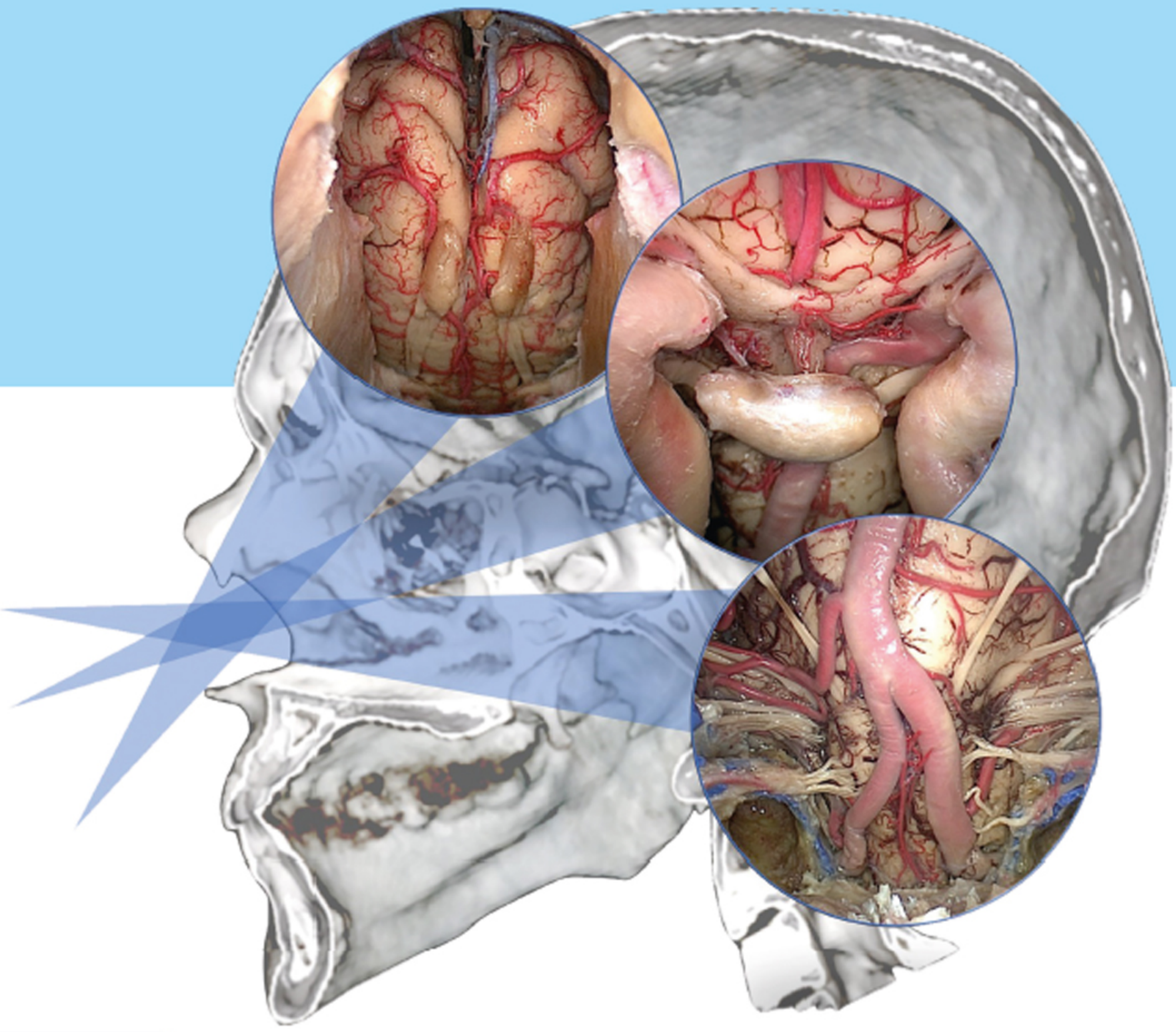
Transnasal Endoscopic Skull Base and Brain Surgery

Surgical Anatomy and its Applications

Second Edition

Aldo C. Stamm

Associate Editor
João Mangussi-Gomes



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I dedicate this second edition to my whole family—my wife Dagmar; my children Raquel and Guilherme; my grandchildren Pedro, Helena, and Luísa; my son-in-law Leonardo; and my daughter-in-law Liana—for their unrelenting support. To my father Arno, who has already gone, and to my mother Ada, who despite her advanced age keeps fighting for life.

