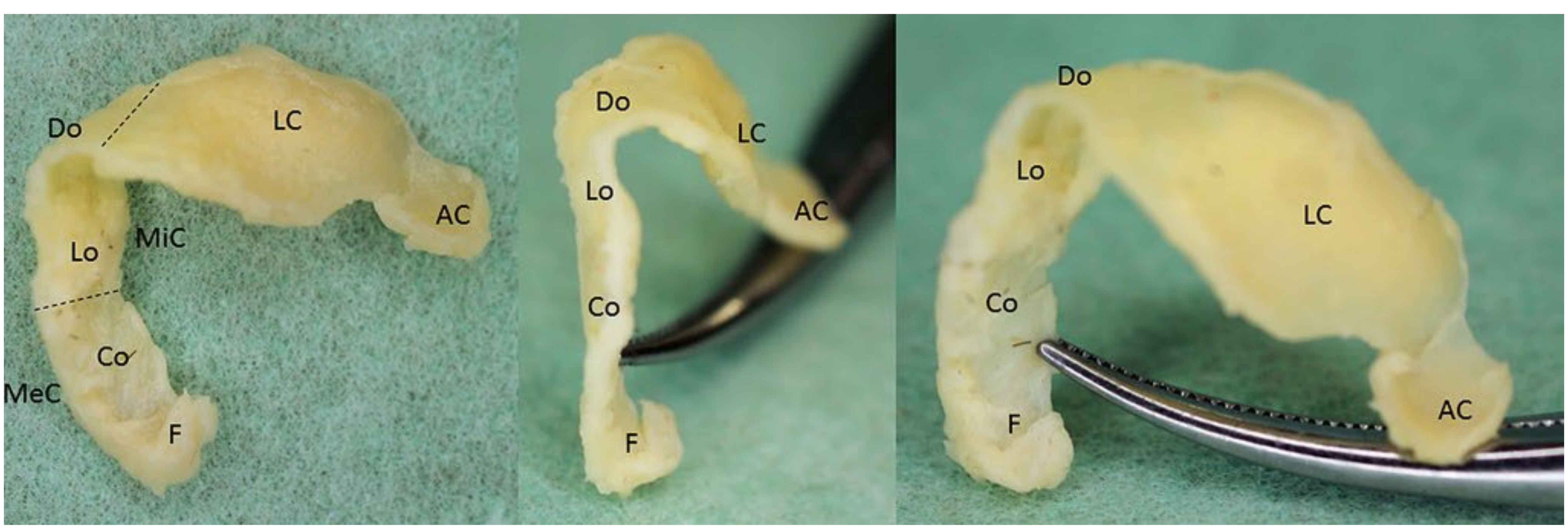


Fig. 17.6 The left alar cartilage (lower lateral cartilage). AC, accessory cartilage; Co, columella segment; Do, domal segment in the middle crura; F, footplate segment; LC, lateral crura; Lo, lobular segment in the middle crura; MiC, middle crura; MeC, medial crura.

The bent part forms the high canopy of the nares. Daniel (1992) described the length of the lobular segment as correlating significantly with tip shape, and the domal segment corresponds to the shape of the soft triangle of the lobule. Lateral to the domal segment is the domal junction, where the transition from the middle crus to the lateral crus is found. The region is located at the border between the tip and ala, with the tip defining points falling on the domal junction line.[12] The lateral crus is located in the alar and is the largest part of the lower lateral cartilage. This region affects the shape, size, and position of the ala. The lateral crus connects to the pyriformis through some accessory cartilages located lateral to the crus.[12] The lower lateral cartilage, accessory cartilage, and the ligaments supporting these cartilages form a ring surrounding the nostril and have an important role in the shape of the nostril.[14,15]

Tip Support Mechanism

The nasal tip lies on the bilateral lower lateral cartilages and is thus supported by the soft elastic pillars. Regarding the supporting system of the nasal tip, Anderson advocated the tripod concept.[16] This system postulates the tip supporting structure as a trigonal pyramid with bilateral lower lateral cartilages and their connection to the surrounding tissues. One pillar of the trigonal pyramid is almost perpendicular and consists of the combination of the bilateral medial crus of the lower lateral cartilages. The other two pillars are sloped and mainly consist of the lateral crus of the lower lateral cartilage. There are also some other structures contributing to the support of the nasal tip, including the ligament connecting the bilateral middle crua, the ligament connecting the bilateral medial crua, the connection between the lateral crus and caudal end of the upper lateral cartilage, known as the scroll area, the membranous septum, the length of the medial crus, the fat pad beneath the columella, and the lateral crus itself.

Conversely, Janeke and Wright and others have reported four kinds of tip-supporting structures, the junction between the lower and upper lateral cartilages, the lateral sesamoid cartilage complex (connection between lower lateral cartilage and the pyriformis), the junction between the medial crus and caudal septum (connection between the caudal septum and the bilateral medial crus), and the interdomal sling (connection between the bilateral middle crus).[17–20] The balance of these three pillars greatly affects the shape of the base of the nose.

References

1. Oneal RM, Beil RJ Jr, Schlesinger J. Surgical anatomy of the nose. Clin Plast Surg 1996;23(2):195–222 PubMed
2. Farkas LG, Kolar JC, Munro IR. Geography of the nose: a morphometric study. Aesthetic Plast Surg 1986;10(4):191–223 PubMed
3. Leong SC, Eccles R. A systematic review of the nasal index and the significance of the shape and size of the nose in rhinology. Clin Otolaryngol 2009;34(3):191–198 PubMed
4. Lessard ML, Daniel RK. Surgical anatomy of septorhinoplasty. Arch Otolaryngol 1985;111(1):25–29 PubMed
5. Letourneau A, Daniel RK. The superficial musculoaponeurotic system of the nose. Plast Reconstr Surg 1988;82(1):48–57 PubMed
6. Griesman BL. Muscles and cartilages of the nose from the standpoint of a typical rhinoplasty. Arch Otolaryngol HeadNeck Surg 1944;39(4):334–341
7. Natvig P, Sether LA, Gingrass RP, Gardner WD. Anatomical details of the osseous-cartilaginous framework of the nose. Plast Reconstr Surg 1971;48(6):528–532 PubMed
8. Basmajian JV, Grant JCB. Grant's Method of Anatomy: By Regions, Descriptive and Deductive. Baltimore, MD: William & Wilkins, 1972
9. McKinney P, Johnson P, Walloch J. Anatomy of the nasal hump. Plast Reconstr Surg 1986;77(3):404–405 PubMed
10. Anderson KJ, Henneberg M, Norris RM. Anatomy of the nasal profile. J Anat 2008;213(2):210–216 PubMed
11. Lam SM, Williams EF III. Anatomic considerations in aesthetic rhinoplasty. Facial Plast Surg 2002;18(4):209–214 PubMed
12. Daniel RK. The nasal tip: anatomy and aesthetics. Plast Reconstr Surg 1992;89(2):216–224 PubMed
13. Sheen JH, Sheen AP. Aesthetic Rhinoplasty. 2nd ed. St. Louis: Mosby; 1987
14. Farkas LG, Deutsch CK, Hreczko TA. Asymmetries in nostrils and the surrounding tissues of the soft nose—a morphometric study. Ann Plast Surg 1984;12(1):10–15 PubMed
15. Stevens MR, Emam HA. Applied surgical anatomy of the nose. Oral Maxillofac Surg Clin North Am 2012;24(1):25–38 PubMed
16. Anderson JR. A reasoned approach to nasal base surgery. Arch Otolaryngol 1984;110(6):349–358 PubMed
17. Bernstein L. Applied anatomy in corrective rhinoplasty. Arch Otolaryngol 1974;99(1):67–70 PubMed
18. Janeke JB, Wright WK. Studies on the support of the nasal tip. Arch Otolaryngol 1971;93(5):458–464 PubMed
19. Han SK, Lee DG, Kim JB, Kim WK. An anatomic study of nasal tip supporting structures. Ann Plast Surg 2004;52(2):134–139 PubMed
20. Rohrich RJ, Hoxworth RE, Thornton JF, Pessa JE. The pyriform ligament. Plast Reconstr Surg 2008;121(1):277–281 PubMed

18 Auricle and External Acoustic Meatus

Noritaka Komune, Junichi Fukushima, and Albert L. Rhoton, Jr.

Introduction

The external ear is formed by the auricle, external acoustic meatus, and tympanic membrane. The auricle is a concave structure that directs sound waves into the external acoustic meatus. It is also cosmetically important and its anatomical structures are extremely complicated and delicate.

The external ear is a focus of otologic and plastic surgery, but it is also important in neurologic and lateral skull-base surgery. Surgery resulting in cosmetic and functional satisfaction relies not only on the surgeon's skill and use of advanced technologies but also on their complete understanding of the area's microsurgical anatomy, which makes surgery gentler and safer.

This chapter examines the microsurgical anatomy of the auricle and external acoustic meatus in cadaveric dissections and organizes the results in the following sections: (1) bone structure, (2) auricle, (3) cartilaginous skeleton of the auricle, (4) external acoustic meatus, (5) muscles, (6) neural innervation, (7) vascular supply, and (8) fascial structure. Finally, there is a short description of clinical considerations.

Bone Structure

The temporal bone consists of five components: squamous, tympanic, petrous, mastoid, and styloid parts (**Fig. 18.1a**). The bony canal of the external acoustic meatus is composed of three parts of the temporal bone: squamous, tympanic, and mastoid. The anterior and inferior bony walls are formed by the tympanic part. The superior and posterior bony walls are formed by the squamous and mastoid parts, and the squamomastoid suture can be identified (**Fig. 18.1b**). The tympanic part produces three sutures: tympanosquamous, tympanomastoid, and petrotympanic. The tympanosquamous suture, between the squamous and tympanic parts, is continuous medially with the petrotympanic and petrosquamous fissures (**Fig. 18.1b**). Additionally, two spines are identified in the bony portion of the meatus: endomeatal and suprameatal spines. The suprameatal spine (Henle's spine) is situated at the upper and posterior part of the orifice of the external acoustic meatus. The endomeatal spine is formed by a projection of the tympanosquamous suture into the canal.

The posterior root of the zygomatic arch of the squamous part forms the roof of the external acoustic meatus. At the anterior edge of this roof, the postglenoid process is positioned between the mandibular fossa and anterior wall of the external acoustic meatus. The tympanosquamous suture runs between the postglenoid process and the tympanic part of the temporal bone.

The edge of the tympanic membrane is thickened to form a fibrocartilaginous ring (tympanic annulus) attached to the tympanic sulcus, an incomplete ring of the tympanic bone that is interrupted by the notch of Rivinus. Above the superior end of the tympanic sulcus, the tympanic annulus becomes a fibrous band. The tympanic membrane within the notch of Rivinus, above the anterior and posterior malleolar folds extending to the lateral process of the malleus, is called the pars flaccida. This part is closely related to the anterior and posterior canal for the chorda tympani and the petrotympanic suture.

Auricle

The auricle is the lateral-most part of the external ear and is composed mainly of cartilage and skin. It is divided into two surfaces: lateral and medial.

The lateral surface is covered by a thin layer of skin, which is formed mainly by the perichondrium and an extremely fine subcutaneous layer. On this surface, the marginal edge is formed mainly by the helix, which is a smooth and round arch. The helix starts at the crus of the helix, passes anterosuperiorly, turns posteriorly and then inferiorly, and finally ends at the helical tail, which is continuous with the lobule. The scaphoid fossa is located just anterior to the helix along most of its length (**Fig. 18.2a,b**).

Next to the entrance of the external acoustic meatus, a well-defined hollow, the concha, leads into the meatus. This hollow has two parts: the cymba and the cavum conchae, separated by the crus of the helix. The antihelix, which has a Y shape, passes upward anterior to the posterior rim of the helix and divides into superior and inferior crura, separated by the triangular fossa. The root of the inferior crus of the antihelix forms the sharp rim of the concha and separates it from the triangular fossa. The superior crus of the antihelix forms the anterior border of the scaphoid fossa. The tail of the antihelix joins the antitragus. The inferior crus, tragus, and antitragus overhang the concha, making it look smaller. The well-defined notch between the tragus and antitragus is called the intertragic notch.

The skin of the medial surface is thicker than that of the lateral surface. On the medial surface, the prominences and sulci follow an obviously inverse pattern to that on the lateral surface (**Fig. 18.2c**). From the medial view, the concha and fossa on the lateral surface are seen as eminences, and the crura are seen as grooves. Eminences include the scaphoid, triangular, and conchal eminences. The antihelix on the lateral surface forms a depression on the medial surface called the antihelical fossa.

The most inferior part of the auricle is the lobule. The lobule is soft, formed mainly by fatty tissue between two cutaneous layers. The main defining feature of this area is the lack of cartilage, which makes the reconstruction of the lobule difficult because of postoperative retraction.

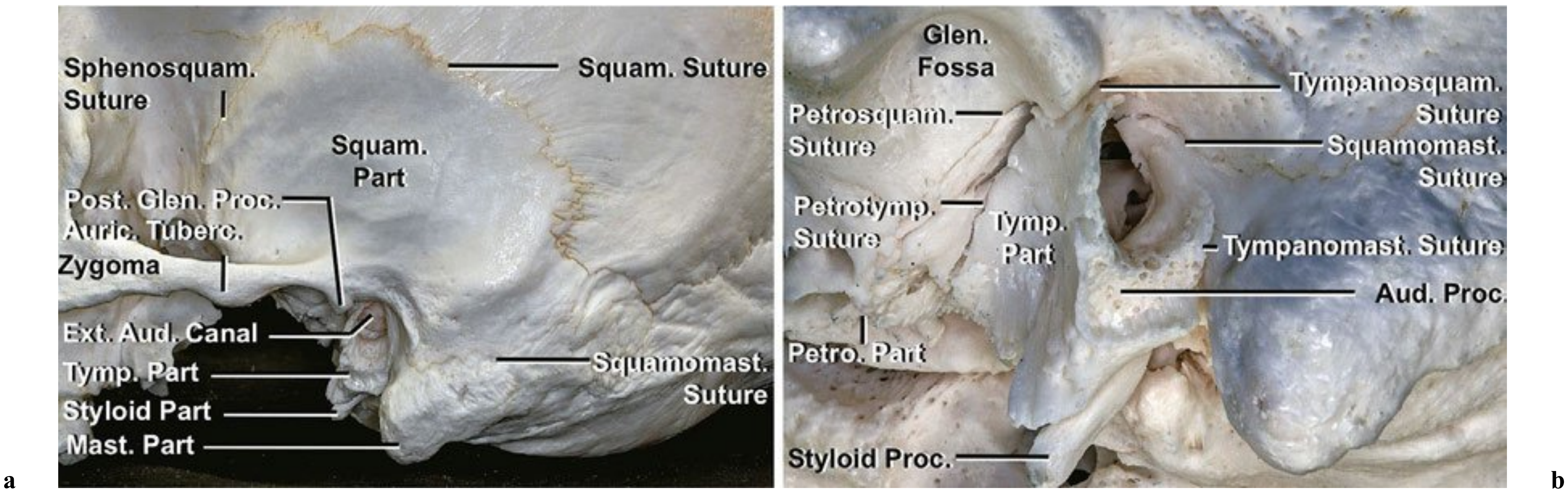


Fig. 18.1 Osseous anatomy and relationships of the external acoustic canal. **(a)** Lateral view. **(b)** Oblique view from anterior, laterally and inferiorly. Aud., Auditory; Ext., external; Glen., glenoid; Mast., mastoid; Petro., petrous; Petrosquam., petrosquamous; Petrotymp., petrotympanic; Proc., process; Sphenosquam., sphenosquamous; Squam., squamous; Squamomast., squamomastoid; Tymp., tympanic; Tympanomast., tympanomastoid; Tympanosquam., tympanosquamous.

Cartilage

The entire auricle except the lobule has elastic cartilage as its framework (**Fig. 18.3**). This cartilage allows the auricle to be flattened, bent, and folded. Repair of cartilage defects and reconstruction of the auricle remain challenging because the cartilage is a unique tissue without its own vascularization. A thin, adherent layer of perichondrium covers the auricular cartilage and can be separated from it; however, this perichondrium is more adherent in some lesions to the fossae.

The cartilage is strikingly similar to the surface of the auricle. Convexities on the lateral surface of the auricle include the helix, antihelix, superior and inferior crura of the antihelix, crus of helix, tragus, and antitragus. Concavities include the triangular fossa, cymbal and cavum conchae, and scaphoid fossa. The depressions and elevations on the lateral surface are aligned with the elevations and depressions on the medial surface.

From the surface of the auricle, some cartilaginous structures that are not seen are the incisura terminalis, ponticulus, antitragohelicina fissure, cauda of the helix, cartilage of the external acoustic meatus, and spine of the helix. The incisura terminalis separates the tragal lamina, which is the vertical curved plate of the tragus, and the cartilage of the external acoustic meatus from the main auricular cartilage. The lower part of the helix continues downward as a process called the cauda of the helix. The cauda of the helix is separated from the antitragus by a deep fissure, the antitragohelicine fissure. The spine of the helix is the anterior extremity of the crus of the helix. The ponticulus is the vertical ridge crossing the eminence of the concha on the medial surface. A deep groove can be identified on the medial surface between the eminences of the triangular fossa and concha. This deep groove is called the transverse sulcus of the antihelix and corresponds to the antihelix and its inferior crus on the lateral surface.

The cartilage of the external acoustic meatus forms a semicanal that extends medially from the lateral lamina of the tragus. This cartilaginous semicanal is usually interrupted by two vertical fissures in the anterior portion of the cartilage (Santorini fissures). These fissures can allow infections and malignant tumors to extend between the external acoustic meatus and parotid gland.

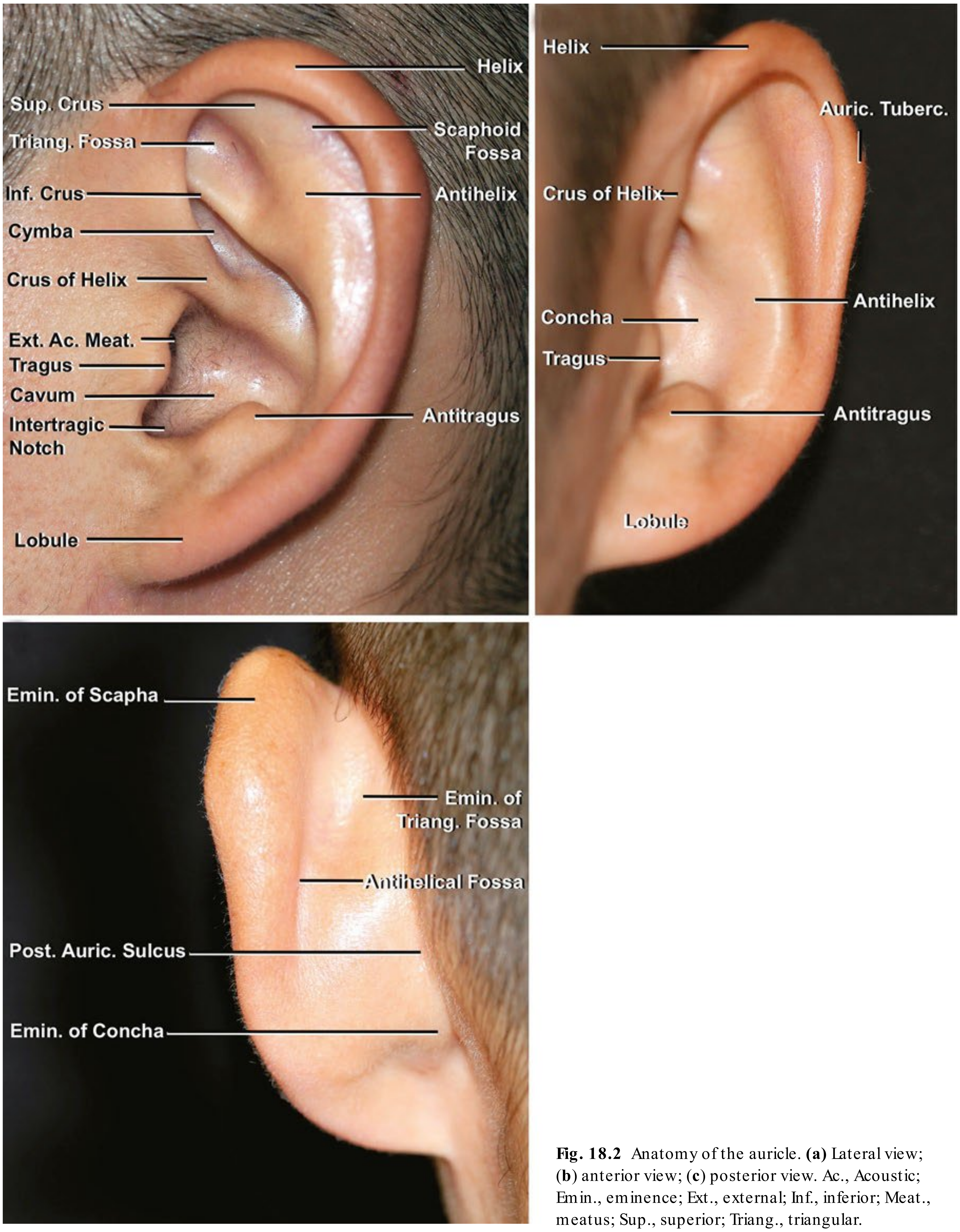
The cartilage of the auricle is attached to the auditory process, which is the lateral edge of the tympanic part of the temporal bone and has an extremely rough surface (**Fig. 18.1b**), and fixed to the skull by three ligaments: anterior, superior and posterior. The anterior ligament attaches the helix and tragus to the zygomatic process. The superior ligament attaches the spine of the helix to the superior margin of the bony external auditory canal. Furthermore, the posterior ligament is located between the medial surface of the concha and the mastoid process.

External Acoustic Meatus

The external acoustic meatus extends from the bottom of the concha to the tympanic membrane, forming an S shape that is divided into cartilaginous and bony portions (**Fig. 18.4**). First, it extends medially and slightly anteriorly and superiorly, then it turns medially and slightly posteriorly (cartilaginous part), and finally passes medially, anteriorly and slightly inferiorly (bony part). Pulling the auricle posteriorly and superiorly makes the canal straight and provides better visualization of the tympanic membrane.

The external canal has two narrow portions. One is close to the inner end of the cartilaginous portion (cartilage-bony junction), and the other is the isthmus in the osseous portion. The isthmus is the narrowest point along the canal and is located not at the cartilage-bony junction but in the bony portion.

The cartilaginous portion is continuous with the cartilage of the auricle and attaches to the auditory process, where the cartilage is attached medially to the bony part with dense connective tissue (**Fig. 18.1b**). The posterior and superior part of the cartilaginous part actually lacks cartilage but is filled with fibrous tissue.



a b c

Fig. 18.2 Anatomy of the auricle. **(a)** Lateral view; (**b**) anterior view; (**c**) posterior view. Ac., Acoustic; Emin., eminence; Ext., external; Inf., inferior; Meat., meatus; Sup., superior; Triang., triangular.

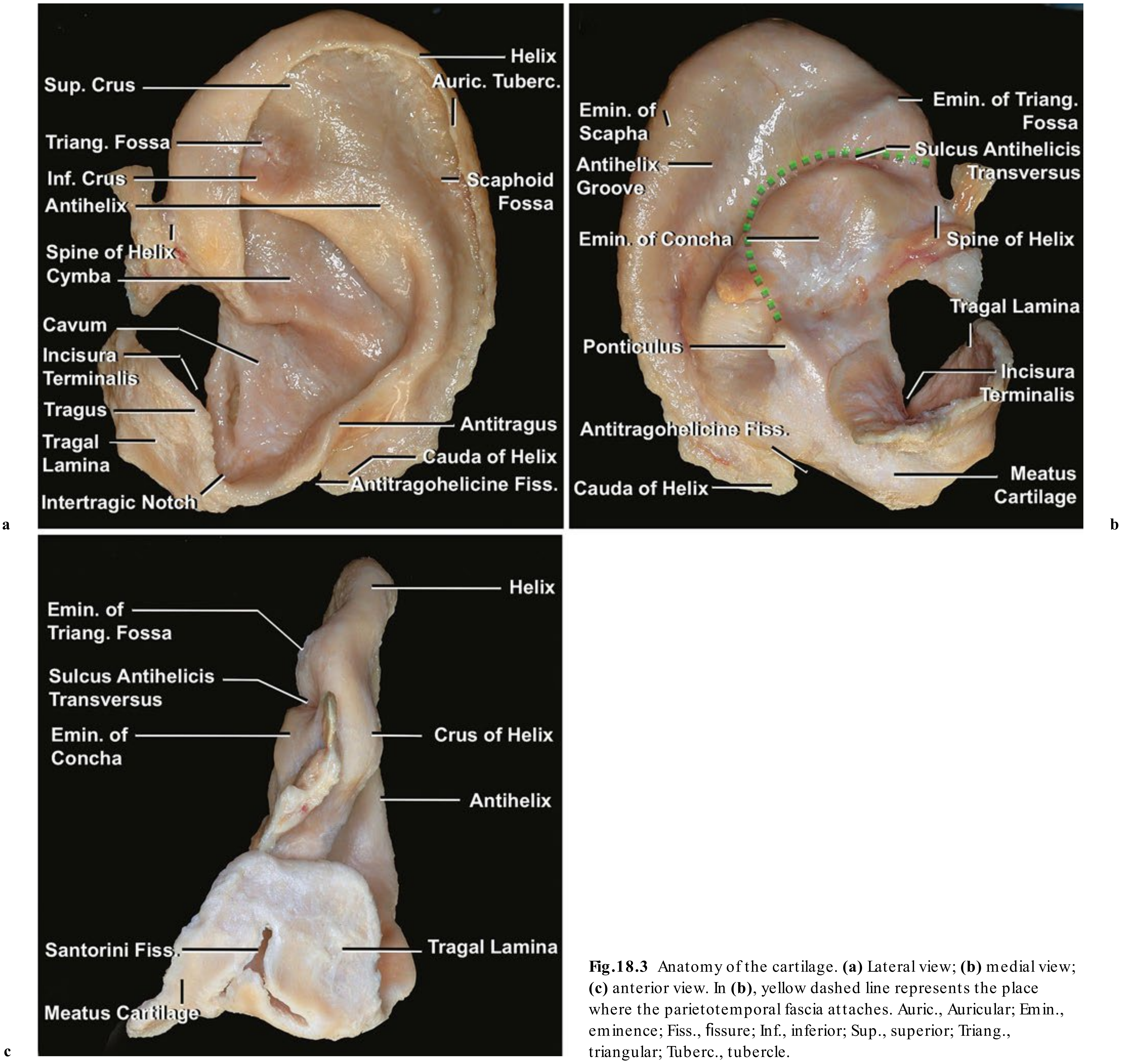


Fig.18.3 Anatomy of the cartilage. **(a)** Lateral view; **(b)** medial view; **(c)** anterior view. In **(b)**, yellow dashed line represents the place where the parietotemporal fascia attaches. Auric., Auricular; Emin., eminence; Fiss., fissure; Inf., inferior; Sup., superior; Triang., triangular; Tuberc., tubercle.

The bony portion is narrower than the cartilaginous portion. The conically shaped tympanic membrane is located at the medial end of the meatus and is titled anteroinferiorly. The angle between the tympanic membrane and the anteroinferior bony wall (anterior tympanomeatal angle) is acute and often obstructed by the bony eminence of the anterior wall.

The tympanic membrane is composed of three layers. The lateral epithelial layer is continuous with the skin of the external acoustic meatus. The middle fibrous layer is called the lamina propria, which is not identified in the pars flaccida. The medial mucosal layer is continuous with the mucosa of the middle ear cavity.

The skin covering the meatus is visibly thin, though slightly thicker on the cartilaginous portion than the bony portion, and it adheres closely to the cartilaginous and osseous portions of the meatus. The skin of the bony portion has no hair or glands. In the cartilaginous part, the subcutaneous tissue has hair follicles and ceruminous and sebaceous glands, which secrete the yellowish brown earwax.[1,2] In the auricle, the sebaceous glands are predominant in the concha and triangular fossa; ceruminous glands are located around the orifice of the external acoustic meatus.[3,4]

In three regions, the skin is more firmly adherent to the bony canal: (1) supra meatal spine (Henle's spine), (2) tympanomastoid suture, and (3) endomeatal spine and tympano-

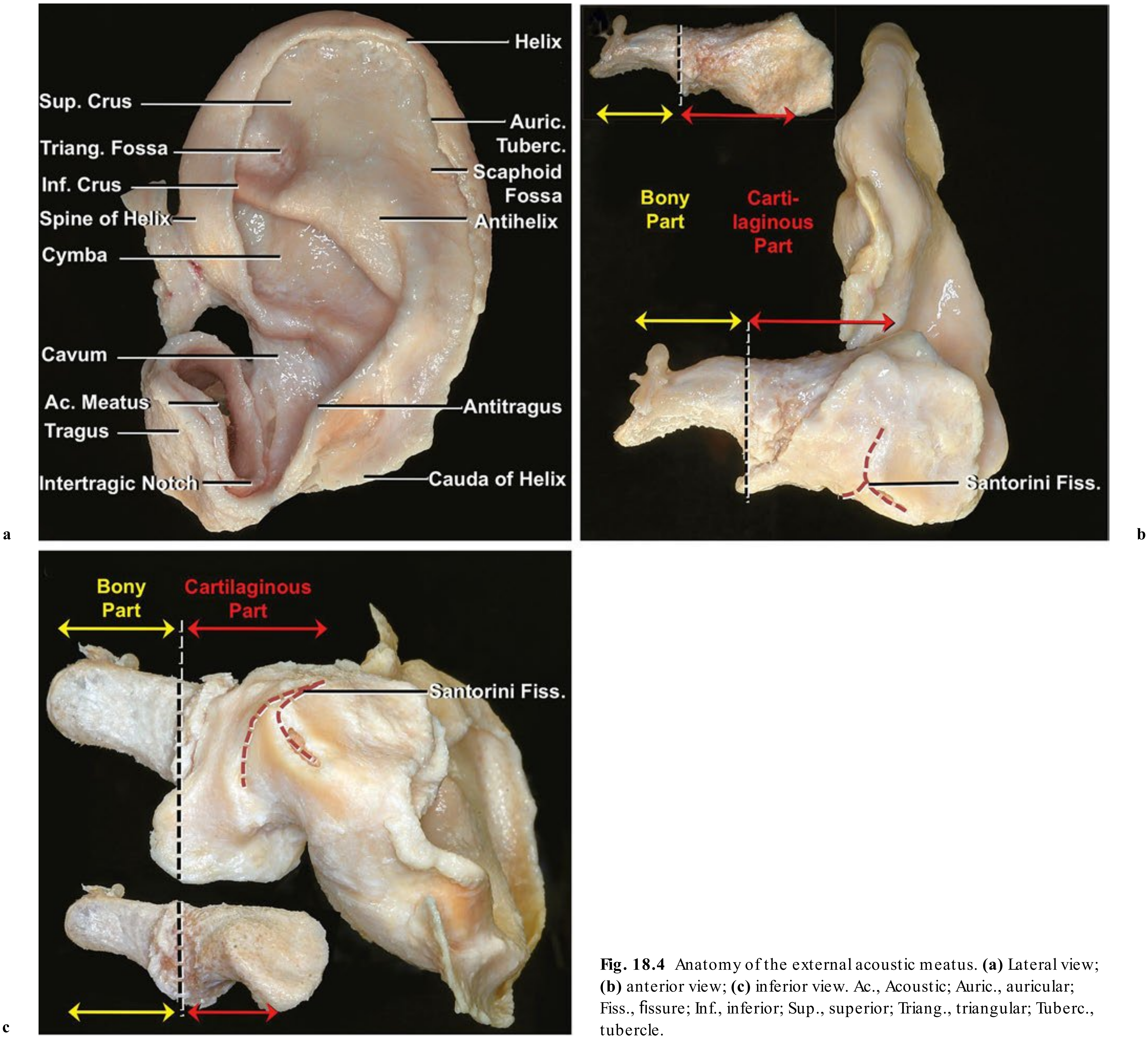


Fig. 18.4 Anatomy of the external acoustic meatus. **(a)** Lateral view; **(b)** anterior view; **(c)** inferior view. Ac., Acoustic; Auric., auricular; Fiss., fissure; Inf., inferior; Sup., superior; Triang., triangular; Tuberc., tubercle.

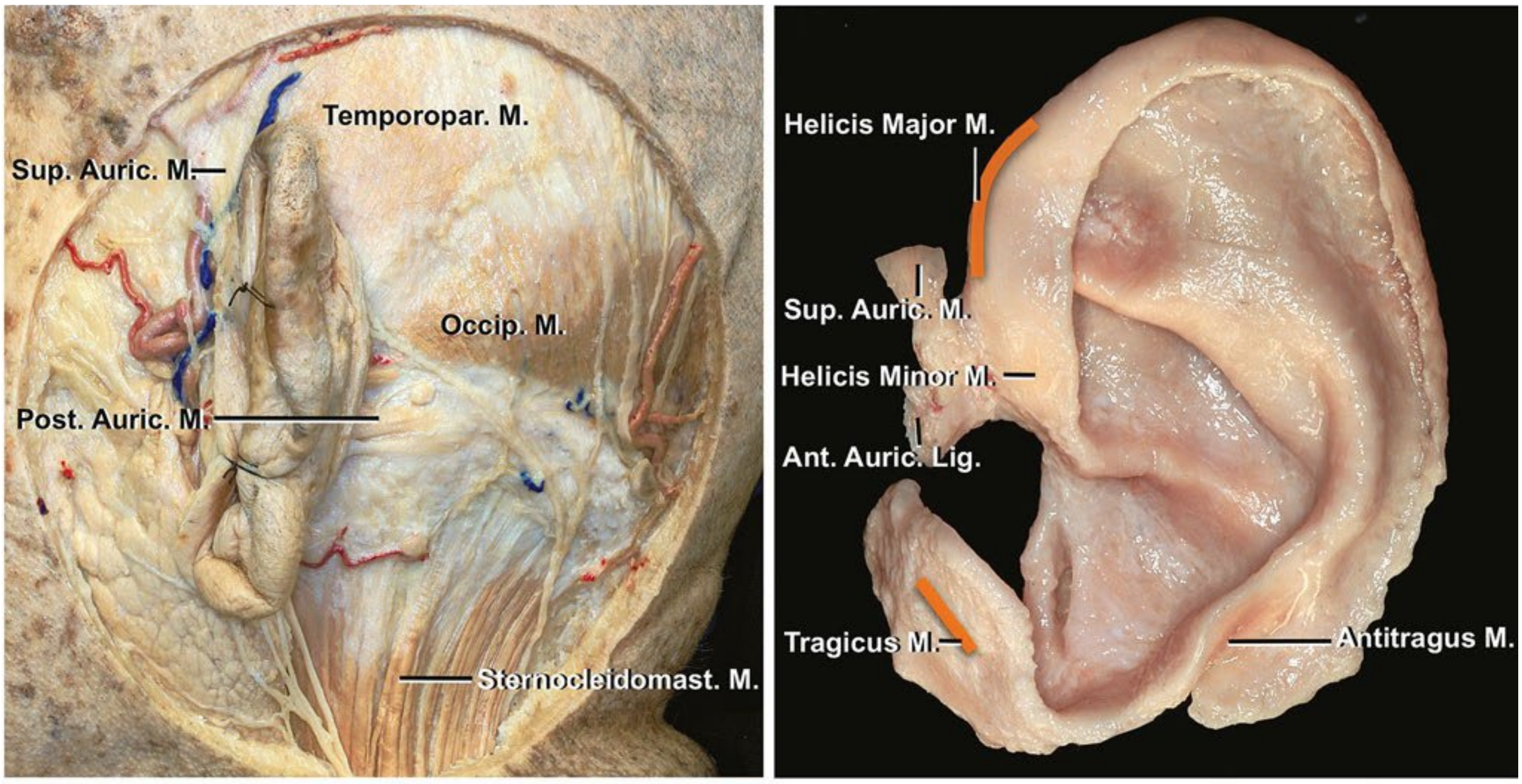
squamous suture. These sutures and spines make elevating a tympanomeatal flap from the bony canal difficult.

Muscle and Facial Nerve

The muscles and ligaments that attach to the auricle are divided into two types: extrinsic and intrinsic (**Fig. 18.5**). The extrinsic muscles include the posterior, superior, and anterior auricular muscles. These muscles are small but hold the auricle firmly in place. The intrinsic muscles include the helicis major, helicis minor, tragicus, antitragicus, transverse auricular, oblique auricular, pyramidal auricular, and incisurae helicis muscles (**Table 18.1**). These intrinsic muscles contribute to creating the complex folded configuration of the cartilage. In humans, the auricular muscles are considered vestigial remnants and thus useless structures.

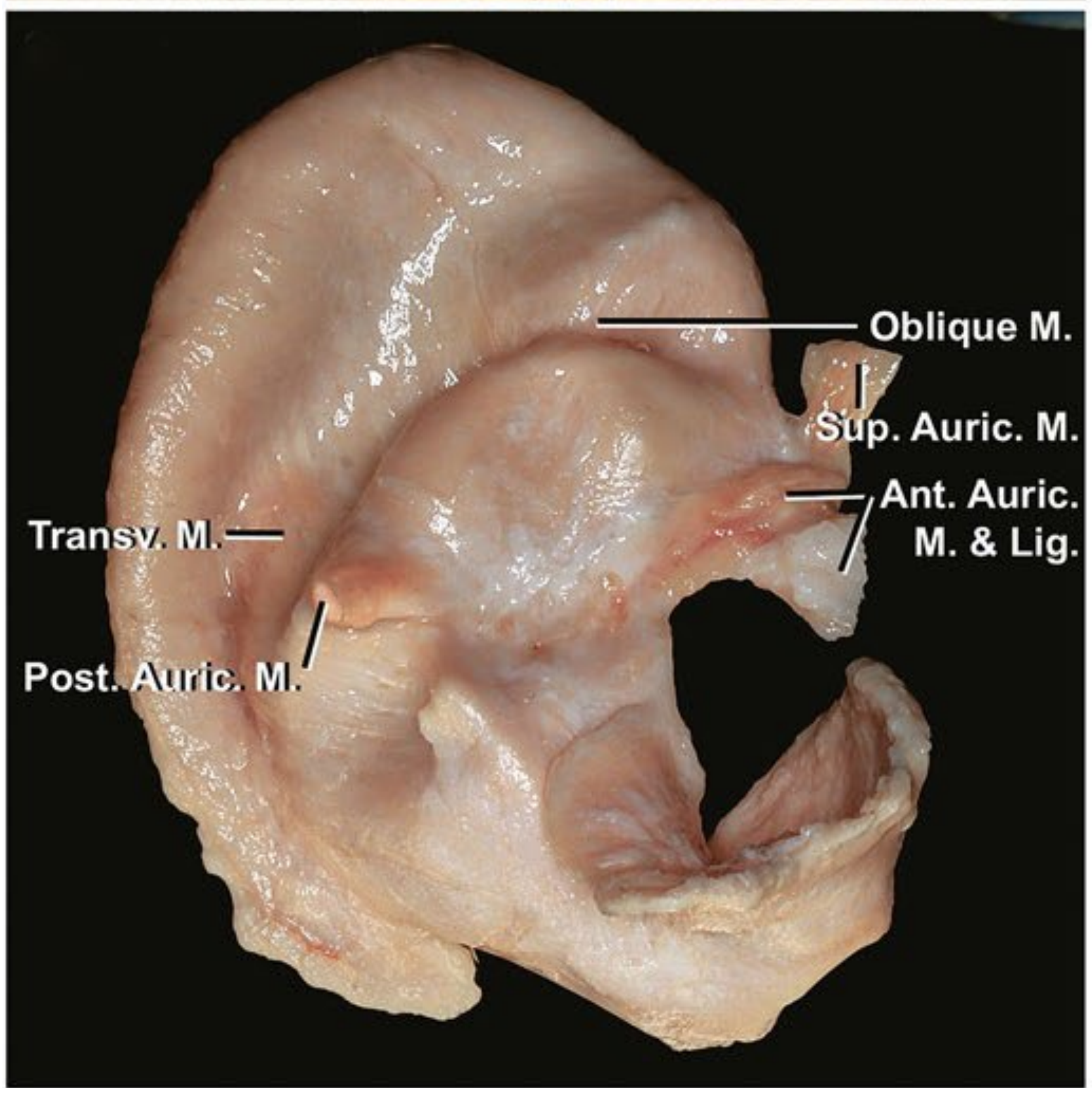
Theoretically, the superior, posterior, and anterior auricular muscles function to pull the auricle, upward, backward, and forward, respectively; however, these muscles are generally too weak to do so. In our dissection, we did not identify the helicis major, incisurae helicis, and pyramidal auricular muscles.

The superior auricular muscle arises from the galeal aponeurosis, which is continuous with the temporoparietal fascia, and inserts into the area around the spine of the helix. The posterior auricular muscle usually has two or three fascicles and is supported by the posterior auricular ligament. These muscles and



a

b



c

Fig. 18.5 **(a)** Muscular structures of the auricle. **(b, c)** Intrinsic muscles on the lateral and medial surfaces, respectively. The orange line in **(b)** shows the intrinsic muscles that are not identified in our dissection. Ant., Anterior; Auric., auricular; Lig., ligament; M., muscle; Occip., occipital; Post., posterior; Sternocleidomast., sternocleido-mastoid; Sup., superior; Temporopar., temporoparietal; Transv., transverse.

Table 18.1 Origin and insertion of the auricular muscles

Muscles	Origin	Insertion
Lateral surface		
Helicis major	Helix	Spine of helix
Helicis minor	Spine of helix	Crus of helix
Tragicus	Tragus	Tragus
Antitragicus	Antitragus	Antitragus
Pyramidal	Tragus	Spine of helix
Medial surface		
Transverse auricular	Eminence of concha	Eminence of scaphoid fossa
Oblique auricular	Eminence of triangular Fossa	Eminence of concha
Incisurae helicis	Tragus	Antitragohelicine fissure

ligament arise from the mastoid periosteum and are attached to the eminence of the cymbal concha and the ponticulus. The posterior auricular ligament supports this muscle and runs parallel to it. The anterior auricular muscle attaches to the zygomatic arch and temporoparietal fascia at the anterior end, and the spine of the helix at the posterior end. This muscle is supported by the anterior auricular ligament, which tethers the tragus and the spine of the helix to the zygomatic arch and temporoparietal fascia. In addition to these three extrinsic muscles, the temporoparietal muscles and part of the occipital muscle are also attached to the medial surface of the auricle by a fibrous ligament, which is part of the temporoparietal fascia.

Innervation

Both cranial and cervical nerves are involved in the sensory innervation of the auricle (**Fig. 18.6**). Four cranial nerves contribute to the innervation of this region: trigeminal, facial, glossopharyngeal, and vagus nerves. Two branches of the cervical plexus are involved: the lesser occipital and great auricular nerves.

The auriculotemporal nerve is a branch of the mandibular nerve, which is the third division of the trigeminal nerve.[5] It arises as two roots from the posterior division of the mandibular nerve and encircles the middle meningeal artery before forming a single trunk. It runs between the neck of the mandible and the sphenomandibular ligament and enters the retromandibular region of the parotid gland posterior to the temporomandibular joint and mandibular neck. It gives off parotid branches and turns superiorly to give off anterior branches to the auricle, which innervate the anterosuperior parts of the lateral surface. It then crosses over the root of the zygomatic process of the temporal bone, parallel to the superficial temporal artery. It penetrates the superficial muscular aponeurotic system (SMAS) and passes upward superficial to the temporoparietal fascia. The fibers of the superior root of this nerve pass through the otic ganglion without synapsing and supply cutaneous sensation to the anterior region of the auricle, external acoustic meatus, outside of the tympanic membrane and skin in the temporal region. The branch innervating the anterior part of the external acoustic meatus and outside of the tympanic membrane passes into the petrotympanic fissure in the glenoid fossa. The glossopharyngeal nerve gives off the parasympathetic fibers that form the tympanic nerve. This nerve enters the tympanic cavity and forms the tympanic plexus with the internal carotid nerve, which is composed of sympathetic fibers, on the promontory in the middle ear cavity. This plexus gives off the lesser petrosal nerve, which synapses in the otic ganglion, and its postganglionic fibers form the inferior root of the auriculotemporal nerve, which provides sympathetic innervation to the scalp, and parasympathetic innervation to the parotid gland.

Four cervical branches, the transverse cervical, greater, and lesser occipital and supraclavicular nerves exit the posterior edge of the sternocleidomastoid muscle at the nerve point. These nerves arise from the cervical nerve plexus formed by the ventral ramus of the C2 and C3. The lesser occipital nerve penetrates the postauricular fascia, where the fasciae of the occipital and sternocleidomastoid muscles attach tightly to the superior nuchal line, divide into the auricular and the occipital branches, and communicate with the greater occipital, postauricular, and great auricular nerves.