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Video 54.1 Clinical case of anterior skull base malignant tumor management. A 74-year-old woman presented with left epistaxis, nasal obstruction, and headache. CT and MR scans revealed a bulky lesion involving the left nasal fossa, ethmoid sinus and orbit. Biopsy of the lesion revealed a sinonasal undifferentiated carcinoma. A total body PET-CT scan excluded systemic dissemination of the disease. The patient underwent induction chemotherapy (5 cycles), with partial response (regression of the intraorbital component of the tumor). A combined approach (cranio-endoscopic) was performed, and free-margins were obtained. Finally, the patient underwent adjuvant radiotherapy (surgical field – 60 Gy; elective neck – 54 Gy) with intensity modulated technique (IMRT). After 27 months of follow-up, the patient is alive with no evidence of disease.

Video 57.1 Transnasal endoscopic nasopharyngectomy for a squamous cell carcinoma.

Video 69.1 This video demonstrates an endoscopic endonasal approach to patient with a chordoma, whom had had previous surgeries and proton beam therapy. Knowing that the Internal Carotid Artery was involved by tumor, the approach was done carefully, using neuronavigation guidance and microdoppler probe to identify the ICA. Despite the precautions taken, when removing tumor from behind the ICA using a blunt ball probe, the ICA ruptured and large-volume, brisk bleeding is seen. The bleeding is controlled in the OR using a muscle patch and tamponade and the patient is immediately taken to the angio-suite. Stenting the artery was not possible and the ICA had to be occluded. Fortunately, this patient had good contralateral flow and did not have an ischemic insult nor required bypass.

Foreword

From humble beginnings about 20 years ago the disciplines of endoscopic skull base surgery and endoscopic cranial surgery have grown considerably and now encompass a large volume of surgical cases in both specialties. This idea of “minimally invasive surgery” has grown and blossomed. However, the correct terminology is “minimal access surgery,” since through a small opening, very extensive surgery may be performed. Similar to other cranial base and cranial approaches, this type of surgery can also produce severe complications occasionally, which in some patients may be difficult to manage due to the small opening. The endoscopes, the display systems, and instruments we use for this surgery are still in their infancy and are still developing. The use of robotic and artificial intelligence technologies will have a great impact on this field in future. Like other types of surgery, an excellent understanding of the anatomy, especially as seen through the endoscope, is needed. In many cases, neuronavigation is extremely useful. Observation and learning with master surgeons who have perfected these techniques is essential for young surgeons who wish to enter this field of surgery.

Professor Aldo Stamm is now an internationally recognized expert in the area of endonasal and skull base surgery. He has done significant pioneering work in this field, and also has a track record of working collaboratively with neurosurgery and other disciplines to achieve optimal patient outcomes. In this book, he has masterfully assembled a team of international collaborators who have presented different aspects to endoscopic cranial base and cranial surgery. The book is well organized into 14 sections and is very readable. All aspects of the surgery, including instrumentation, anatomy, operative technique, and potential complications are well covered. I strongly recommend this book to any junior surgeon who wishes to pursue this field. I thank Prof. Stamm and his contributors for this valuable addition to our knowledge.

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Preface

This second edition is an extension of our first, as new technologies and improvements of the transnasal endoscopic skull base and brain surgery have undergone a remarkable evolution in recent years. New topics were incorporated aiming at including a much larger number of clinical entities. The development of more ergonomic and precise surgical instruments, such as the bipolar coagulation systems, special tweezers and scissors, and new hemostatic agents has allowed a safer and more effective treatment of lesions that affect this complex region of the human body.