The great auricular nerve ascends from the nerve point and plays a major role in the sensory innervation of the auricle. This nerve divides into three types of branches. The most anterior branches innervate the preauricular area. Branches of the second type pass through the lobule and innervate the inferior and posterosuperior parts of the lateral surface of the auricle. The third type of branches passes under or behind the lobule and supplies the medial surface of the auricle and the skin over the mastoid tip.

The vagus nerve, when it exits the intrajugular part of the jugular foramen, gives off the auricular branch, also called Arnold's nerve. A branch of the glossopharyngeal nerve then joins Arnold's nerve, which passes along the anterolateral edge of the jugular fossa and enters the mastoid canaliculus. It travels in the temporal bone and crosses the facial nerve, giving off a tiny branch to the facial nerve, which divides into two branches. One joins the posterior auricular nerve, and the other passes through the tympanomastoid fissure, located between the mastoid process and the tympanic part of the temporal bone, to innervate the posterior wall of the external acoustic meatus and skin around the meatal entrance.

The posterior auricular and frontal branches of the facial nerve innervate the auricular muscles. The posterior auricular nerve arises just after the facial nerve exits the stylomastoid foramen. This nerve passes backward and upward along the anterior surface of the mastoid process. The auricular branch of the vagus and the great auricular and lesser occipital nerves give off branches that join the posterior auricular nerve. This nerve gives off the two main branches that innervate the occipital and auricular regions and the occipital, posterior auricular, and intrinsic muscles on the medial surface of the auricle. In our dissection, the occipital branch passed medial to the posterior auricular muscles and gave off tiny branches to the occipital region and posterior auricular muscle. The branches to the occipital region course between the fascicles of the posterior auricular muscle passing along the superior nuchal line. The frontal and posterior auricular branches innervate the anterior auricular and posterior auricular muscles, respectively.

Vascular Supply

The arterial supply of this area is derived from branches of the external carotid artery (**Fig. 18.7**). The venous drainage follows the arteries. The external jugular vein, maxillary vein, and pterygoid venous plexus are responsible for venous drainage. The external carotid artery gives off occipital and posterior auricular branches and finally divides in the parotid gland into two terminal branches: maxillary and superficial temporal. These four arteries play an important role in the vascularization of the external ear.

The three main arteries supplying the auricle are the posterior auricular, superficial temporal, and occipital arteries. These vessels form a complex network between the skin and perichondrium of the auricle. The posterior auricular artery passes around the mastoid process, gives off the mastoid branch to the

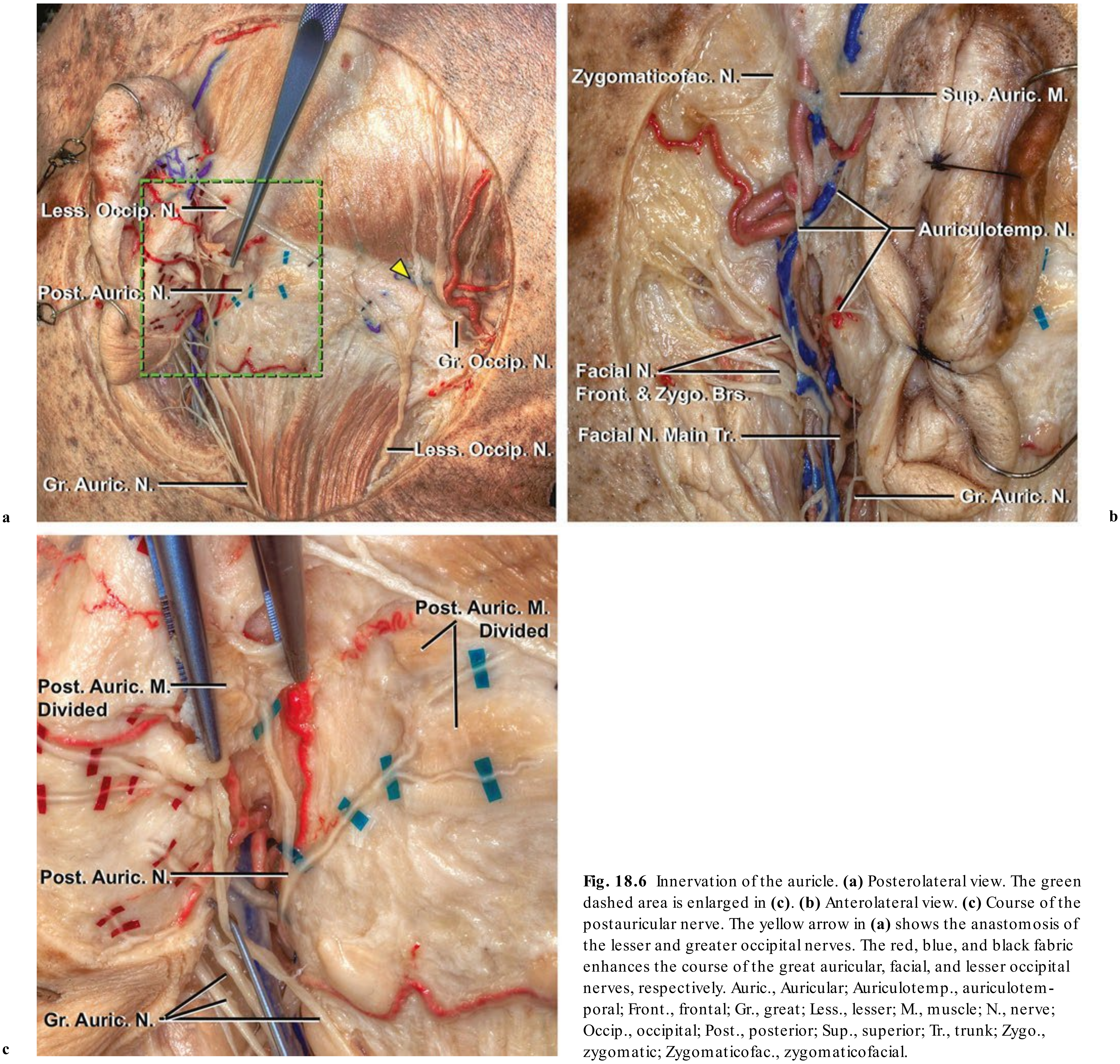
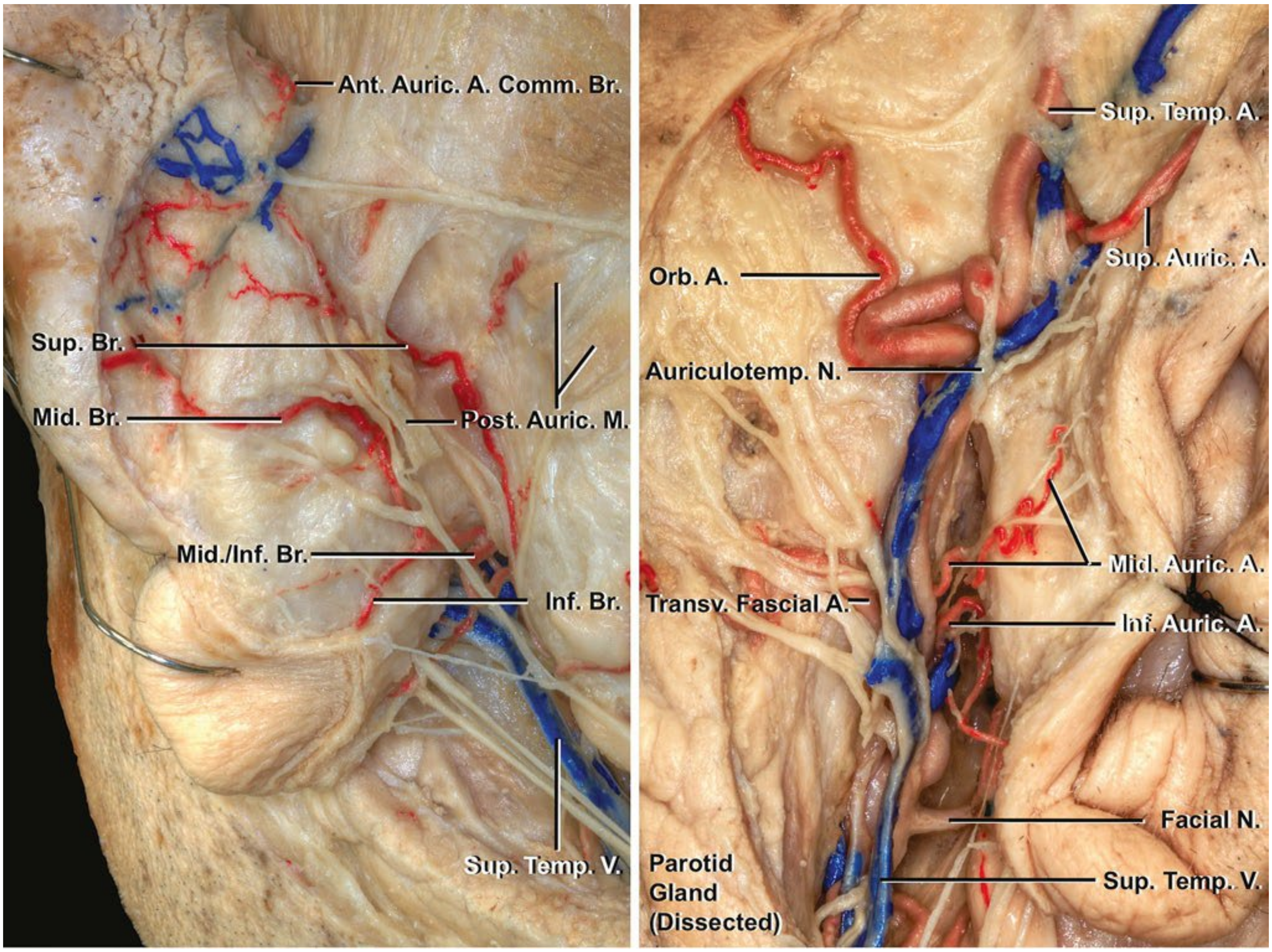


Fig. 18.6 Innervation of the auricle. **(a)** Posterolateral view. The green dashed area is enlarged in **(c)**. **(b)** Anterolateral view. **(c)** Course of the postauricular nerve. The yellow arrow in **(a)** shows the anastomosis of the lesser and greater occipital nerves. The red, blue, and black fabric enhances the course of the great auricular, facial, and lesser occipital nerves, respectively. Auric., Auricular; Auriculotemp., auriculotemporal; Front., frontal; Gr., great; Less., lesser; M., muscle; N., nerve; Occip., occipital; Post., posterior; Sup., superior; Tr., trunk; Zygo., zygomatic; Zygomaticofac., zygomaticofacial.

skin on the mastoid process, and passes superiorly to supply the medial surface of the auricle through three main branches: superior, middle, and inferior.

These branches perforate the cartilage to anastomose with the arterial network on the lateral surface. The superficial temporal artery gives off the anterior auricular branches, which include superior, middle, and inferior auricular arteries that supply the lateral surface of the auricle from the helix to the lobule. There are also perforating branches that penetrate the cartilage from the regions of the antitragus, cymbal conchae, and triangular fossa to supply the medial surface of the auricle. The superior auricular artery's typical course connects the superior temporal artery and the posterior auricular arterial network. The auricular branch of the occipital artery supplies the medial surface of the auricle, especially around the eminence of the concha.

The external acoustic meatus is supplied mainly by three arteries: posterior auricular, superficial temporal, and maxillary. The auricular branches of the superficial temporal artery supply the anterior region and the roof of the external acoustic meatus. The auricular branches of the posterior auricular artery penetrate the cartilage of the auricle and supply the posterior por-



a b

Fig. 18.7 Vascular supply of the auricle. **(a)** Medial surface of the auricle. **(b)** Lateral surface of the auricle. A., Artery; Ant., anterior; Auric., auricular; Auriculotemp., auriculotemp; Br., branch; Comm., communicating; Inf., inferior; M., muscle; Mid., middle; N., nerve; Orb., orbital; Post., posterior; Sup., superior; Temp., temporal; Transv., transverse; V., vein.

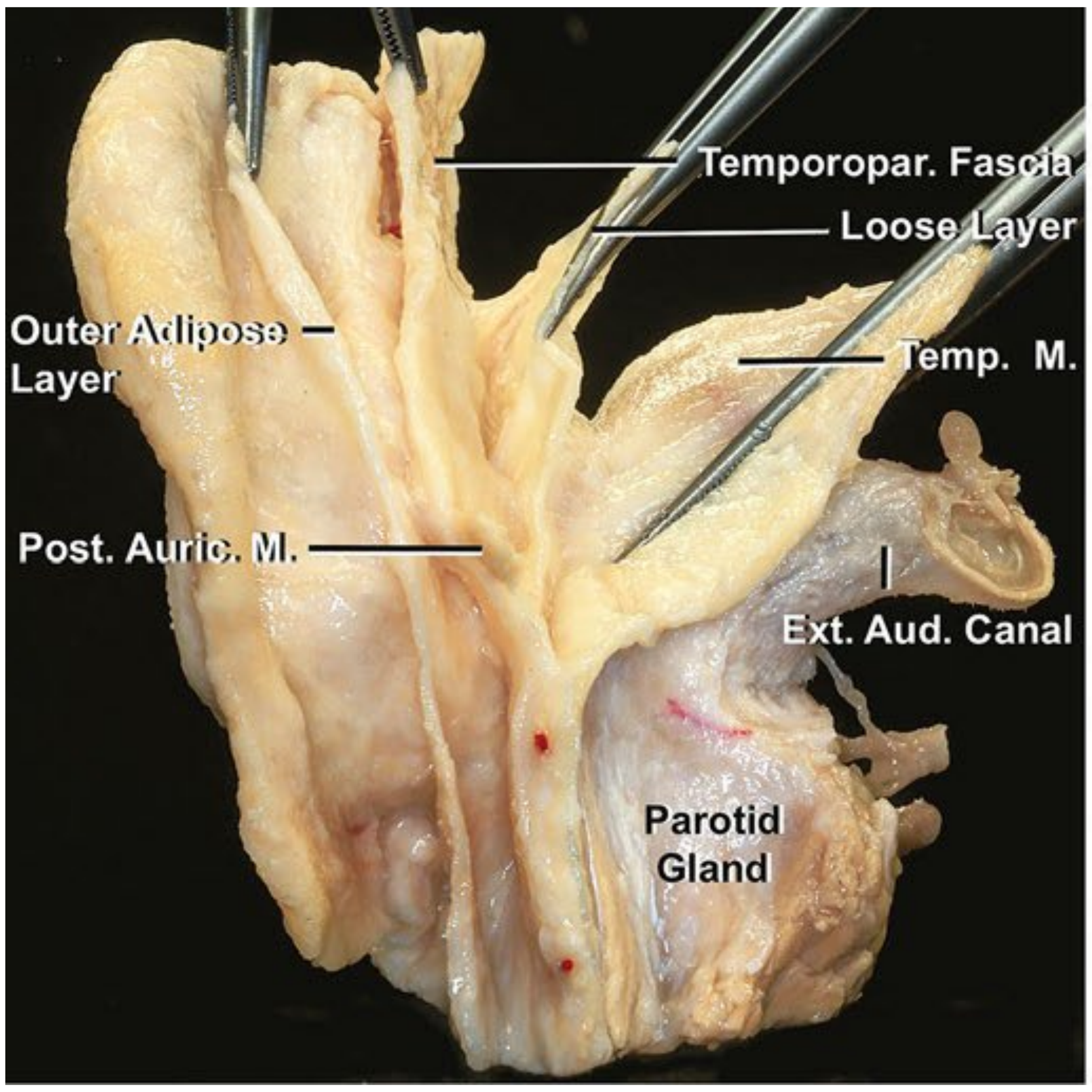
tion of the canal. The deep auricular branch arises from the first portion of the maxillary artery and ascends in the parotid gland behind the temporomandibular joint to pierce the cartilaginous or bony portion of the external acoustic meatus to supply the anterior wall of the meatus and the outer surface of the tympanic membrane.

Aydin et al[6] demonstrated the lymphatic drainage pattern of the auricle. The lymphatic drainage pattern closely follows the vascular supply. Their study with lymphoscintigraphies showed that the injection sites of the technetium-99–labeled nanocolloid within the territory of the superficial temporal artery drained along the superficial temporal vein to the parotid sentinel lymph nodes. The sites within the territory of the posterior auricular artery drained along the posterior auricular vein to the extraparotid sentinel lymph nodes. This drainage pattern has a parallel relationship with embryonic development. The anterior three hillocks derived from the mandibular arch correspond predominantly to the territories of the superficial temporal artery. On the other hand, the posterior three hillocks derived from the hyoid arch correspond to the territories of the posterior auricular artery.

Fascial Layers

The skin of the lateral surface of the auricle is tightly adherent to the perichondrium covering the cartilage framework without the interposition of fatty tissue (**Fig. 18.8**). Vessels and nerves pass within an extremely thin layer between the skin and perichondrium. The skin covering the anterior surface of the lamina of the tragus and the area between the antitragus and helical tail located above the lobule is thicker than that covering the other area of the lateral surface and slides over the cartilage.

In contrast, the skin of the medial surface is loosely adherent to the cartilage with interposition of adipose tissue, which is composed of two layers: superficial and deep. The superficial layer is firm with large fat cells. The deep layer overlying the



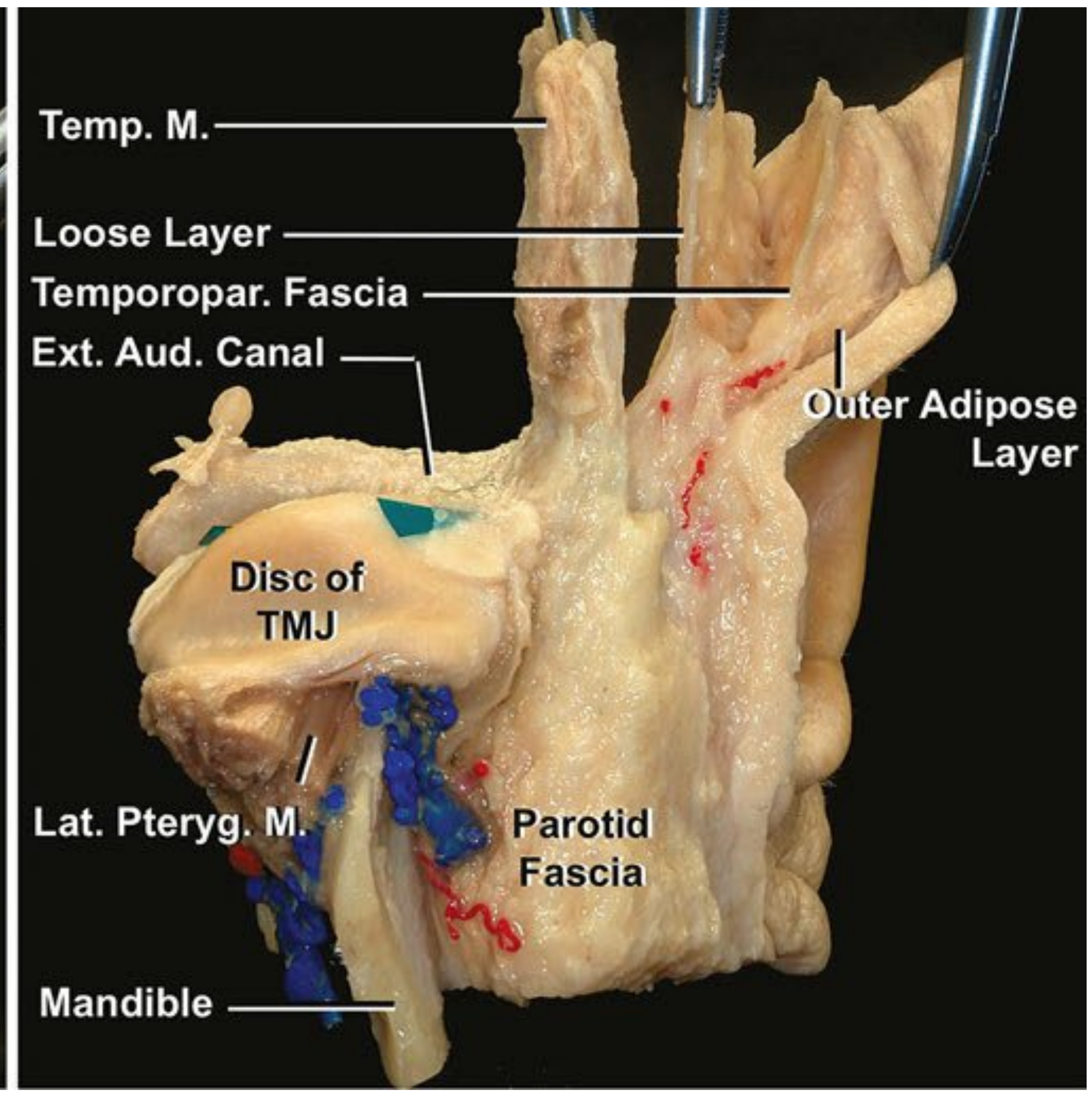


Fig. 18.8 Fascial layers of the auricle. **(a)** Anterior view. **(b)** Posterior view. Blue fabric shows the periosteum of the glenoid fossa covering the auricular disc of the temporomandibular joint. Aud., auditory; Auric., auricular; Ext., external; Lat., lateral; M., muscle; Post., posterior; Pteryg., pterygoid; Temp., temporal; Temporopar., temporoparietal; TMJ, temporomandibular joint.

perichondrium is thin and loose. The nerves, vessels, and lymphatics pass through this adipose tissue, mainly between its two layers. The subcutaneous vascular network also passes more superficially. The skin extends over the helical rim with the transition of its structure from one type to the other.

Generally, the soft tissue of the face is divided into five basic layers: (1) skin, (2) subcutaneous, (3) musculoaponeurotic layers, (4) areolar tissue, and (5) deep fascia/periosteum.[7,8] In the parietotemporal region, the temporal muscle layer is located between the fourth and fifth layers. Davidge et al[9] reviewed previous studies on the layers of the temporoparietal area and proposed, based on the terminologica anatomica,[10] that the layers of fascia in the temporoparietal region are (1) skin and subcutaneous tissue, (2) temporoparietal fascia, (3) loose areolar tissue plane, (4) superficial leaflet of temporal fascia, (5) temporal fat pad of temporal fascia, (6) deep leaflet of temporal fascia, (7) fat pad deep to temporal muscle, (8) temporal muscle, and (9) pericranium. These layers are closed related to the fasciae of the auricle. Our dissection showed the relationship between the auricular and cranial fascial layers is shown.