The main focus of this second edition is the correlation between the skull base anatomy as seen from the endonasal perspective and its surgical applications. To achieve this objective, we invited leading experts on the subject from all over the world, making this book a multicentric and multidisciplinary one, since many medical specialties are involved, especially neurosurgery, otorhinolaryngology, head and neck surgery, neuroendocrinology, intensive care, neuro-anesthesiology, among others. Thus, our colleagues will be able to appreciate the experience of different groups in what is best in the field of the transnasal endoscopic surgery of the skull base and brain.

Each chapter is provided with a summary and chapter highlights, which facilitates and illustrates beforehand what is most significant in the chapter. We also added to this edition a series of videos from different institutions, therefore contributing to a better understanding of the described techniques.

I wish you all a great and enjoyable reading!

Aldo C. Stamm, MD, PhD

Acknowledgments

This project is the result of hard work and commitment. First, I would like to thank all authors and collaborators who have made it possible to carry out this project, for all their effort and dedication. I would like to thank the staff at Thieme Publishers, especially Mr. Timothy Hiscock, who greatly encouraged and believed in the publishing of this second edition. I would also like to thank Mr. J. Owen Zurhellen and Ms. Mary Wilson for their constant help and guidance.

Thanks to the great masters and professors Wolgang Draf (In memoriam) and Albert Rhoton Jr. (In memoriam), as well as to their respective fellows, for all their teachings and constant encouragement throughout this journey.

Thanks to Dr. Eduardo A. Vellutini, a great partner in the skull base surgeries, present in the good and bad moments, always encouraging the development and improvement of this type of surgery, pushing its limits beyond the early standards.

My special thanks to Dr. João Mangussi-Gomes, a great friend and co-editor of this book, for his untiring and dedicated work in taking and revising the chapters of this edition, so they would become more attractive and educational.

I would also like to thank Dr. Leonardo Balsalobre and Dr. Marcos Queiroz Gomes for their friendship and dedication to all patients undergoing this type of surgery, and to my fellows and residents, old and new, for their constant help and follow-up of our patients.

And finally, my deepest thanks to my family for their support, patience, and encouragement during all these more than 30 years dedicated to this complex and difficult branch of medicine.

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Part I

Principles of Transnasal Endoscopic Skull Base and Brain Surgery

I

1 Anatomy and Osteology of the Skull Base

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Summary
This chapter reviews the bony architecture of the anterior, middle, and posterior skull base. Relying on a series of dry skull images, this anatomy is explained through a progressive disassembly of the skull base. This approach allows introduction of concepts on the corresponding exo- and endocranial divisions of each of the cranial fossae and relevant surgical notions as the formation of the center and lateral corridors of the skull base.

Keywords: skull base, skull base anatomy, osteology, endoscopic skull base surgery

Key Points

- Each skull base area has a center, or midline portion, and two lateral parts.
- The center areas are lined up as a corridor, whereas the lateral parts radiate from the skull base center.
- On the endocranial side, the center surgical corridor comprises, from anterior to posterior, (1) the cribriform area; (2) planum; (3) sellae; (4) clivus; and (5) craniovertebral junction.
- On the exocranial side, the center surgical corridor comprises (1) the nasal cavity; (2) the sphenoid sinus; and (3) the pharynx, which enable surgical access to the corresponding endocranial areas.
- In the center surgical corridor, the anterior, middle, and posterior skull base areas are close together and bridged by the sphenoid body.

1.1 Introduction

Understanding the osteology of the skull base is a fundamental step in skull base surgery. It enables accurate topographic location and helps tailor surgical routes to specific skull base areas. This chapter reviews the bony architecture of the anterior, middle, and posterior skull base.

1.2 General Anatomy

The skull is divided into the cranium and facial skeleton. The cranium in its turn is divided into calvaria, which is the domelike superior portion of the cranium, formed by the frontal, parietal, and squamous parts of the occipital and temporal bones and greater sphenoid wings, and the cranial base. The cranial base is formed by the occipital, temporal, ethmoid, and frontal bones arranged around, and connected by, a center element: the sphenoid bone.

The cranial base has an endocranial surface, which faces the brain and is naturally divided into anterior, middle, and posterior fossae (▶ Fig. 1.1), and an exocranial surface (▶ Fig. 1.2), which faces the nasal cavity, sinuses, orbits, pharynx, infratemporal fossae, and pterygopalatine, parapharyngeal, and infrapetrosal spaces.[1,2]

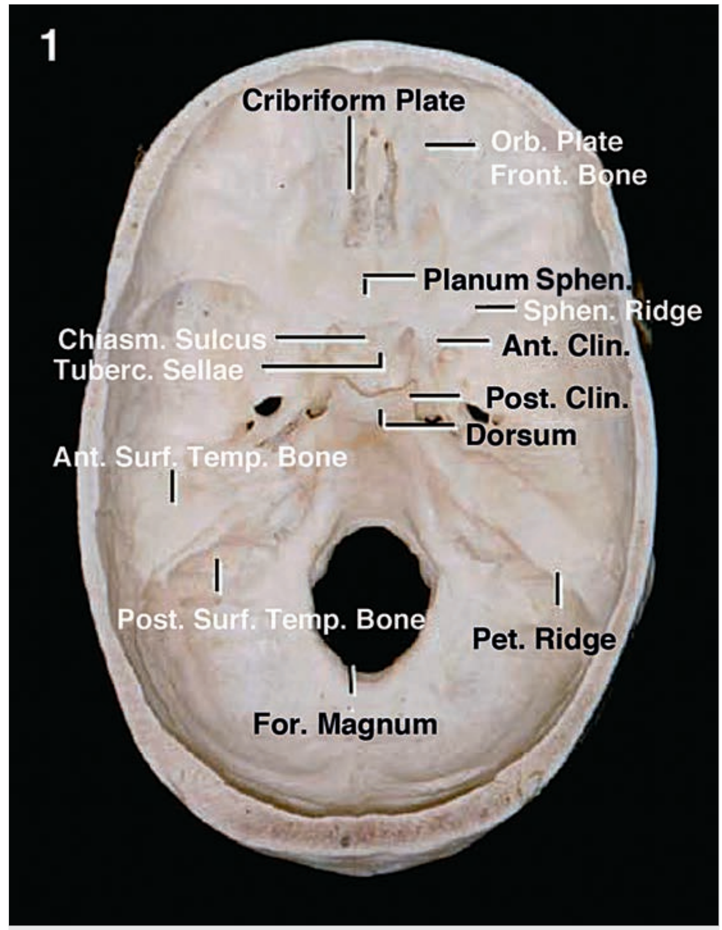

Fig. 1.1 Cranial base: endocranial surface. The upper surface of the anterior cranial base is formed by the frontal bone, which roofs the orbit; the ethmoid bone, which is interposed between the frontal bones and is the site of the cribriform plate; and the lesser wing and the anterior part of the body of the sphenoid, which form the posterior part of the floor of the anterior fossa. The upper surface of the middle cranial base is formed by the greater sphenoid wing and the sphenoid body anteriorly and the upper surface of the temporal bone posteriorly. The posterior part of the cranial base is formed by the temporal and occipital bones. Ant.: anterior; Chiasm.: chiasmatic; Clin.: clinoid; For.: foramen; Front.: frontal; Orb.: orbital; Pet.: petrous; Post.: posterior; Sphen.: sphenoid, sphenoidale; Surf.: surface; Temp.: temporal; Tuberc.: tuberculum.

On the endocranial side of the skull base, the border between the anterior and middle fossa is marked by the sphenoid ridge, joined medially by the chiasmatic sulcus. The border between the middle and posterior fossae is formed by the petrous ridges joined by the dorsum sellae and posterior clinoid processes (▶ Fig. 1.3).

On the exocranial side, the anterior and middle fossae are divided by a transverse line, extending through the pterygomaxillary fissures and pterygopalatine fossae at the upper level, and the posterior edge of the alveolar processes of the maxillae at a lower level. Medially, this corresponds to the attachment of the vomer to the sphenoid bone. The middle and posterior cranial fossae are separated on each side by a transverse line crossing near the posterior border of the vomer–sphenoid junction, foramen lacerum, carotid canal, jugular foramen, styloid process, and mastoid tip (▶ Fig. 1.4).