The temporoparietal fasciae include the superior auricular and parietotemporal muscles and are continuous with the frontal muscle anteriorly, occipital muscle posteriorly, and galea aponeurotica superiorly. This layer attaches around the auricle along the transverse sulcus and ponticulus. Furthermore, it fuses with the superficial layer of the adipose layer of the auricle. Thus, the auriculocephalic sulcus corresponds to the junction of the temporoparietal fascia on the cranial surface and the superficial adipose layer of the auricle. The temporoparietal fascia is tightly adherent to the surface of the mastoid process and is continuous with the strong, heavythick fibrous fasciae, called the superficial mastoid fascia.[11] Datta and Carlucci[11] examined the facial layers around the mastoid process. In this region, the temporoparietal fascia gets thicker and more fibrous and is better vascularized. The areolar layer in the parietotemporal region is continuous with the deep mastoid fascia. In our dissection, these fasciae attached tightly to the superior nuchal line and posterolateral surface of the mastoid process.

The superficial fascia of the temporal muscle (superficial temporal fascia) is one of the two fascia layers covering the temporal muscle and is tightly attached to the anterior border of the zygomatic arch and anterior ligament of the auricle, which attaches to the posterior root of the zygomatic process. Loose areolar tissue is located between the superficial temporal and temporoparietal fasciae. On the posterolateral surface of the mastoid process, these layers are fused with thick fibrous tissue. This areolar layer covers the perichondrium of the cartilage of the auricle on the medial surface of the auricle. The anterior auricular muscle is in a different layer from the temporoparietal fascia and was related to the looser areolar layer on the cranial side in our dissection.

Two adipose layers are present on the medial surface of the auricle between the anterior surface of the lamina of the tragus and the anterior surface of the helix. The outer adipose layer and parietotemporal fascia are fused together and attached to the zygomatic process. The anterior auricular ligament, which arises from the spine of the helix, is also attached to the zygomatic process.

In the area between the cartilage of the tragus and the posterior border of the platysma, which is included in the SMAS, is a diffuse area of the ligamentous attachment, described as the platysma auricular fascia.[12] In this area, the layers from subcutaneous to deep cervical are attached as a retaining ligament and are difficult to separate into layers. This ligamentous region is named by a variety of authors, including Furnas, Stuzin et al, and Loré, as the platysma auricular ligament, parotid cutaneous ligament, and tympanoparotid fascia (Loré's fascia), respectively.[7,12,13]

The deep cervical fascia is attached from the superior nuchal line of the occipital bone to the mastoid process of the temporal bone, and extends to the inferior border of the body of the mandible. This fascia encloses the sternocleidomastoid muscle and binds its anterior edge to the mandible. It also encloses the parotid gland under the parotidomasseteric fascia, and together they extend superiorly and posteriorly to attach to the zygomatic arch, auricle, and mastoid process. A thick fibrous band is located inferior to the auricle, where it firmly tethers the parotid grand to the auricle and the sternocleidomastoid. This fibrous layer extends upward and medial to the parotid gland to the styloid process forming the stylomandibular ligament.

Clinical Considerations

Reconstruction of deformities of the auricle is one of the main concerns of plastic and otologic surgeons. Deformities of the auricle are classified into two groups: congenital and acquired. Previous studies presented a classification of congenital anomalies of the auricle: anotia, microtia, prominent ear, and so forth.[14–16] These classifications utilized embryologic, anatomical, functional, and clinical elements to identify the anomalies of the ear. Appropriate surgical planning for reconstruction depends on the classification of the abnormality. Acquired deformities of the auricle are also difficult to reconstruct. Because of its location, the auricle is vulnerable to deformities caused by external trauma. Furthermore, deformities can also be caused by surgery for malignancies of the lateral skull base. Defects or damages affecting the cartilage are more difficult to reconstruct than skin-only defects. The postauricular flap, used to repair defects of the auricle, is constructed of skin from the posterior ear, which has an abundant vascular supply, and its location ensures that the postoperative scar is hidden behind the auricle. This flap in the postauricular region from the medial surface of the auricle to the superficial mastoid surface has been used in a variety of applications in cosmetic and otologic surgery.

The posterior auricular artery has been reported to be a donor artery for the middle cerebral artery bypass, although it is usually too small for this use.[17,18] Preoperative angiography may reveal that the posterior auricular artery is large enough to use for bypass.

The anatomy of the external ear is complex. It is important to understand the microsurgical anatomy of the external ear to obtain satisfactory cosmetic and functional surgical results. The external ear is important in cosmetic, general, and otologic surgery, as well as neurologic and lateral skull-base surgery.

References

1. Perry ET, Shelley WB. The histology of the human ear canal with special reference to the ceruminous gland. J Invest Dermatol 1955; 25(6):439–451 PubMed
2. Shelley WB, Perry ET. The physiology of the apocrine (ceruminous) gland of the human ear canal. J Invest Dermatol 1956;26(1):13–22 PubMed
3. Morris H, McMurrich JP. Morris's Human Anatomy: A Complete Systematic Treatise by English and American Authors. 4th ed. Philadelphia: P. Blakiston's Son & Co.; 1907
4. Shiffman MA. Advanced Cosmetic Otoplasty Art, Science, and New Clinical Techniques. Berlin, New York: Springer; 2013
5. Joo W, Yoshioka F, Funaki T, Mizokami K, Rhoton AL Jr. Microsurgical anatomy of the trigeminal nerve. Clin Anat 2014;27(1):61–88 PubMed
6. Aydin MA, Okudan B, Aydin ZD, Ozbek FM, Nasir S. Lymphoscintigraphic drainage patterns of the auricle in healthy subjects. Head Neck 2005;27(10):893–900 PubMed
7. Stuzin JM, Baker TJ, Gordon HL. The relationship of the superficial and deep facial fascias: relevance to rhytidectomy and aging. Plast Reconstr Surg 1992;89(3):441–451 PubMed
8. Mendelson BC. Advances in the understanding of the surgical anatomy of the face. In: Eisenmann-Klein M, Neuhann-Lorenz C, eds. Innovations in Plastic and Aesthetic Surgery. New York: Springer Verlag; 2007:141–145
9. Davidge KM, van Furth WR, Agur A, Cusimano M. Naming the soft tissue layers of the temporoparietal region: unifying anatomic terminology across surgical disciplines. Neurosurgery 2010; 67(3, Suppl Operative):120–130 PubMed
10. Federative Committee on Anatomical Terminology, International Federation of Associations of Anatomists. Terminologia Anatomica International Anatomical Terminology. 2nd ed. Stuttgart: Thieme; 2011
11. Datta G, Carlucci S. Reconstruction of the retroauricular fold by 'nonpedicled' superficial mastoid fascia: details of anatomy and surgical technique. J Plast Reconstr Aesthet Surg 2008;61(Suppl 1): S92–S97 PubMed
12. Furnas DW. The retaining ligaments of the cheek. Plast Reconstr Surg 1989;83(1):11–16 PubMed
13. Loré JM, Wabnitz R. An Atlas of Head and Neck Surgery. Vol 2. 3rd ed. Philadelphia: Saunders; 1988
14. Tanzer RC. The constricted (cup and lop) ear. Plast Reconstr Surg 1975;55(4):406–415 PubMed
15. Rogers BO. Microtic, lop, cup and protruding ears: four directly inheritable deformities? Plast Reconstr Surg 1968;41(3):208–231 PubMed
16. Melnick M, Myrianthopoulos NC, Paul NW. External ear malformations: epidemiology, genetics, and natural history. Birth Defects Orig Artic Ser 1979;15(9):i–ix, 1–140 PubMed
17. Horiuchi T, Kusano Y, Asanuma M, Hongo K. Posterior auricular artery-middle cerebral artery bypass for additional surgery of moyamoya disease. Acta Neurochir (Wien) 2012;154(3):455–456 PubMed
18. Tokugawa J, Nakao Y, Kudo K, et al. Posterior auricular artery-middle cerebral artery bypass: a rare superficial temporal artery variant with well-developed posterior auricular artery: case report. Neurol Med Chir (Tokyo) 2013;(Oct):21 PubMed

19 Mandible and Masticatory Muscles

Kyung-Seok Hu and Yang Hun Mu

Introduction

The mandible provides support for the teeth and attachment of the maxillofacial muscles and with the temporal bone, forms the temporomandibular joint (TMJ). Tributaries of the inferior alveolar neurovascular bundle, passing through the mandibular canals, are distributed to the skin of the chin and mandibular teeth. An impingement of the mandibular canal can result in sensory disorders of the mandibular teeth and skin of the chin.

The masticatory muscles consist of the masseter, temporalis, and medial and lateral pterygoids, and these are innervated by the mandibular nerve. The masticatory muscles and their associated neurovascular and fascial systems are important in various surgical approaches.

Mandible

The mandible is the only bone of the lower jaw. It consists of an arch-shaped body and two quadrilateral rami (**Fig. 19.1**). The mandible provides support for the mandibular teeth; provides for attachment of muscles, including facial, masticatory, and infrahyoid muscles; and is the lower component for the TMJ. The bone also provides passage for the inferior alveolar nerve and vessels supplying the mandibular teeth and lower face.

Body

The body of the mandible is U-shaped and convex anteriorly. It has external and internal surfaces and an alveolar part (tooth-bearing portion). The inferior border of the body continues with the ramus, and together they form the mandibular base.

External Surface of the Body of the Mandible

During development, half-sides of the mandible are fused by a mandibular symphysis in the midline (**Fig. 19.2**). A vague median ridge at the upper external surface in an adult mandible can indicate the fused site. The ridge bifurcates at the lower external surface, and the mental protuberance lies between them and is triangular-shaped. Two mental tubercles and the small central depression between them lie on the base of the mental protuberance.

The mental protuberance and tubercles constitute the chin (i.e., the mentum). The mental foramen is usually located below the interval between the premolar teeth or second premolar, approximately on the midpoint between upper and lower border of the mandible. The mental neurovascular bundle emerges from the mental foramen after passing through a canal inside the mandible (mandibular canal). The bundle emerges backward, and thus the posterior rim of the foramen is smooth, whereas the anterior rim is more distinct. The exact position of the mental foramen and the course of the neurovascular bundle within it are important during dental implant procedures.

The external oblique line is faint and ascends posteriorly from the mental tubercle to the anterior border of the ramus of the mandible. The line is distinct farther backward and continuous with the sharp anterior border of the ramus.

Surgical Annotation. Harvesting Bone from the Chin

Alveolar bone resorption resulting from tooth loss reduces supporting bone for the dental implant placement. To enhance vertical bone dimensions, the mandibular symphysis area is recommended as the donor site for the autogenous bone graft. An osteotomy should be made away from the apex of the root of the incisors. It is suggested that the surgical site of the osteotomy be located 5 mm from the dental roots.[1]

Additionally, encroachment of the mental foramen by the osteotomy results in insensitivity on the chin. According to dentition, the mental foramen lies below the premolar area, especially in the interval between these teeth. Superficially, the mental foramen lies about 2 cm below the corner of the mouth and slightly lateral to it. The distance between the bilateral mental nerves is about 45 mm.[2] Regarding the anterior loop (mandibular canal anterior to mental foramen (**Fig. 19.3**), the safe area might be narrower than the interval between the mental foramina.

The cortical plate on the chin is thick further downward. Anatomical research in Asians has demonstrated that the maximum volume of graft block can be harvested from the rectangular site from the mandibular symphysis with a height of 1 to 1.5 cm and a width of 4.0 cm centered at the midline.[1]

Internal Surface of the Body of the Mandible

An oblique mylohyoid line extends from the area below the mandibular third molar as far forward as the midline and gives attachment to the mylohyoid (**Fig. 19.4**). The concave area below the line is a submandibular fossa providing space for the submandibular gland. The line is faint further forward and ends by widening into a concave sublingual fossa for the sublingual gland. The mylohyoid groove from the ramus lies below the mylohyoid line at the posterior end of the mylohyoid line. The digastric fossa lies near the midline on each side on the internal

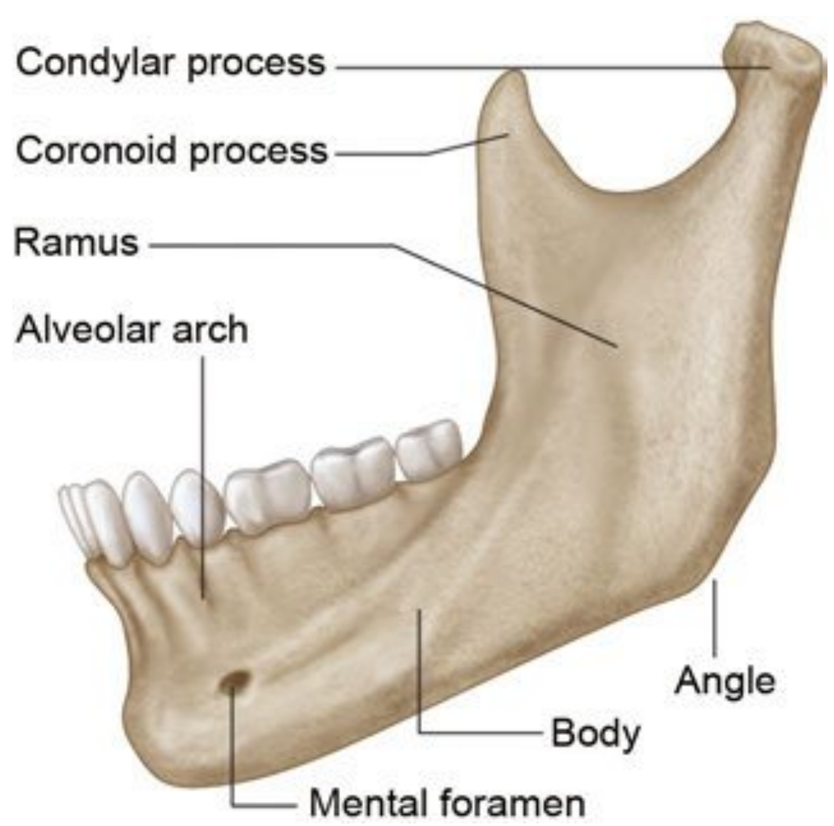


Fig. 19.1 Body and ramus of mandible.

surface of the mandible and gives attachment to the anterior belly of digastric.

Mental spines lie near the internal aspect of the mandibular symphysis on both sides. Although it sometimes merges into a single tubercle or is absent, the spine usually divides into two parts: an upper part for attachment to genioglossus and a lower part for attachment to geniohyoid.

Alveolar Part

The upper border between the internal and external surfaces of the mandible forms the alveolar part, giving support for the mandibular teeth. It contains the alveoli (alveolar sockets) for seven to eight mandibular teeth on one side. The alveolar part consists of the buccal and lingual plates, which are located on the external

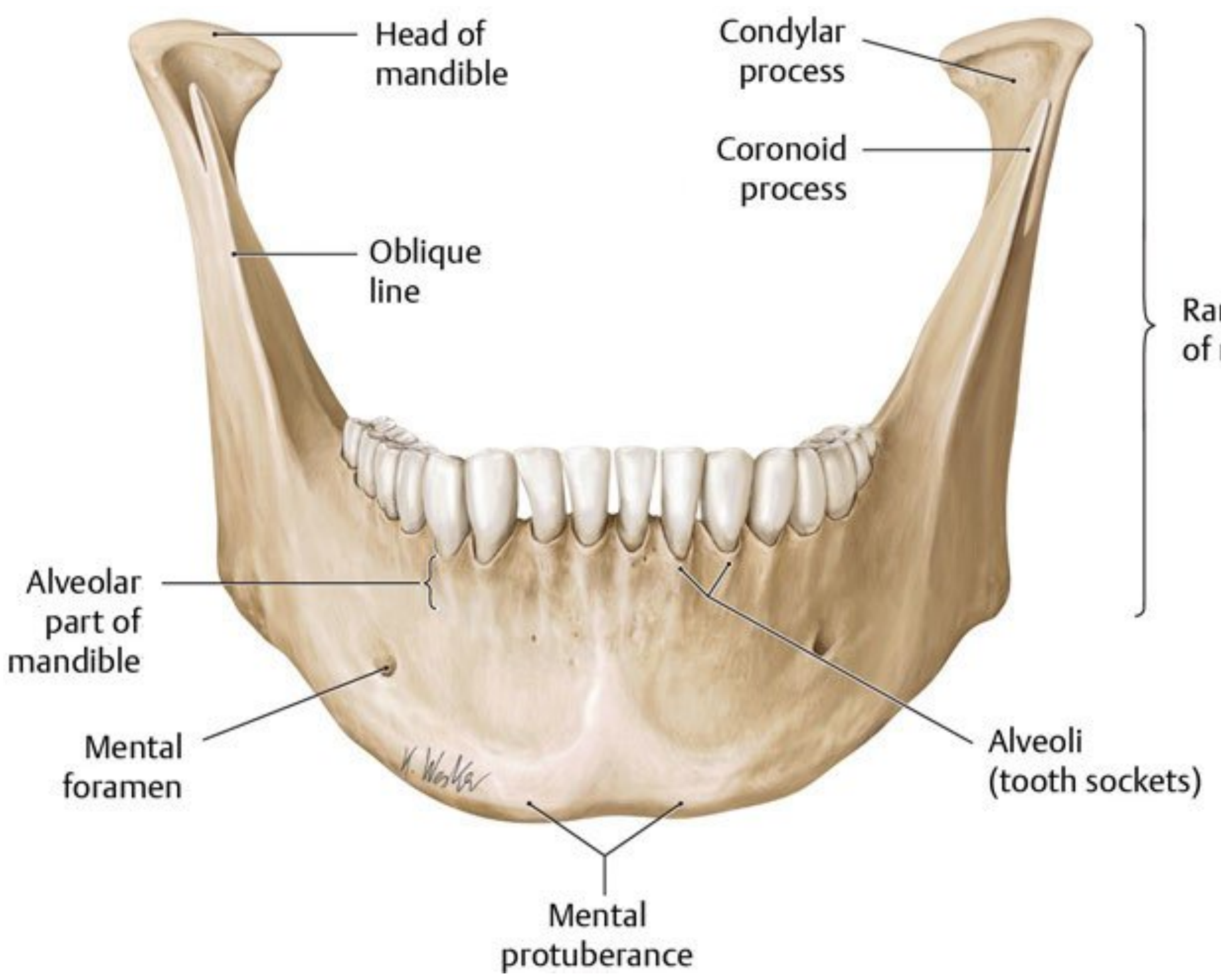


Fig. 19.2 External surface of mandible. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

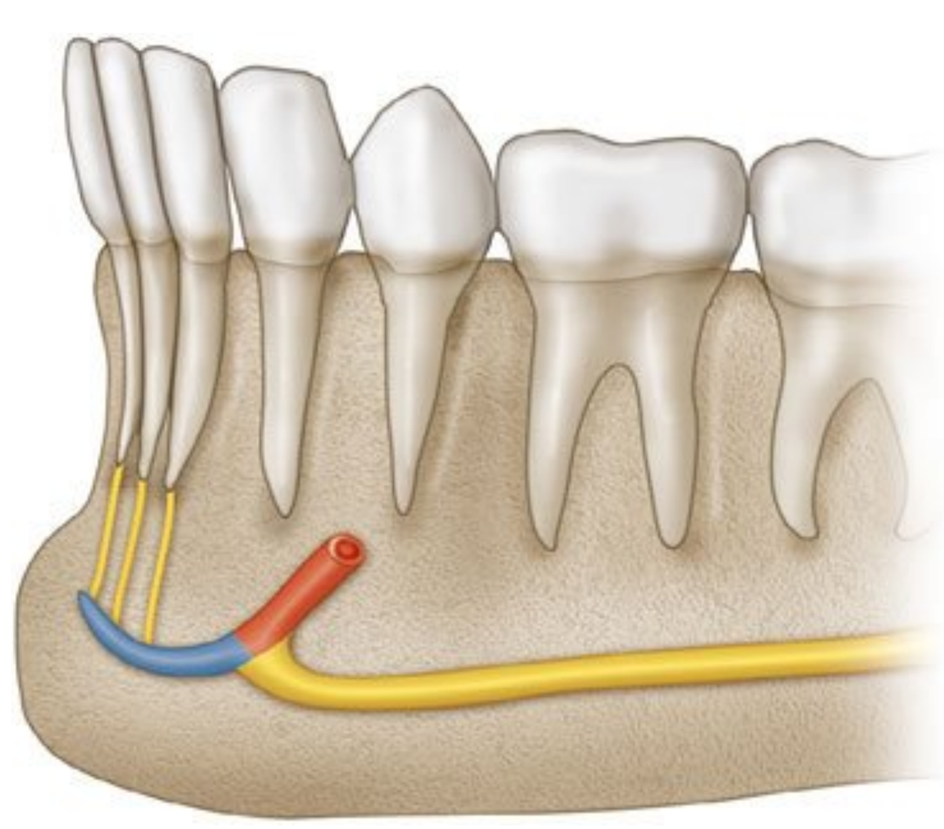


Fig. 19.3 Anterior loop of the mandibular canal. The yellow portion of thick canal represents the mandibular canal, and the red represents the anterior loop of the mandibular canal proceeding toward the mental foramen. The blue portion presents the incisive canal. The yellow small lines in the anterior region indicate the incisive nerves innervating the incisive teeth.

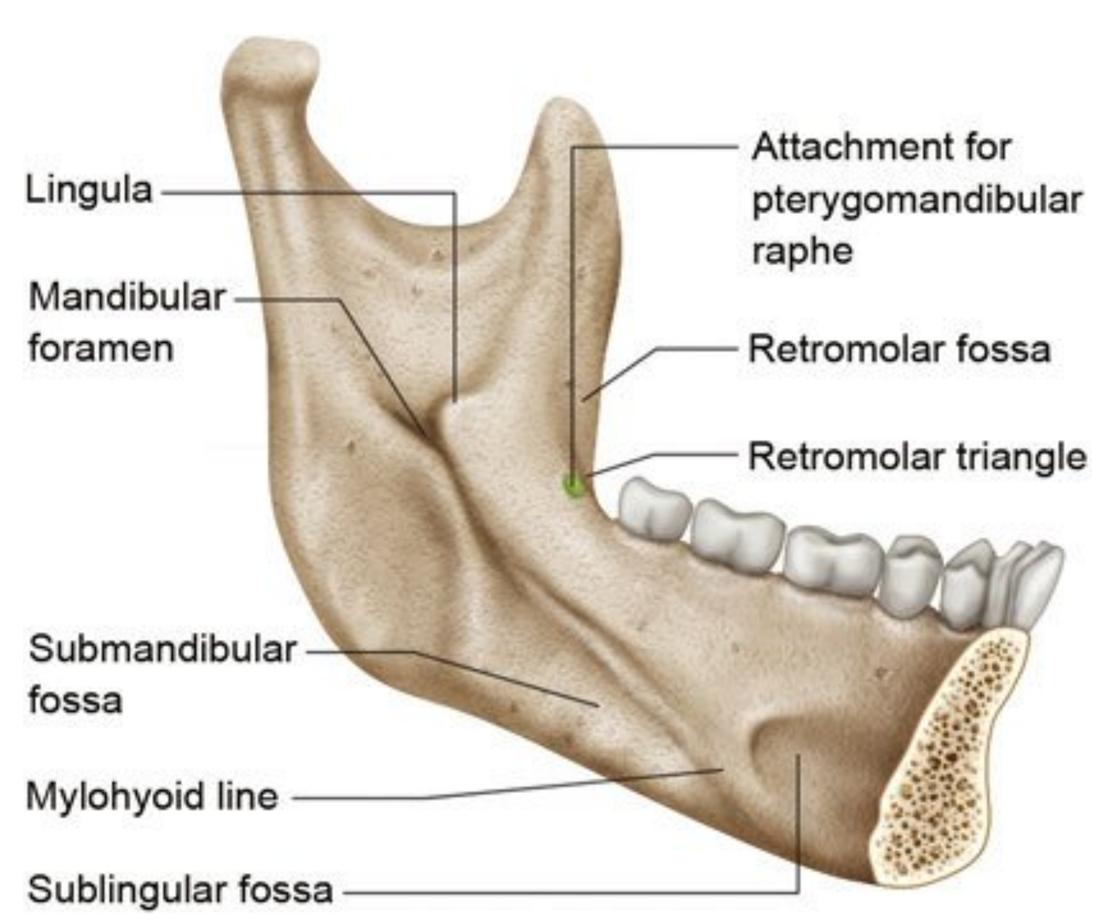


Fig. 19.4 Internal surface of mandible.

and internal aspects of the bone, and interdental and interradicular septa, which separate each tooth and root, respectively.

Ramus

The ramus of the mandible is a broad square-shaped part extending backward and upward from behind the body (**Fig. 19.5**). It consists of lateral and medial surfaces, four borders (superior, inferior, anterior, and posterior), condylar, and coronoid processes. The ramus provides entrance and passage for the inferior alveolar bundle (mandibular foramen and canal), attachment for masticatory muscles, and the condylar process for articulation at the TMJ.

Surfaces and Borders

The lateral surface is smooth except where the masseter attaches to its lower part. The medial surface of the ramus is more complicated. The mandibular foramen, the opening of the mandibular canal, is located at the point just above a center of the ramus. The anterior portion of the foramen is partially covered by a sharp triangular spine, the lingula. The tip of the needle should be placed at the vicinity of the lingula during an inferior alveolar nerve block (**Fig. 19.6**). The ligula lies about 1 cm above the occlusal plane.

The mylohyoid groove extends forward and downward from the lowermost part of the mandibular foramen. The anterior end of the groove lies below the mylohyoid line. Nerve and vessels proceed on the groove and distribute to the mylohyoid, which is the main muscle forming the floor of the mouth. The medial pterygoid muscle attaches to a rough surface behind and below the mylohyoid groove.

The external oblique ridge continues along the anterior border of the ramus on its lateral surface. From the tip of the anterior border (coronoid process), a ridge descends on the medial side of the process to the area posterior to the third molar region. This ridge, the temporal crest, constitutes a small triangular depression (retromolar fossa) with the external oblique line.

The joining of the mandibular base and the posterior border of the ramus forms the angle of mandible. A portion of the mandibular base anterior to the angle is slightly curved superiorly and is called the premasseteric notch. The facial artery passes beneath the premasseteric notch; thus, the pulsation of the artery can be palpated here.

The superior border bears a sharp, triangular coronoid process and a round and claviform condylar process. The mandibular notch is an incisure with a sharp superior edge between two distinct processes. Nerve and vessels to the masseter on the lateral surface of the ramus pass though the mandibular notch.

Surgical Annotation: Identifying the Mandibular Foramen

With a thumb on the anterior border of the ramus fits on the concave line of the border, the line through the distal end of the thumbnail and the interproximal point of the two premolars on the opposite side passes through the vicinity of the mandibular foramen. This line is usually used for an inferior alveolar nerve block.

Coronoid Process

The coronoid process is thin, triangular shaped, and protects upward. Its anterior border is a continuum of the external oblique ridge, and the mandibular notch limits its posterior border. The

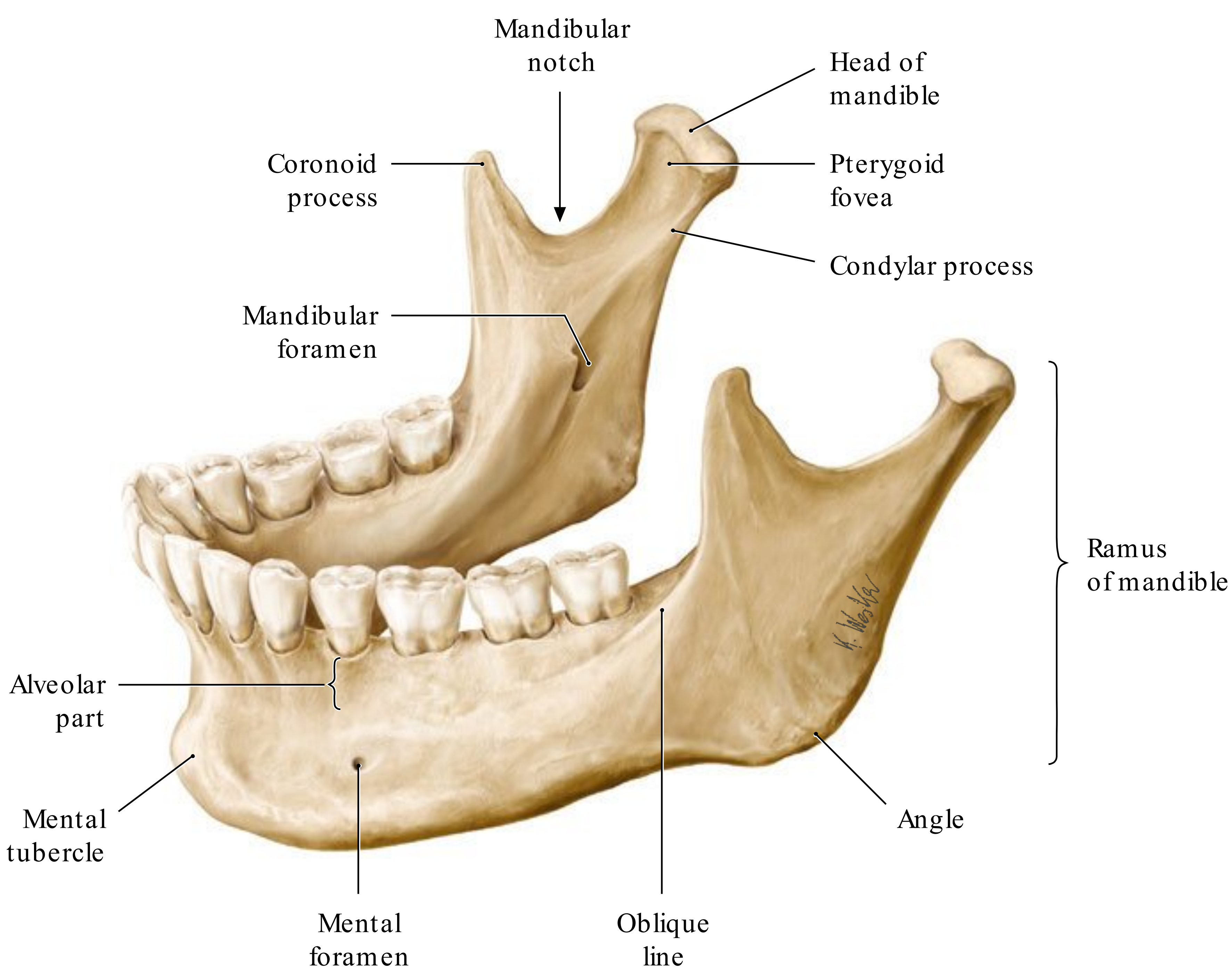


Fig. 19.5 Internal surface of ramus of mandible. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

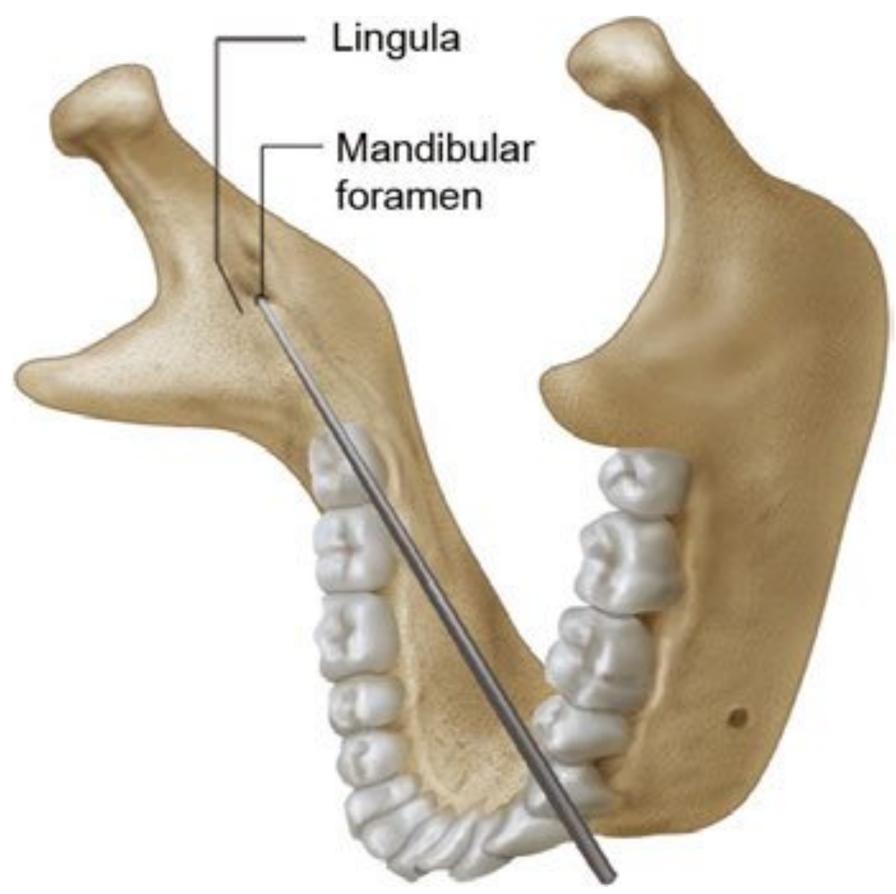


Fig. 19.6 Passage of needle to mandibular foramen for inferior mandibular block.

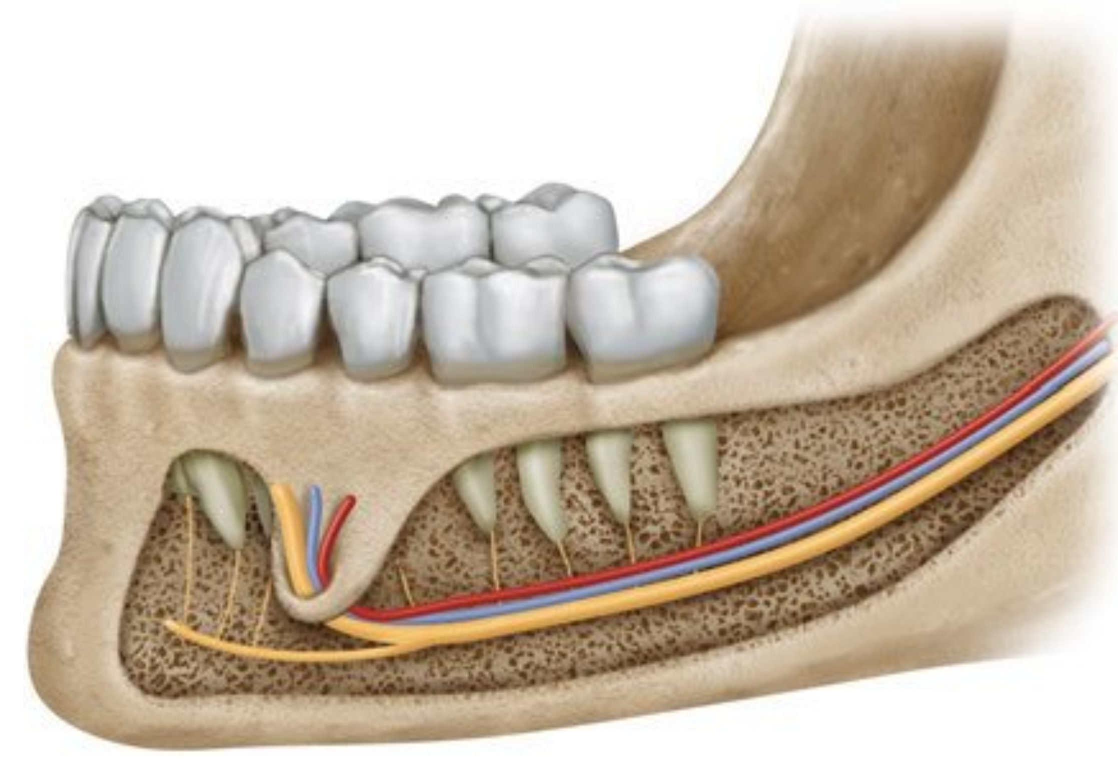


Fig. 19.7 Arrangement of inferior alveolar neurovascular bundle. Yellow represents the inferior alveolar nerve, mental nerve, and incisive nerve. Red and blue represent the inferior alveolar artery and vein, respectively.

temporalis is attached to the anterior, posterior, and medial borders of the coronoid process.

Condylar Process

The condylar process consists of the articular head and the neck. The articular head participates in articulation with the mandibular fossa of the temporal bone. The pterygoid fovea is a small fossa on the anterior surface of the neck and gives attachment to the upper head of the lateral pterygoid. Since the head of the condylar process is larger than its neck and the condylar process acts as an axis of jaw joint, the condylar process is frequently fractured with trauma.

Mandibular Canal

The mandibular canal is the bony canal extending from the mandibular foramen to the mental foramen. The canal runs downward and forward within the ramus then runs horizontally within the body under the tooth-bearing portion. The canal is closer to the external surface (labial cortical plate) farther forward. In the anterior end of the canal, it extends anterior to the mental foramen and curves back to the foramen, forming the anterior loop.

The inferior alveolar nerve and vessels enter the mandibular canal through the mandibular foramen. The trunk of the inferior alveolar nerve divides into mental and incisive nerves. The former exits through the mental foramen and innervates the skin of the chin. The latter passes medially within the mandible and innervates the incisors. The bony passage of the incisive nerve is called the incisive canal.

The neurovascular bundle from the inferior alveolar nerve and vessels to the teeth is within numerous tiny canaliculi between the canal and the alveolar part. Radiographically, the mandibular canal's upper border is less distinct compared with its lower border.

Damage to the Mandibular Canal

The inferior alveolar nerve innervates all mandibular teeth, and the mental nerve supplies sensation of the skin and mucosa of the chin. Intrusion of an instrument or dental implant can result in a sensory disorder of the teeth distal to the injury site.[1] Therefore, an injury of the inferior alveolar nerve within the mandibular canal causes partial or complete numbness of the chin area.

Additionally, the mental nerve is a branch from the inferior alveolar nerve, and its sensory component is conveyed through the buccal portion of the inferior alveolar nerve. The foramen is located below the premolars in about half the cases.[2] The position of the mental foramen varies among races and individuals. Therefore, its position on radiography should be performed before surgical intervention on the premolar area.

The inferior alveolar nerve lies below the inferior alveolar vessels, and the artery is located lingual to the vein in most cases (**Fig. 19.7**).[1] Therefore, transient numbness can result indirectly from the compression of, for example, a hematoma.

Some surgeons try to overcome limitation of a fixture placement because of the mandibular canal by altering angulation or position of the fixture; however, some difficult situations (more than 10%) occur in which the mandibular canal follows midway or a lingual one-third passage within the mandible.[1] The buccolingual position should be evaluated radiographically before intervention.

Masticatory Muscles

The main masticatory muscles consist of the masseter, temporalis, and medial and lateral pterygoids. The masseter lies on the external surface of the ramus of the mandible and the temporalis is located in the temporal fossa. The two pterygoid muscles and the tendon of temporalis are located in the infratemporal fossa (**Fig. 19.8a–c**).

The four muscles are derived from the first pharyngeal arch and are innervated by the mandibular division of the trigeminal nerve. The maxillary artery from the external carotid artery and supplementary branches from the facial or superficial temporal arteries supply blood to the masticatory muscles. The masticatory muscles produce movements of the mandible at the TMJ; elevate the mandible (masseter, temporalis, medial pterygoid); pull down (lateral pterygoid), protrude (lateral pterygoid) and retract it (temporalis). They also act together to provide complicated side-to-side movements. Functionally, the infrahyoid muscles, including the digastric, stylohyoid, geniohyoid, and myohyoid muscles, participate in accessory mastication functions such as opening the mandible. The four masticatory muscles innervated by the mandibular nerve are commonly regarded as principal movers of the jaw.

Masseter

The masseter has been commonly described as a muscle arising from the maxillary process of the zygomatic bone and the zygomatic arch and inserting into the angle and the lower part of the lateral surface of the ramus of the mandible. The main action of the masseter is to occlude the teeth by elevating the mandible.

Actually, the masseter consists of three layers; superficial, middle, and deep layers. Although the fibers of the three layers mostly pass downward and backward, detailed directions of the muscle fibers are slightly different according to the layer. The superficial layer arises from the maxillary process of the zygomatic bone and the anterior two-thirds of the zygomatic arch and inserts into the angle and its neighboring portion of the external surface of the ramus. The origin of the middle layer lies posterior to the superficial layer. The middle layer arises from the medial aspect of the anterior two-thirds of the zygomatic arch and the lower border of the posterior one-third of the arch and inserts into the central part of the ramus. The direction of the superficial layer is anterior to the middle one, and thus the superficial layer participates more in protraction of the mandible. The deep layer arises from the deep surface of the zygomatic arch and inserts into the upper part of the ramus and the