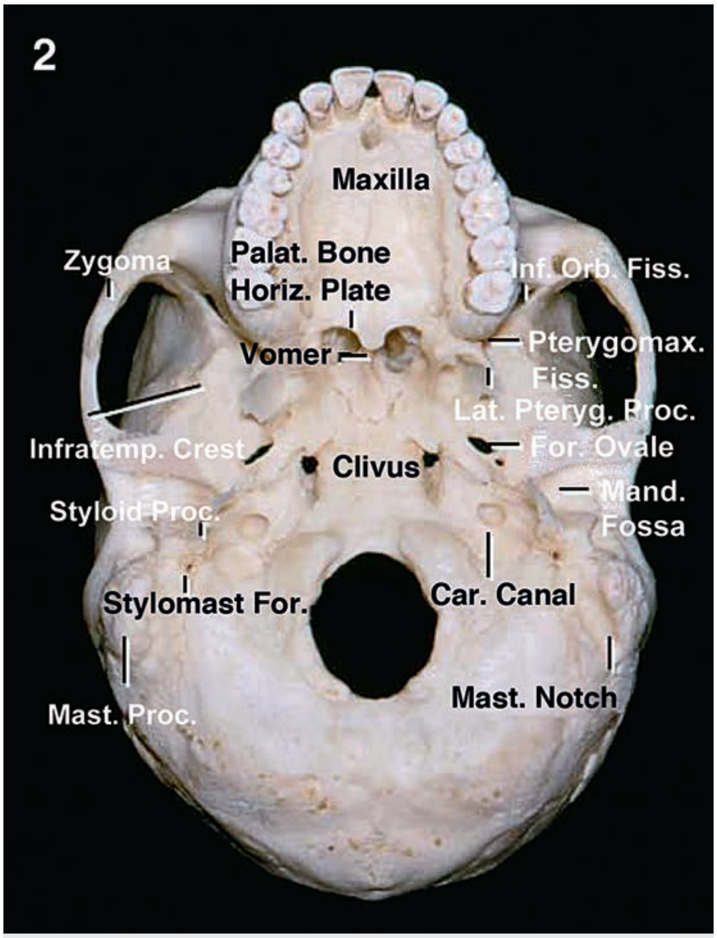

Fig. 1.2 Cranial base: exocranial surface. The exocranial surface is formed mainly by the maxillae, zygomatic, palatine, sphenoid, temporal, and occipital bones and vomer. The maxillae, the orbits, and the nasal cavity are located below the anterior fossa. The anterior part of the hard palate is formed by the maxillae, and the posterior part is formed by the palatine bone. The vomer attaches to the lower part of the body of the sphenoid and forms the posterior part of the nasal septum. The anterior part of the zygomatic arch is formed by the zygoma and the posterior part by the squamosal part of the temporal bones. The mandibular fossa is located below the posterior part of the middle fossa. The infratemporal fossa is located below the greater sphenoid wing and is limited anteriorly by the infratemporal crest. Car.: carotid; Fiss.: fissure; For.: foramen; Horiz.: horizontal; Inf.: inferior; Infratemp.: infratemporal; Lat.: lateral; Mand.: mandibular; Mast.: mastoid; Orb.: orbital; Palat.: palatine; Proc.: process; Pteryg.: pterygoid; Pterygomax.: pterygomaxillary; Stylomast.: stylomastoid.