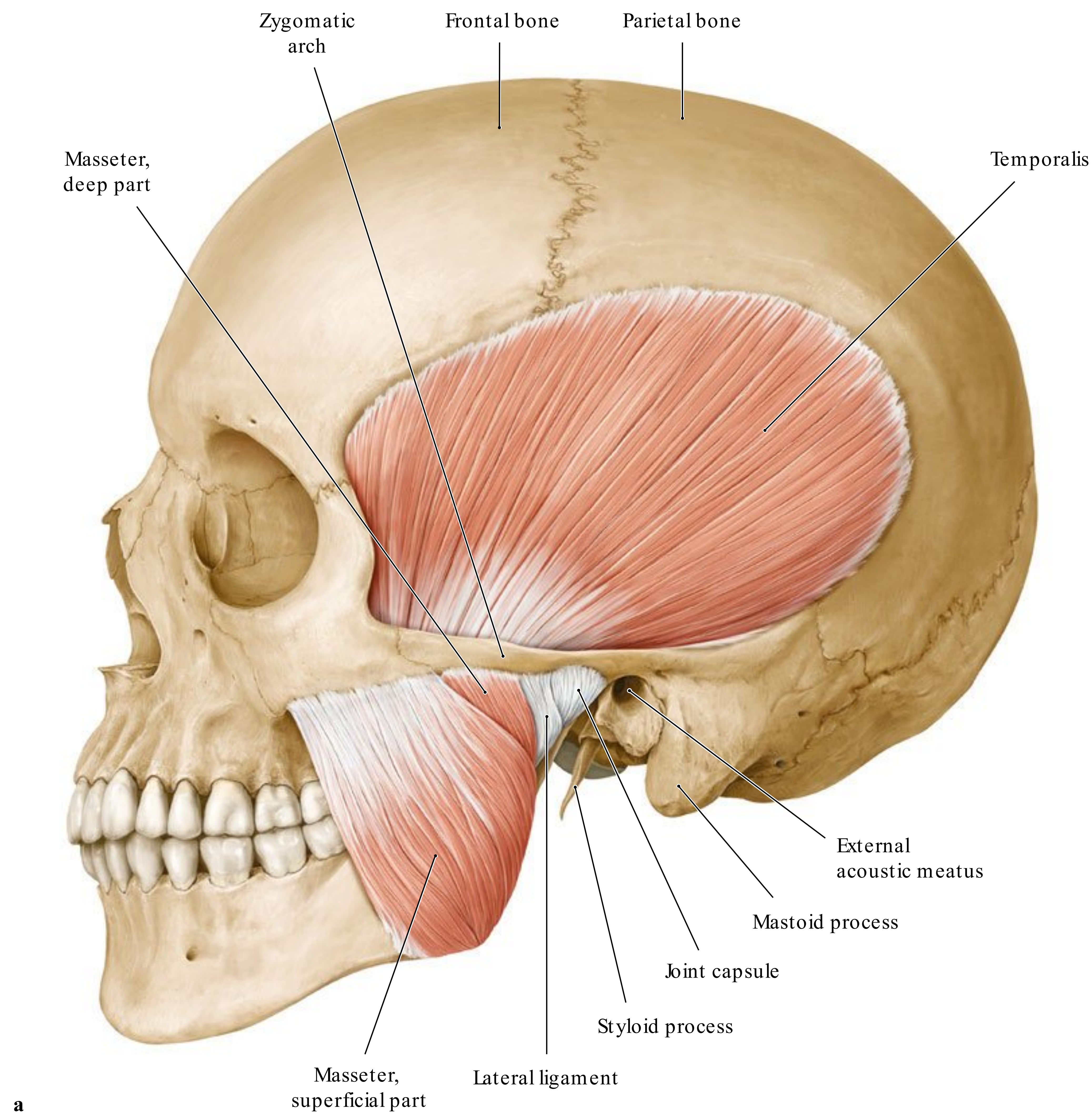
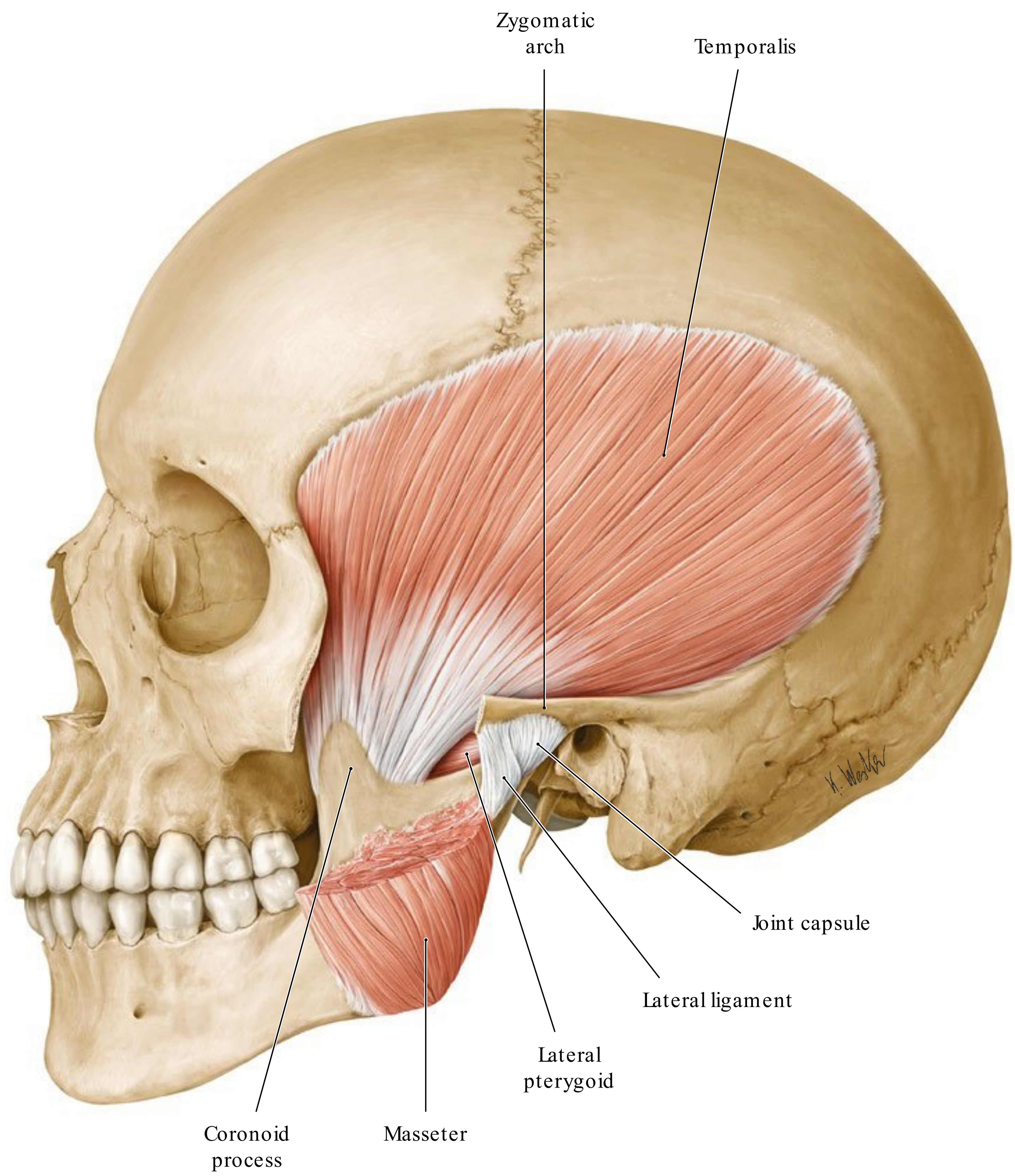
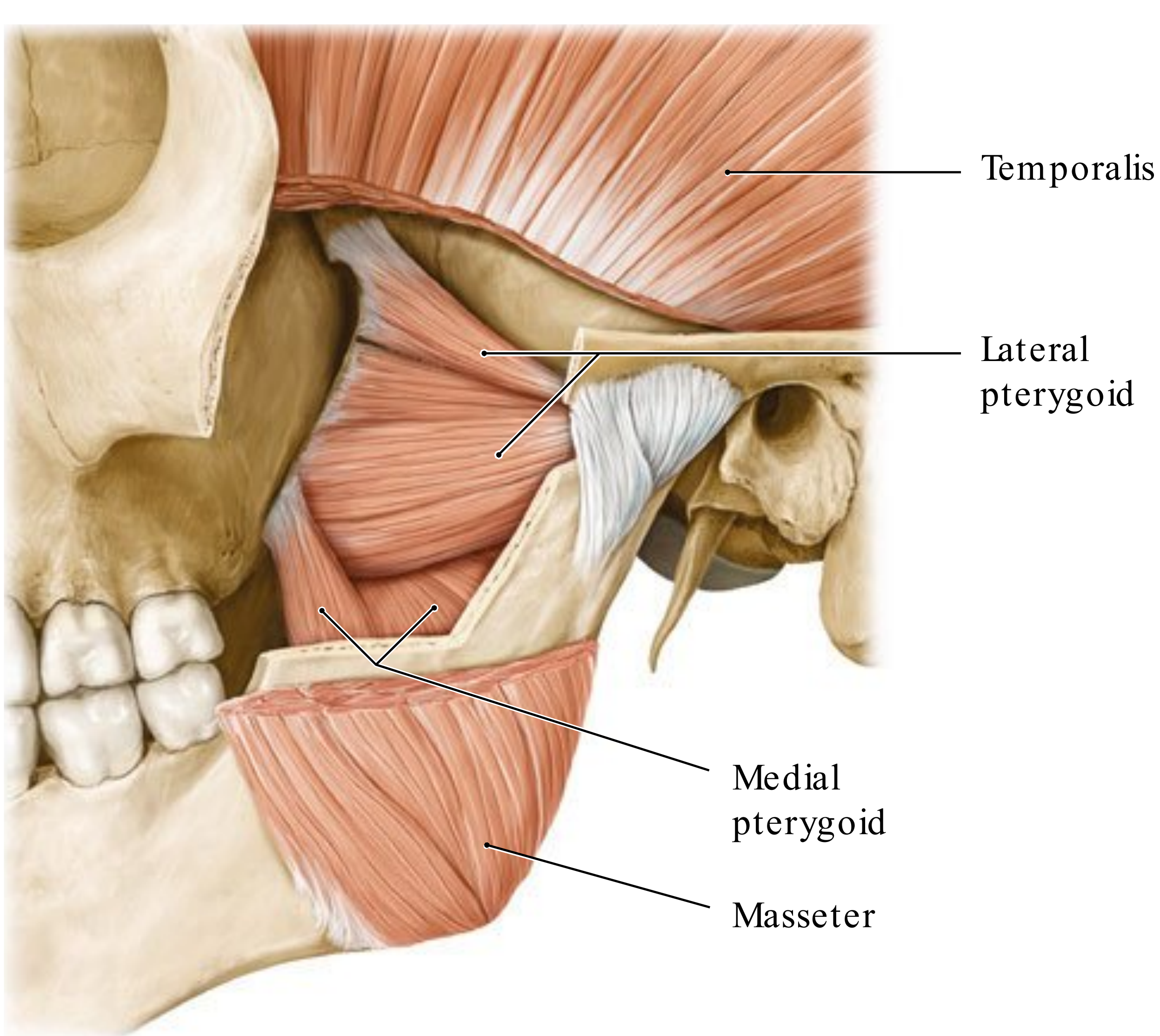


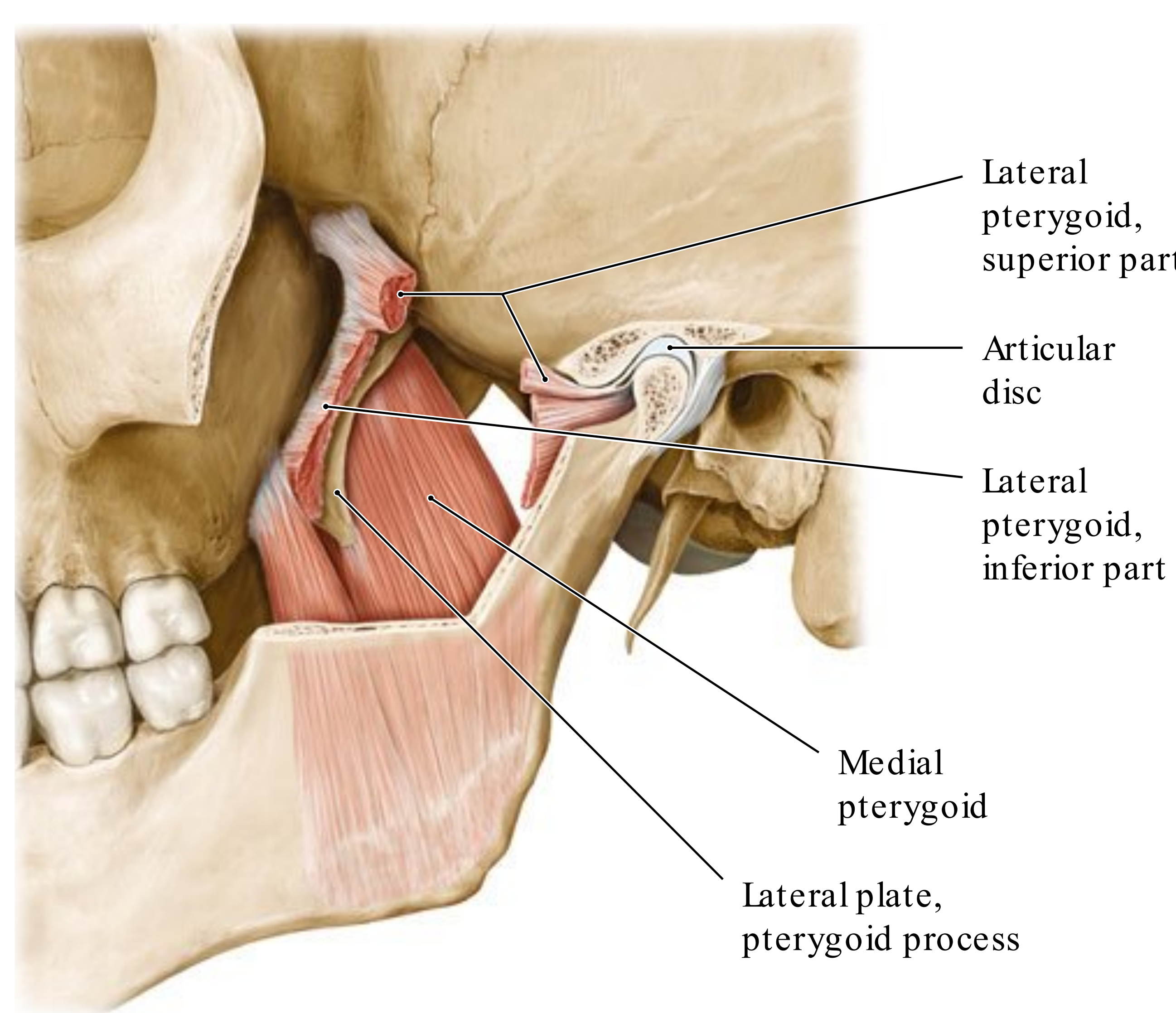
Fig. 19.8 Four masticatory muscles; masseter, temporalis, medial, and lateral pterygoids. **(a)** Masseter with temporalis muscle.



b



c



d

Fig. 19.8 (continued) **(b)** Temporalis muscle (masseter and zygomatic arch are removed). **(c)** Lateral pterygoid muscle (coronoid process of mandible is removed). **(d)** Medial pterygoid muscle (lateral pterygoid muscle is removed). (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustrations by Karl Wesker.)

coronoid process. Some parts of the middle and deep layers are involved in retraction of the mandible. The temporalis and buccinator muscles lie deep to the masseter. Most of the buccal branches, some zygomatic branches of the facial nerve, and facial vein cross over the masseter. The parotid gland overlaps the posterior part of masseter.

Vascular Supply of the Masseter

The maxillary artery gives rise to the masseteric artery, which supplies the masseter. The main trunk of the maxillary artery proceeds anteriorly and medial to the mandibular condyle within the infratemporal fossa. It gives off the masseteric artery near the lateral pterygoid and the artery leaves the infratemporal fossa with the masseteric nerve through the mandibular notch. Several branches from the facial artery and the transverse temporal artery are located on the external surface of the masseter; they supply blood to the anterior and superior parts of the masseter, respectively. The facial artery gives off the premasseteric artery passing upward along the anterior border of the masseter. The transverse facial artery arises from the superficial temporal artery and also supplies the masseter. It usually travels anteriorly between the parotid duct and the zygomatic arch.

Various Masseteric Branches

Knowledge of the arterial distribution to masseter is crucial in preventing vascular complications during various surgical procedures, such as masseter flap formation, reduction of the mandibular angle, parotidectomy, and ramus osteotomy. Although the massteric artery from the maxillary artery is delineated primarily as a main vessel distributing masseter, the muscle can be supplied by several other arterial branches from the external carotid artery (**Fig. 19.9**).[3] (1) The transverse facial artery from the superficial temporal artery gives off masseteric branches that cross transversely over the muscle. Its intramuscular branches to the masseter are distributed to a broad posterior area of the muscle. (2) The external carotid artery and superficial temporal artery give rise to direct masseteric branches to the angular and articular portions of the masseter. The facial artery directly gives off the masseteric branch as it emerges on the external surface of the mandible after turning upward. It is distributed to the anterior lower portion of the muscle. The facial artery gives off the premasseteric artery running along the anterior border of masseter, and it also gives rise to a small masseteric branch supplying blood to the anterior midportion of the muscle. (3) The deep temporal artery, another tributary of the maxillary artery, also supplies a branch to the masseter and specifically to its anterior upper portion.

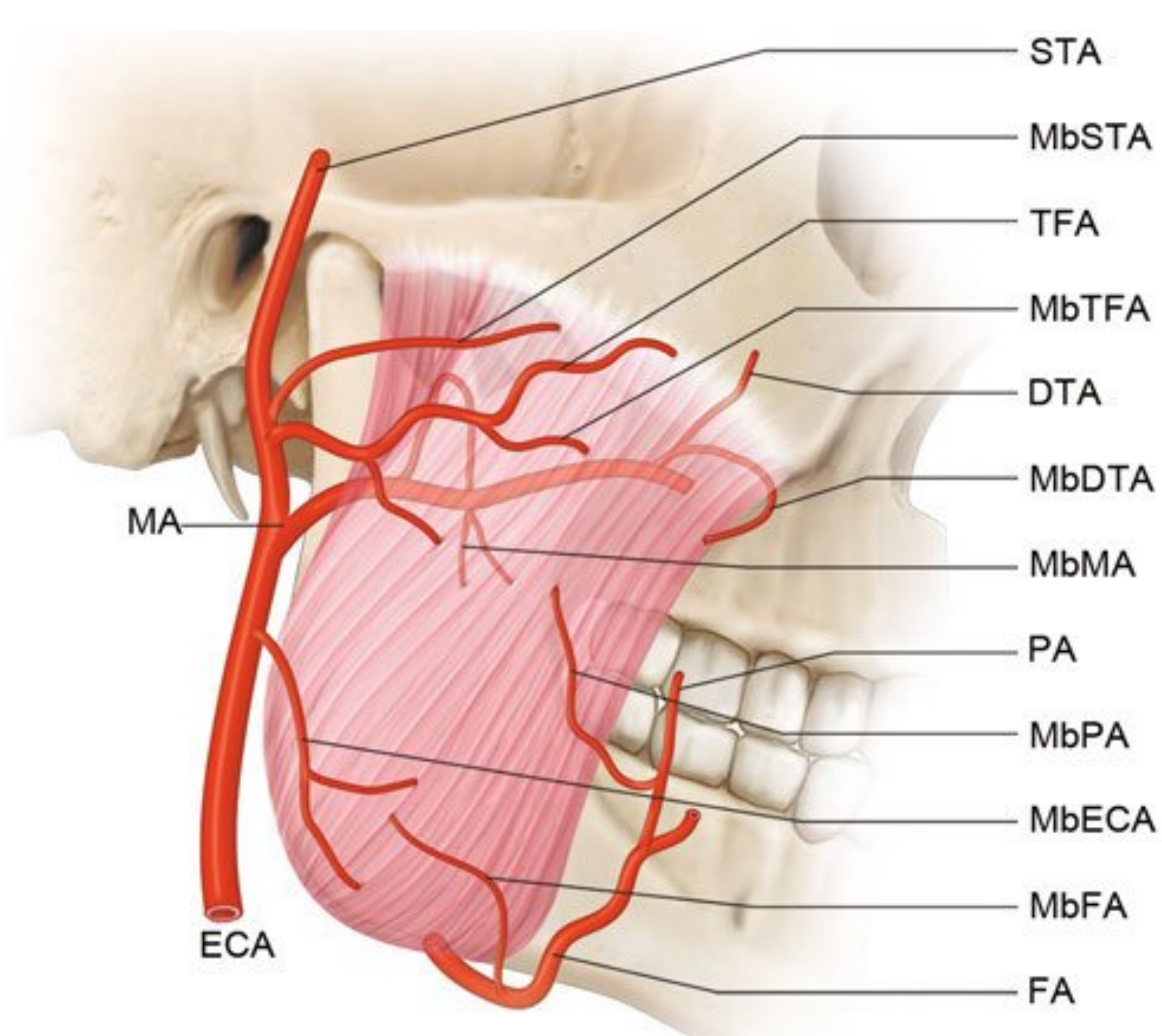


Fig. 19.9 Arteries to the masseter muscle. DTA, deep temporal artery; ECA, external carotid artery; FA, facial artery; MA, maxillary artery; PA, premasseteric artery; STA, superfcial temporal artery; TFA, transverse facial artery. Masseteric branches from ECA(MbECA), STA(MbSTA), TFA(MbTFA), DTA(MbDTA), MA(MbMA), PA (MbPA), and FA (MbFA).

Innervation of the Masseter

The masseteric nerve of the mandibular nerve innervates the masseter. The masseteric nerve passes though the mandibular notch and is accompanied by the masseteric artery. The proximal part of the masseteric nerve is located between the mandibular notch and the attachment of the masseter (submasseteric tissue space). Abscess resulting from infection of the mandibular third molar tooth has been known to invade the submasseteric tissue space and irritate the masseteric nerve with resultant muscle spasm and trismus (pathologic limitation of jaw opening).

Intramuscular Innervation to Masseter

The masseteric nerve runs downward and forward between the middle and deep layers of masseter and is divided into four twig groups: anterosuperior, anteroinferior, posterosuperior, and posteroinferior groups (**Fig. 19.10**).[4]

The superficial, middle, and deep layers of the masseter are mostly innervated by the anteroinferior, posterosuperior, and posteroinferior groups, respectively. The anteroinferior group provides perforating branches to the superficial layers, and its termination lies mostly on the inferior midportion of the masseter. The inferior midportion might be an efficient site for botulin injection.

Temporalis

The temporalis is a fan-shaped masticatory muscle that arises from the temporal fossa and the inner surface of the temporal fascia. The muscle’s tendon converges and passes to the infratemporal fossa between the zygomatic arch and the lateral side of the skull. The tendon of temporalis attaches to the medial surface, apex, and apical border of the coronoid process. Temporalis elevates and its posterior fibers retract the mandible. Directions of the muscle fibers of temporalis vary according to their location. The muscle fibers of temporalis are arranged more horizontally posteriorly. The anterior parts of temporalis are arranged more vertically. Some fibers of its anterior parts arise from the inner surface of the zygomatic bone. These fibers strongly elevate the mandible by pulling the coronoid process

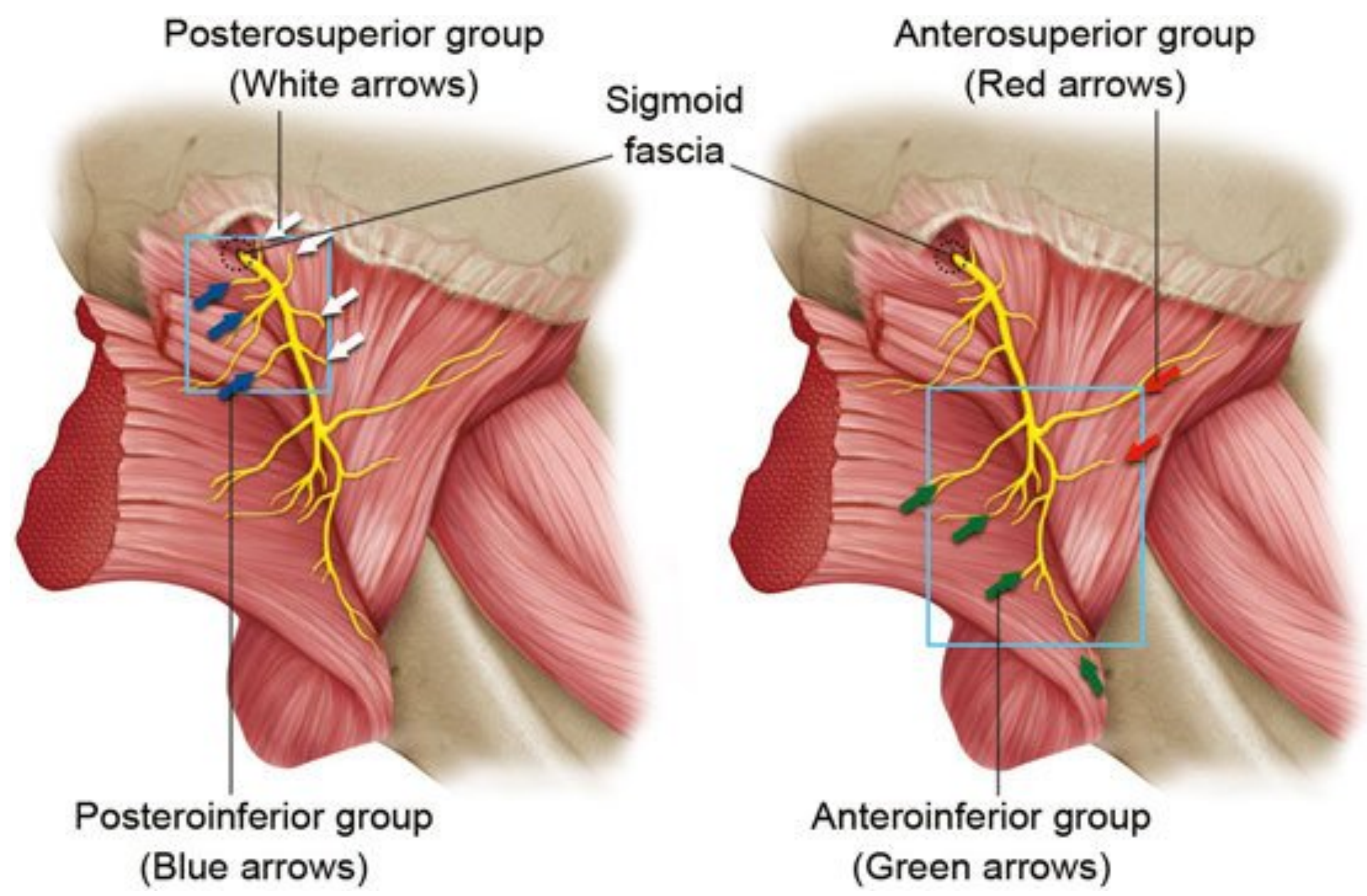


Fig. 19.10 Four groups of masseteric nerves.

upward. The posterior more horizontal parts of temporalis also participate in closing the mouth by rotating the mandible toward the maxilla on the axis of the jaw joint.

Significant structures, including the superficial temporal vessels, the auriculotemporal nerve, and temporal branches of the facial nerve, lie on the temporalis and the temporal fascia.

Vascular Supply

Artery

The maxillary artery gives rise to the anterior and posterior deep temporal arteries on the lateral pterygoid. The deep temporal arteries ascend on the lateral pterygoid and infratemporal crest of the sphenoid bone and then enter temporalis with the deep temporal branches of the mandibular nerve. The superficial temporal artery gives rise to the middle temporal artery just above the zygomatic arch and enters the temporalis after piercing the temporal fascia. The anterior deep temporal artery supplies blood to the anterior portion of temporalis and the posterior deep temporal artery supplies the posterior parts. The middle temporal artery is distributed to the midportion of the temporalis. The frontal branch of the superficial temporal artery ascends on temporalis upward and forward.

Superf cial Temporal Artery Over the Anterior Temporalis

The anterior portion of temporalis lies over the temple near the pterion. Various surgical interventions near this area include face lift procedures, the injection of filler material, the injection of botulin toxin for aesthetic purposes, and the injection of anesthetics for the treatment of headaches. Therefore, knowledge of the superficial temporal artery and its topography is important to the clinician.

The superficial temporal artery branches from the external carotid artery in the preauricular area at a distance of 2 to 5 cm from the Frankfurt line (line through the lowermost point of the orbit to the uppermost part of the portion), and it passes forward and upward over the temporalis (**Fig. 19.11**). Because the frontal branch lies within the temporal fascia or between the temporoparietal fascia and temporal fascia, a surgical approach can be safely performed deep to the temporalis.

The artery divides into several frontal branches as it passes over the temporalis. Usually, one or two will reach the border between the temporalis and frontalis (the frontal belly of occipitotemporalis) about 2 cm (approximately the width of the thumb) above the eyebrow. The pulsation of the frontal branch can easily be detected by palpation at its branching point from the superficial temporal artery and as it enters frontalis. Therefore, the surgeon can predict its course by palpation of the branching points because the frontal branch rarely bifurcates except between muscles.

Veins

The veins of the temporal, frontal, and parietal areas converge as the sentinel vein. The medial temporal vein and its continuum (i.e., the superior temporal vein) drain to the retromandibular vein, the anterior and posterior branches of which drain to

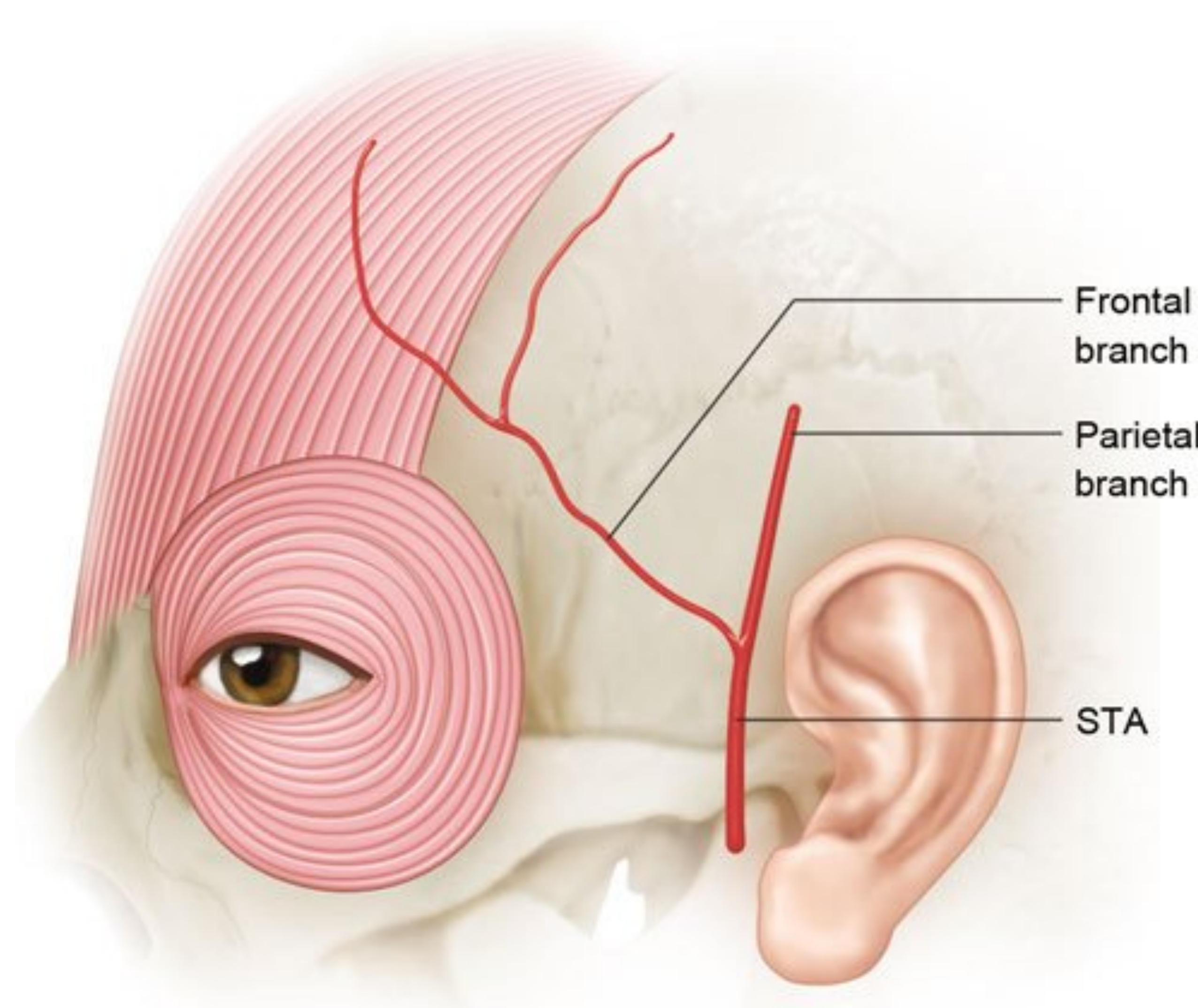


Fig. 19.11 Superf cial temporal artery (STA) passing over temporalis.

the external and internal jugular veins, respectively. The blood flow in the sentinel vein can actually flow toward both the infraorbital space and the thoracic area via the valveless venous vessels of the head and neck.

The medial zygomaticotemporal vein has been observed in the vicinity of the temporal branch of the facial nerve during endoscopic procedures aimed at lifting the upper face. The sentinel vein is easily identified on direct or endoscopic view during facelift procedures and is readily detected in recumbent patients or in conscious patients using a Valsalva maneuver.

The sentinel vein pierces the parietotemporal fascia, which is part of the superficial musculoaponeurotic system (SMAS) in about 17%of cases.

Innervation

The deep temporal nerve branches from the mandibular nerve and innervates the temporalis. The deep temporal nerve consists of two or three branches. The branches of the deep temporal nerve pass between the infratemporal crest and upper border of the lateral pterygoid. They enter temporalis with the deep temporal arteries. Sometimes the anterior branch of the deep temporal nerve branches from the buccal nerve and the posterior branch branches from the masseteric nerve.

Fasciae of the Temporal Region

The auriculotemporal nerve, temporal branches of the facial nerve, and superficial temporal vessels are involved in various surgical interventions of the temporalis or temporal region, regardless of their distribution to the temporalis. The anatomy of the fasciae of temporalis is therefore important in the preservation of these neurovascular structures. The temporal fascia is a dense aponeurotic layer covering the temporalis and providing attachment for the surface for the muscle. Its uppermost portion merges with the periosteum at the superior temporal line. The temporal fascia divides into superficial and deep sublayers, which attach to the medial and lateral margins of the zygomatic arch, respectively. The adipose tissue (superficial temporal fat pad) lies between them, and they surround branches of the superficial temporal artery and zygomaticotemporal nerve. Hence, placement of an instrument deep to the temporal fascia can provide a safe surgical approach for manipulating zygomatic arch fractures (Gillies approach).[5]

The temporoparietal fascia lies superficial to the temporal fascia. It is on the same plane as the superficial musculoaponeurotic system (SMAS) blending with the galea aponeurotica. The space between the temporoparietal fascia and the temporal fascia encloses the loose connective tissue with adipose tissue (temporoparietal fad pad), continuing with a subgaleal loose connective tissue plane of the scalp. The auriculotemporal nerve, facial nerve branches, and superficial temporal vessels are located within or slightly deep to the temporoparietal fascia. Surgeons can use this fascia as a landmark to avoid facial nerve damage. Clinically, the temporoparietal fascia is called the superficial temporal fascia, and the temporal fascia is called the deep temporal fascia.

Medial Pterygoid

The medial pterygoid is a square-shaped masticatory muscle that consists of two heads that arise superficial and deep to the lower head of the lateral pterygoid. The deep head of the medial pterygoid arises from the medial surface of the lateral pterygoid plate of the sphenoid bone. The superficial head arises from the maxillary tuberosity and pyramidal process of the palatine bone. Two heads descend backward and attach to the medial surface of the ramus and the angle of the mandible. The posteroinferior direction of the medial pterygoid and its action of elevating the mandible are similar to those of the masseter. When two pterygoid muscles of one side act together, they rotate the mandible forward and medially to the opposite side.

The lateral pterygoid, the sphenomandibular ligament, maxillary artery, the inferior alveolar artery and vessels, and the lingual nerve are located between the lateral side of the medial pterygoid and the medial surface of the ramus of the mandible. Insertion of the medial pterygoid reaches upward to the mandibular foramen and forward to the mylohyoid line.

Vascular Supply and Innervation

The maxillary artery provides several pterygoid branches supplying blood to the medial and lateral pterygoid muscles. The buccal artery from the maxillary artery also gives off branches to the medial pterygoid. A part of the facial artery proceeds medial to the ramus of the mandible between the submandibular gland and the medial pterygoid along the inferior border of the mandible. Some branches are derived from the facial artery here and are distributed to the medial pterygoid at its insertion near the angle of the mandible. The mandibular nerve gives rise to the nerve to the medial pterygoid.

Medial Pterygoid and Mandibular Angle Reduction

Both the medial pterygoid and masseter lie downward and backward 70 degrees from the mandibular base, and they insert onto the medial and lateral surfaces of the angle of the mandible, respectively. Their insertions are located near the gonion (the most posteroinferior point of the angle of the mandible) by a distance of 2 cm.[6] Therefore, the medial pterygoid is an important landmark for mandibular angle reduction. Injury to the arteries approaching the angle is a complication during mandibular angle reduction. According to most anatomy textbooks, the main branch supplying the medial pterygoid derives from the maxillary artery after passing over the condylar process of the mandible; however, the facial artery provides other branches to the angular portion of the medial pterygoid.[7] The artery gives off the ascending palatine artery medial to the angle of the mandible. It also gives off muscular branches before emerging on the superficial aspect of the mandible. There are also small muscular branches arising directly from the facial artery and traveling to the angular portion of the medial pterygoid (**Fig. 19.12**). Therefore, surgeons approaching the angle of

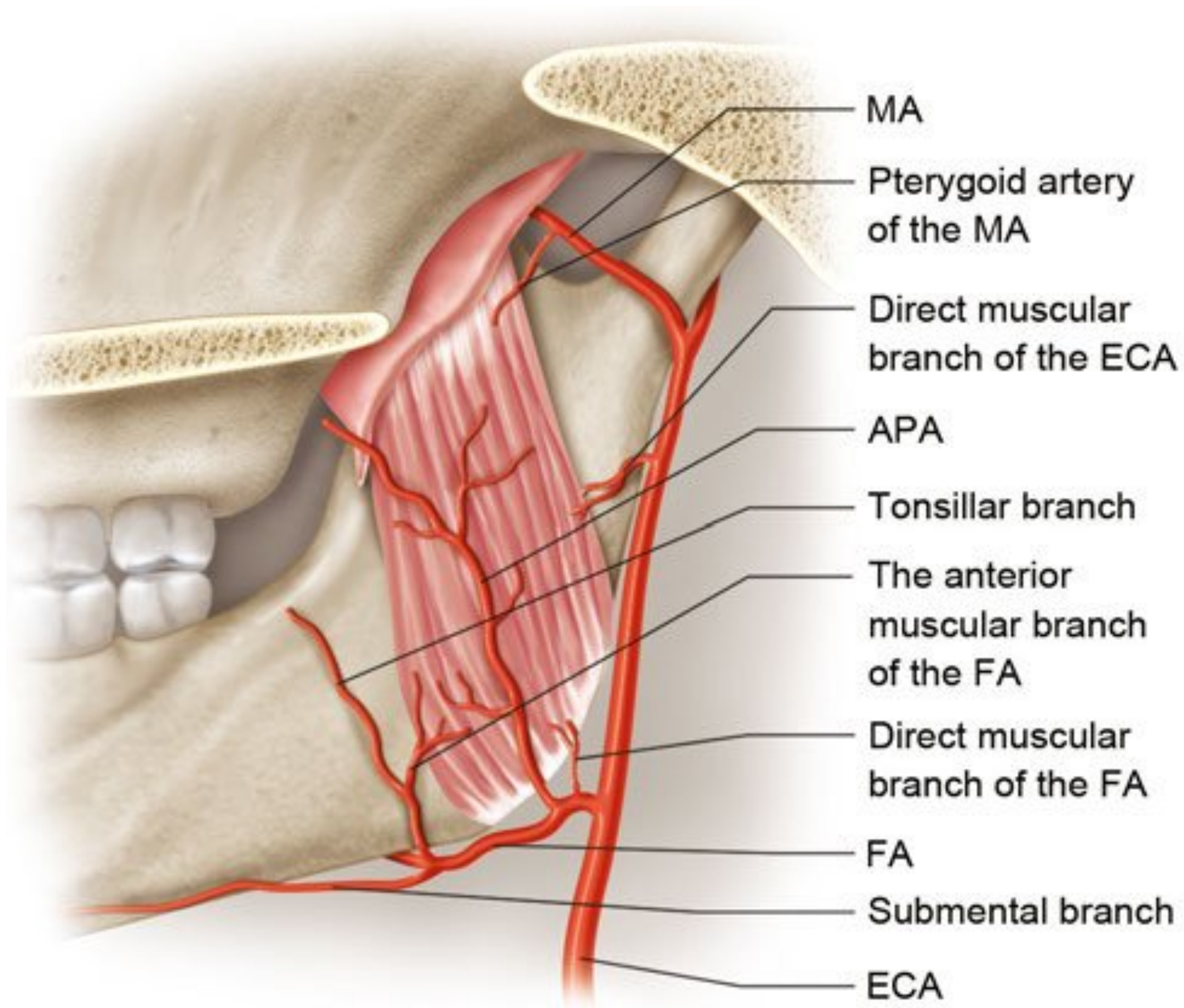


Fig. 19.12 Arteries to medial pterygoid muscle. APA, ascending palatine artery; ECA, external carotid artery; FA, facial artery; MA, maxillary artery.

the mandible should be aware not only of the main trunk of the facial artery but also of the muscular branches to the masseter and medial pterygoid muscles.

Lateral Pterygoid

The lateral pterygoid is a horizontally arranged muscle within the infratemporal fossa muscle and comprises upper and lower heads. The upper head arises from the infratemporal surface and crest of the greater wing of the sphenoid bone, and the lower head arises from the lateral surface of the lateral pterygoid plate. The two heads of the lateral pterygoid run backward, and their muscle fibers converge to be inserted into the pterygoid fovea, a depression on the anterior side of the neck of the mandible. Characteristically, some muscle fibers of the upper head attach to the capsule of the TMJ and the anterior border of the articular disc. Because the TMJ is located lateral to the lateral pterygoid plate, the bellies of the two heads proceed outward, and the muscular fibers of the upper head attach to the medial border of the disc. The lateral pterygoid pulls the neck of the mandible forwards and the condyle of the mandible moves not only forward, but it also downward along the anterior slope of the mandibular fossa.

The rami of the mandible, the masseter, the superficial head of the medial pterygoid, and the tendon of temporalis are superficial to the medial pterygoid and to most of the maxillary artery. The sphenomandibular ligament, the middle meningeal artery, and the mandibular nerve trunk are deep to the muscle.

Function of Lateral Pterygoid: Side-to-Side Movement

The main jaw depressor is not the lateral pterygoid; rather, it is the infrahyoid muscles (e.g., digastric and geniohyoid).[5] Protrusion of the mandible by the lateral pterygoid is limited to an assisting movement for jaw opening and alone is not significant. The most important function provided by the lateral pterygoid is lateral excursion, side-to-side movement of the mandible. The ipsilateral medial and lateral pterygoids pull the mandible medially. The slight but strong medial movement of the jaw is crucial in food grinding. Spasm of the lateral pterygoid can occur in cases of TMJ dysfunction; in such cases, tenderness might be palpated posterior to the maxillary tuberosity.

Vascular Supply and Innervation

The maxillary artery crosses the lateral pterygoid anterosuperiorly. The lateral pterygoid is a landmark for demarcation of the maxillary artery. The proximal portion of the maxillary artery behind the muscle is the mandibular part, the midportion on the muscle is the pterygoid part, and the distal portion in front of the muscle is the pterygopalatine part. The mandibular part of the artery gives off the pterygoid arteries distributed to the lateral pterygoid as the artery crosses it. The ascending palatine artery branches from the facial artery and also supplies the lateral pterygoid. The mandibular nerve gives rise to the nerve to the lateral pterygoid.

Spatial Relations of Lateral Pterygoid to Mandibular Nerves

Many branches from the mandibular nerve have a spatial relationship with the lateral pterygoid.[5] The deep temporal nerves and masseteric nerve run along the infratemporal crest and the upper border of the upper head of the lateral pterygoid. The buccal nerve passes between the upper and lower heads of the muscle. The lingual nerve and inferior alveolar nerve pass below the lower head. The nerve to the lateral pterygoid arises directly from the mandibular nerve or from the buccal nerve passing between the two heads of the muscle. The nerve, after arising directly from the mandibular nerve, enters the deep part of the lateral pterygoid and innervates the medial part of the lower head. The nerve branches from the buccal nerve are distributed to the upper head and lateral part of the lower head. The buccal nerve, after passing through the lateral pterygoid, terminates as a cutaneous nerve supplying the cheek.

References

1. Hu KS, Yun HS, Hur MS, Kwon HJ, Abe S, Kim HJ. Branching patterns and intraosseous course of the mental nerve. J Oral Maxillofac Surg 2007;65(11):2288–2294 PubMed
2. Song WC, Kim SH, Paik DJ, et al. Location of the infraorbital and mental foramen with reference to the soft-tissue landmarks. Plast Reconstr Surg 2007;120(5):1343–1347 PubMed
3. Kwak HH, Hu KS, Hur MS, et al. Clinical implications of the topography of the arteries supplying the medial pterygoid muscle. J Craniofac Surg 2008;19(3):795–799 PubMed
4. Kim DH, Hong HS, Won SY, et al. Intramuscular nerve distribution of the masseter muscle as a basis for botulinum toxin injection. J Craniofac Surg 2010;21(2):588–591 PubMed
5. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th ed. Edinburgh: Churchill Livingstone; 2008:530–539
6. Yang SJ, Hu KS, Kang MK, Youn KH, Kim HJ. Topography and morphology of the medial pterygoid muscle for the surgical approach of the mandibular ramus. Korean J Phy Anthropol. 2007;20(3): 157–167
7. Won SY, Choi DY, Kwak HH, Kim ST, Kim HJ, Hu KS. Topography of the arteries supplying the masseter muscle: Using dissection and Sihler's method. Clin Anat 2012;25(3):308–313 PubMed

20 Oral Cavity and Pharynx

Joe Iwanaga, Shinya Mikushi, and Haruka Tohara

Introduction

The oral cavity is the entrance of the upper digestive tract, continuing into the oropharynx; it is divided into two regions (**Fig. 20.1**). The first region is the oral vestibule, located external to the dental arch. The second region is the oral cavity proper, located internal to the dental arch. The components of the oral cavity include the upper and lower lip mucosa, teeth and gingiva, alveolar mucosa, buccal mucosa, tongue, hard and soft palate, floor of the mouth, and uvula. The palate is the roof of the mouth and separates the oral and nasal cavities. The pharynx is located at the posterior aspect of the oropharyngeal isthmus. Two important functions involving the oral cavity and pharynx are mastication and swallowing. Multiple muscles work together to send a bolus of food to the esophagus. Other major functions are occlusion and aesthetics. The oral cavity and pharynx contain an abundant supply of blood vessels and nerves in a constricted space, providing a particular challenge for clinicians undertaking surgical procedures. In this chapter, we explain the details of the clinical anatomy of oral cavity and pharynx to promote better understanding for clinical practice.

Oral Vestibule

The oral vestibule is the region surrounded by the lip (buccal) mucosa, mucobuccal fold, alveolar mucosa, gingiva, and upper and lower dental arches. Its shape in the axial plane is that of a horseshoe, and it is separated from the oral cavity proper when the upper and lower teeth are in occlusion. Mucosal folds that run from the central incisor region of the alveolar mucosa to the lip mucosa are the frenulum of the upper and lower lips (**Fig. 20.2**). Mucosal folds that run from the molar region of the alveolar mucosa to the buccal mucosa are called buccal frenula. The parotid duct runs from the parotid gland, passes in front of the masseter muscle, enters into the buccal fat pad, and then reaches the parotid papilla located in the buccal mucosa (**Fig. 20.3**). A small triangle (the retromolar triangle) lies just behind the most distal molar and a small ridge in the retromolar region (the retromolar pad) (**Fig. 20.4**). The lingual nerve branches off the mandibular nerve and occasionally crosses over the retromolar triangle.[1] The external oblique ridge, which begins lateral to the retromolar pad, continues on to the anterior border of the ramus. When the mandible opens and closes, or when the lips suck, the bone movement and muscle contraction change the form of the oral vestibule. The lower part of the oral vestibule in particular is affected by the superior pharyngeal constrictor muscle, masseter muscle, buccinator muscle, orbicularis oris muscle, mentalis muscle, and coronoid process; the upper part is affected by the orbicularis oris muscle, buccinator muscle, medial pterygoid muscle, levator anguli oris muscle, nasal muscle, depressor septi muscle, and infrazygomatic crest. If the superior labial frenulum is located in a high position on the gingiva, the right and left maxillary incisor teeth may exhibit a median diastema, and frenoplasty is often required.

The orbicularis oris muscle and buccinator muscle are present beneath the mucous membranes of the labial and buccal mucosae. In the mandible, there are two mental foramina, just inferior to the apex of the second premolars, through which the

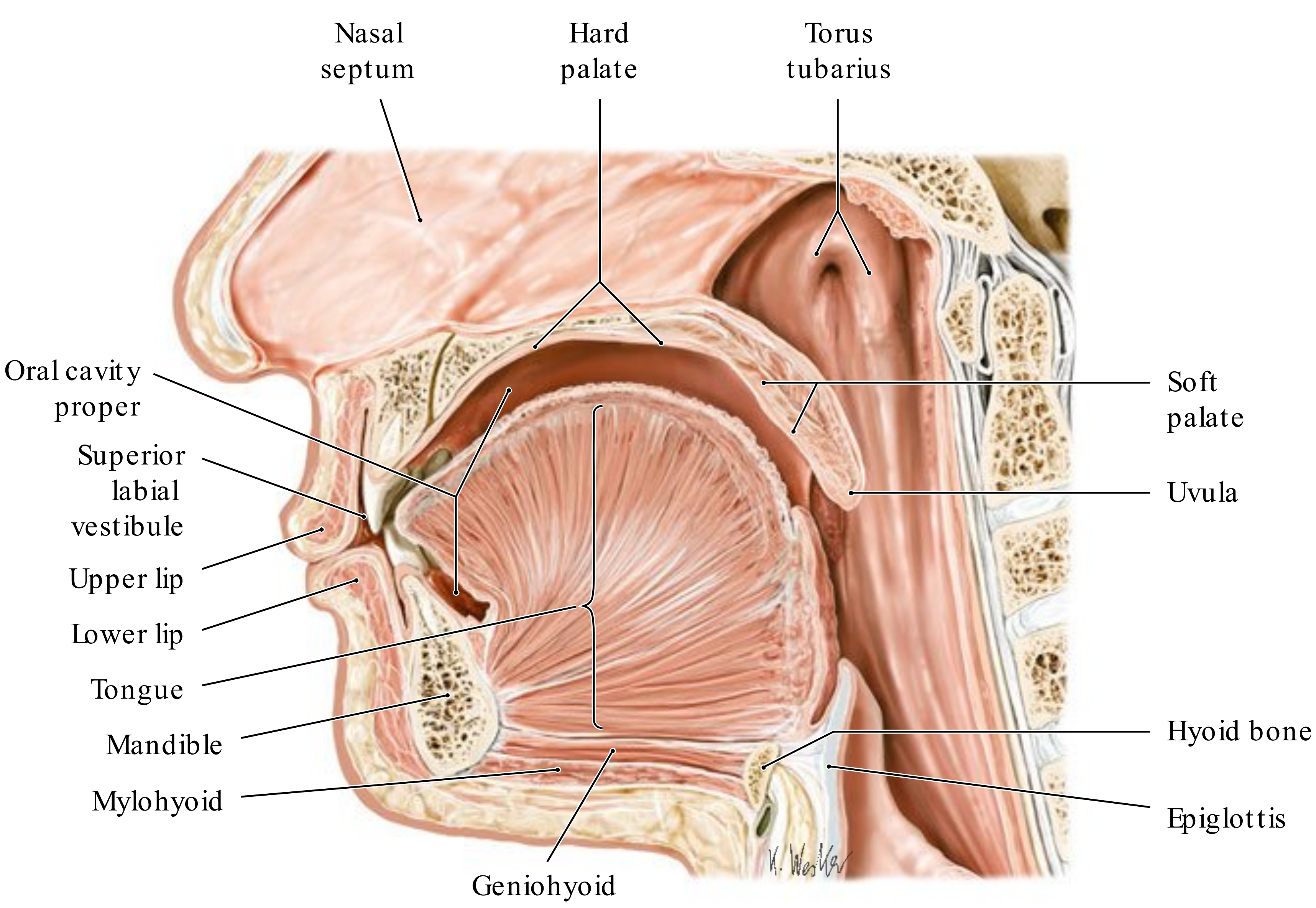


Fig. 20.1 Midsagittal plane of the oral cavity and pharynx. (From THIEME Atlas of Anatomy, Head and Neuroanatomy. © Thieme 2010, Illustration by Karl Wesker.)

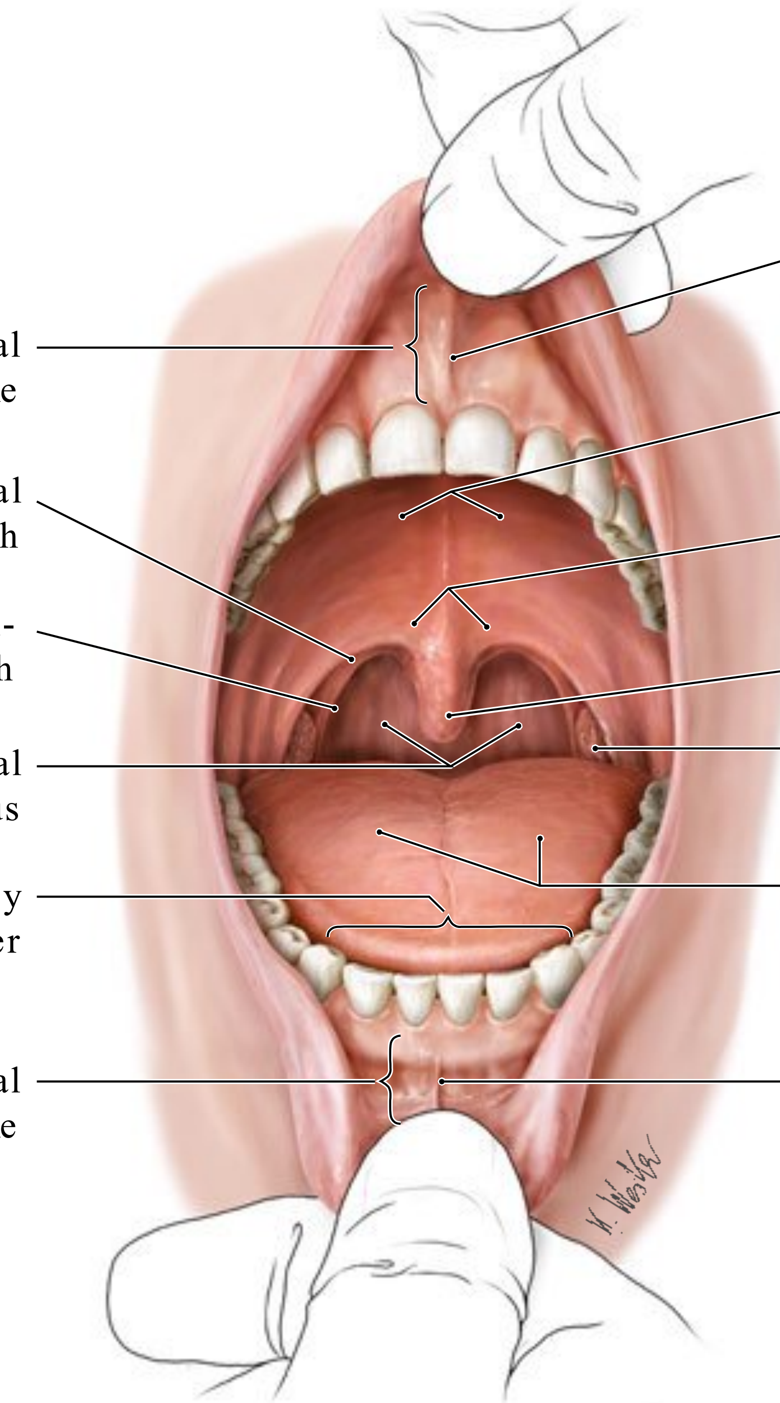


Fig. 20.2 Frenulum of the upper and lower lips. (From THIEME Head and Neck Anatomy for Dental Medicine. © Thieme 2010, Illustration by Karl Wesker.)

mental nerves, arteries, and veins emerge. The vertical distance from the margin of the mandible to the mental foramen is reported to be approximately 12 mm.[2] Surgical procedures in the premolar region should be undertaken carefully. When teeth are lost, the alveolar bone proper resorbs and the thickness of the mandible decreases, so the mental foramina sometimes open just below the alveolar mucosa; nerves exiting the foramina are then easily compressed by dentures. Recent developments in imaging have revealed that accessory mental foramina exist around the mental foramen in approximately 10% of cases[3,4] (**Fig. 20.5**) and that the accessory mental nerve branches off from these accessory foramina.

Teeth and Periodontal Tissues

The teeth consist of a crown, the surface of which is covered by enamel, a hard translucent tissue, and the root, which is covered by cementum. Within the crown and root is a layer of dentin surrounding a central pulp cavity. The apical foramen is a hole at the tip of the root, through which the dental pulp, blood vessels, and lymph vessels enter and exit the dental pulp chamber. The root is surrounded by the periodontal ligament (**Fig. 20.6**). Enamel is the hardest tissue in the human body; at the same time, it is a fragile and breakable tissue. The enamel is approximately 96% inorganic matter called hydroxyapatite; it reaches a maximum thickness of 2.5 mm over the cusps and is quite thin at the cervical margins. After crown formation is complete, no additional enamel forms, but the enamel of young people is easily demineralized and remineralized. Dentin is a yellowish tissue composed of hydroxyapatite (70%), collagen (20%), and water (10%). Dentin is more flexible than enamel, so it acts as a buffer to prevent the enamel from fracturing. Additionally, if inflammation occurs in the dental pulp as a result of dental caries or traumatic injury after the start of occlusal function, secondary dentin will form inside the dentin. The cementum covers the surface of the dentin of the root and is covered by the periodontal ligament, which consists of fibrous connective tissue that is 0.15 to 0.38 mm thick. Sharpey's fibers, which

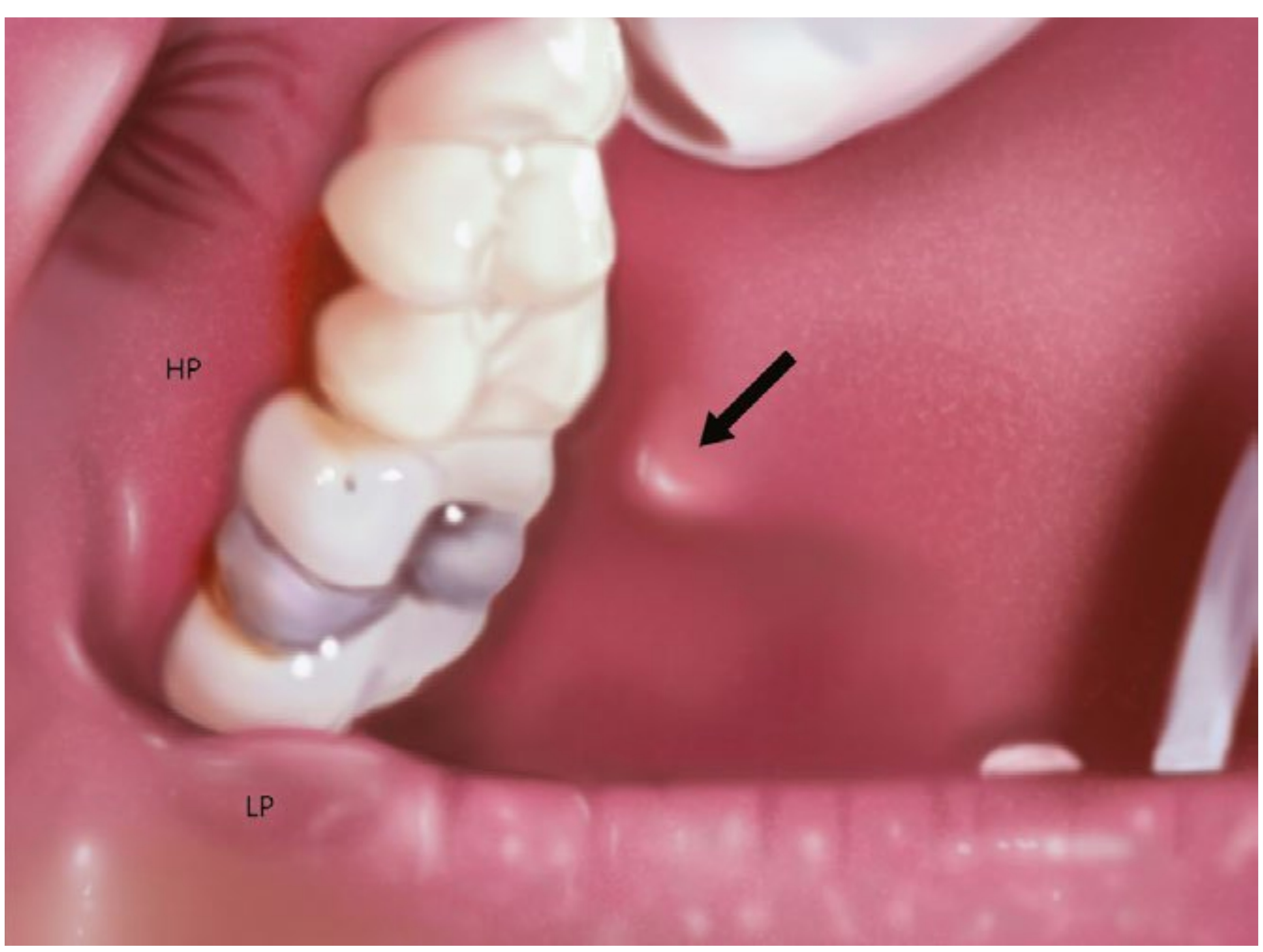


Fig. 20.3 The left parotid papilla (the orifice of the parotid duct) is indicated by the black arrow. HP, Hard palate; LP, lower lip.

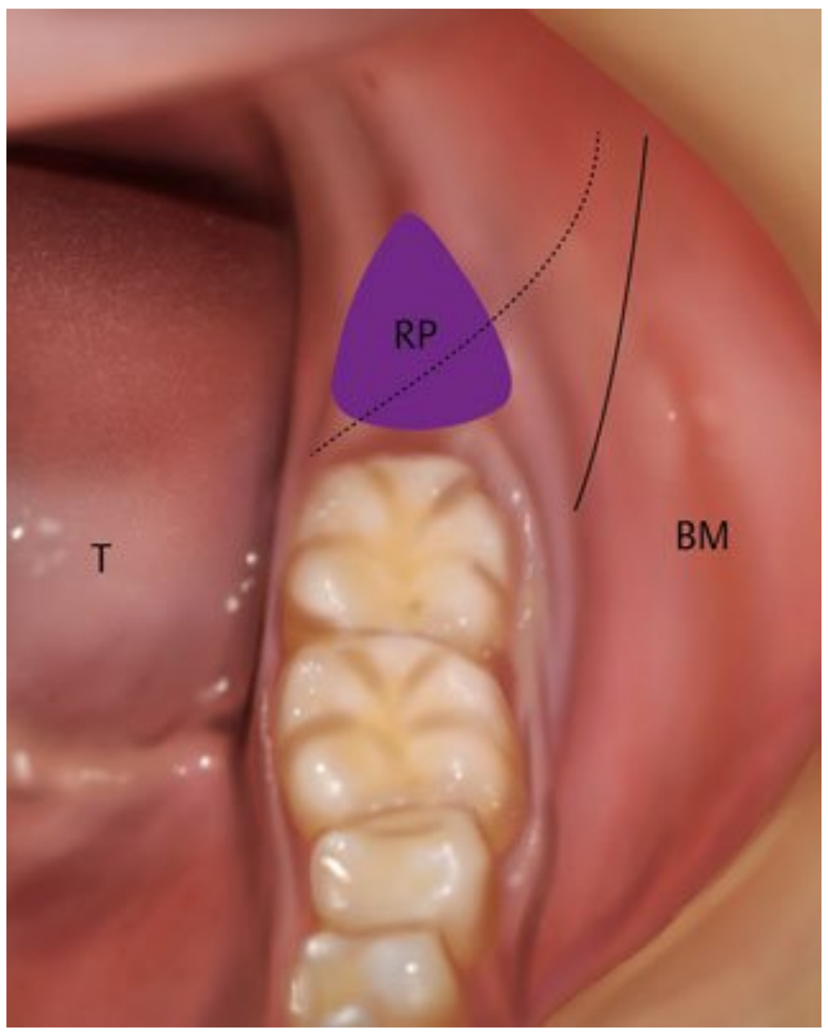


Fig. 20.4 The left retromolar region. Yellow region, retromolar pad; dotted line, internal oblique ridge; solid line, external oblique ridge. BM, Buccal mucosa; RP, retromolar pad; T, tongue.

emerge from the cementum, penetrate the periodontal ligament and enter the alveolar bone. The main roles of the periodontal ligament are to support the teeth, control sensitivity, and provide a blood supply. The activity of the periodontal ligament and the number of fibers it contains decrease with age. Dental pulp is a soft tissue that includes blood vessels, nerve fibers, lymph vessels, and connective tissue. It is divided into two parts, the coronal pulp and the radicular pulp, which communicate at the cervical region. The radicular pulp of anterior teeth is single; but for posterior teeth, there are multiple areas of radicular pulp. Both coronal pulp and radicular pulp become thinner as dentin deposition continues with aging. The apical foramen becomes narrower because of deposition of cementum.

The number of human adult permanent teeth is 32, and these are each surrounded by alveolar bone. Alveolar bone is divided into two parts: alveolar bone proper, which is adjacent to the cementum, and supporting bone. The alveolar bone proper resorbs along with the loss of teeth. There are eight kinds of permanent teeth: central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar, and third molar (wisdom teeth) from the midline to posterolateral. The mesial and distal tooth surfaces are those closest to and farthest from the midline, respectively. The term *labial* is used for incisors and canine teeth, and *buccal* is used for premolar and molar teeth. *Palatal* denotes the inside surface of maxillary teeth, and *lingual* denotes the inside surface of mandibular teeth (**Fig. 20.7**). These designations are used to describe the precise location of small carious lesions. The deciduous teeth total 20, and they are called deciduous central incisor, deciduous lateral incisor, deciduous canine, first deciduous molar, and second deciduous molar from median to posterolateral. Deciduous teeth begin to erupt 6 to 8 months after birth. The deciduous central incisor erupts first, and the deciduous dentition finishes erupting at approximately 2 years of age. Then deciduous teeth begin to be replaced by permanent teeth at age 6 to 7 years. The permanent dentition is complete by the age of 13, except for the third molar, for which the age of eruption differs between individuals. The upper teeth are innervated by three superior nerves arising from the maxillary nerve: the posterior superior alveolar nerve, the middle superior alveolar nerve, and the anterior

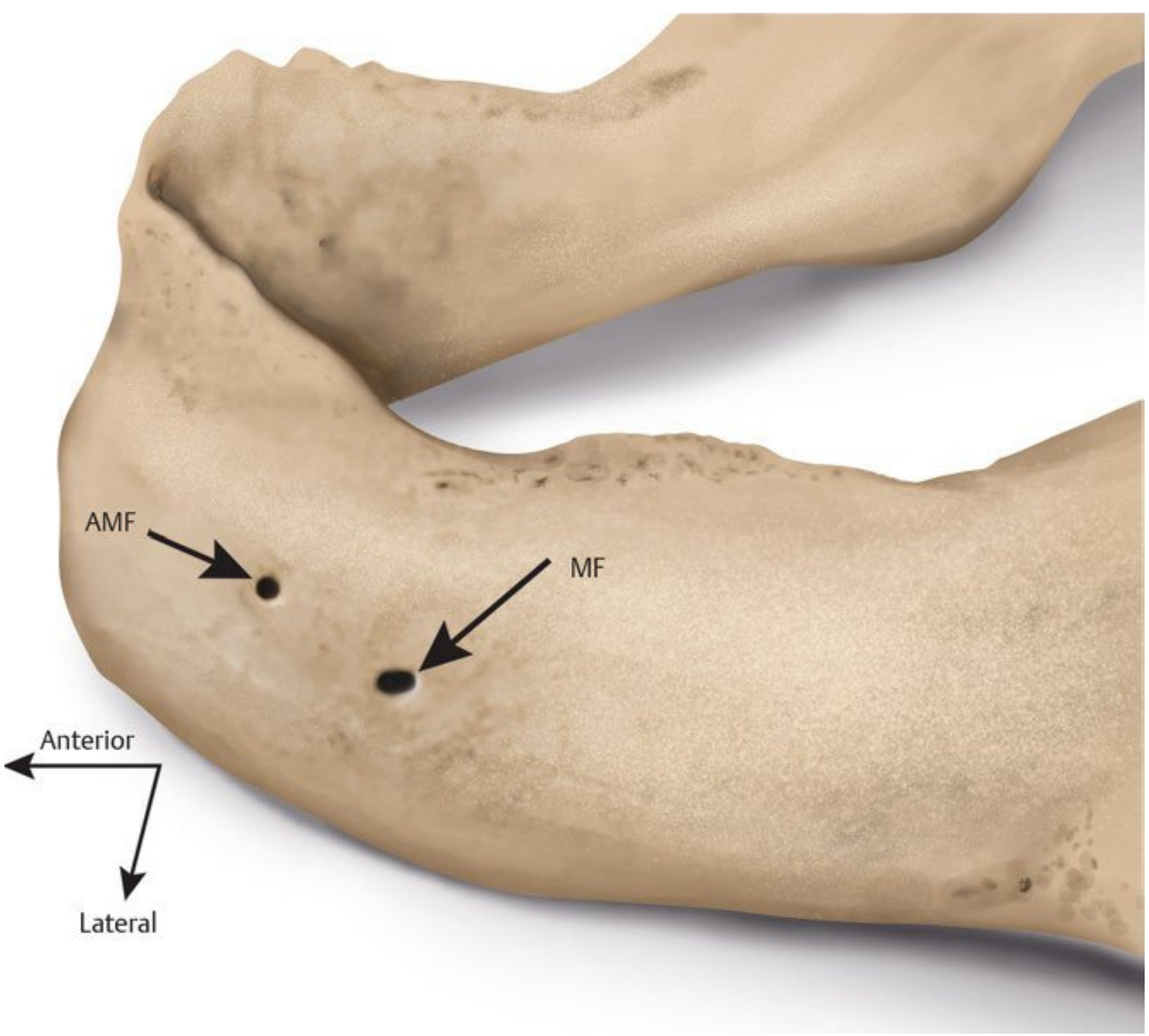


Fig. 20.5 Lateral view of the left mandible. AMF, Accessory mental foramen; MF, mental foramen.