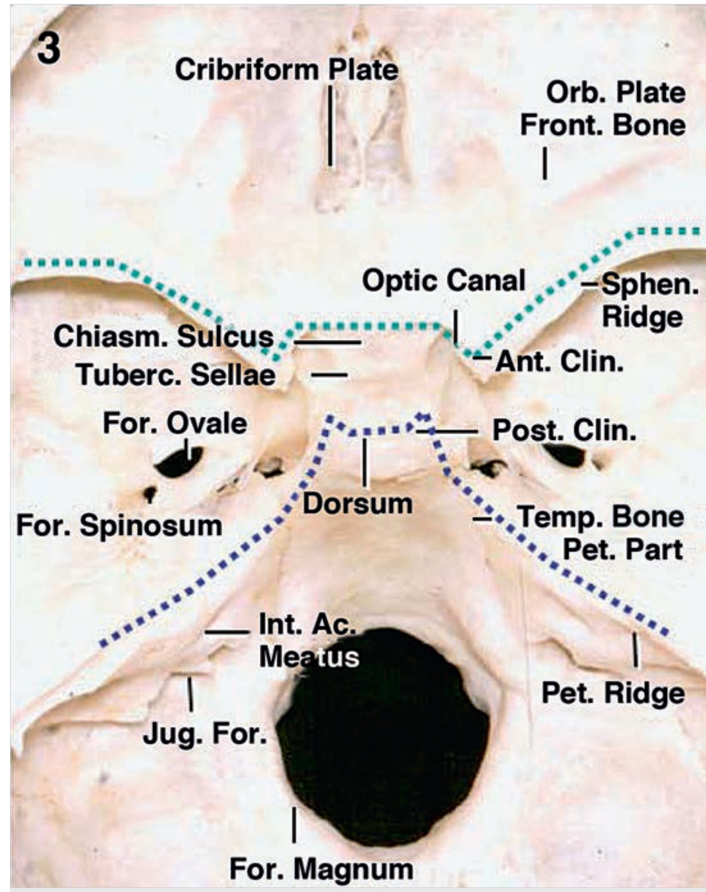

Fig. 1.3 On the endocranial side of the skull base, the border between the anterior and middle fossa is marked by the sphenoid ridge, joined medially by the chiasmatic sulcus (*dotted light blue line*), and the border between the middle and posterior fossae is formed by the petrous ridges joined by the dorsum sellae and posterior clinoid processes (*dotted dark blue line*). Ac.: acoustic; Ant.: anterior; Chiasm.: chiasmatic; Clin.: clinoid; For.: foramen; Front.: frontal; Int.: internal; Jug.: jugular; Orb.: orbital; Pet.: petrous; Post.: posterior; Sphen.: sphenoid; Temp.: temporal; Tuberc.: tuberculum.

Each of the three skull base areas has a center and two lateral parts. The center parts are arranged as a midline corridor and comprise, on the endocranial side, the cribriform area, planum, sellae, clivus, and craniovertebral junction. On the exocranial side, this center corridor encompasses the nasal cavity, sphenoid sinus, and the pharynx.

In the center corridor, the anterior, middle, and posterior skull base areas are close together and bridged by the body of the sphenoid.

1.3 Anatomy of the Anterior Skull Base

The anterior endocranial surface is formed by the combination of three bones: frontal, ethmoid, and sphenoid (▶ Fig. 1.5). The orbital plates of the frontal bones form most of the lateral parts of this fossa, are the roof of the orbital cavities, and give support to the dura and orbital gyri of the frontal lobe. The medial gap between the orbital plates is filled by the cerebral surface of the ethmoid bone, presenting the crista galli and cribriform plates. The crista galli gives attachment to the falx, whereas the cribriform plates give support to the olfactory bulbs and are traversed by the olfactory fila. Posteriorly, the anterior fossa is closed by the lesser wings of the sphenoid laterally and the sphenoid body medially. In this way, the medial portion of the anterior fossa is formed by three bones, whereas the lateral part, which covers the orbit and optic canals, is formed only by two, the orbital plate of frontal bone and the lesser sphenoid wings, on each side.

On the exocranial side, the lateral portion of the anterior skull base is on the top of the orbit and maxillary sinus. Medially, it corresponds to the sphenoid sinus of sphenoid body and the ethmoid sinuses, on top of the nasal cavity (▶ Fig. 1.6).

The most posterior portion of the medial exocranial anterior surface is related to the sphenoid, whereas the medial and anterior thirds are related to the ethmoid bone.

The bony nasal septum, which is formed by the vomer and perpendicular plate of the ethmoid and attached to the sphenoid crest and rostrum, divides the nasal cavity along the midline,

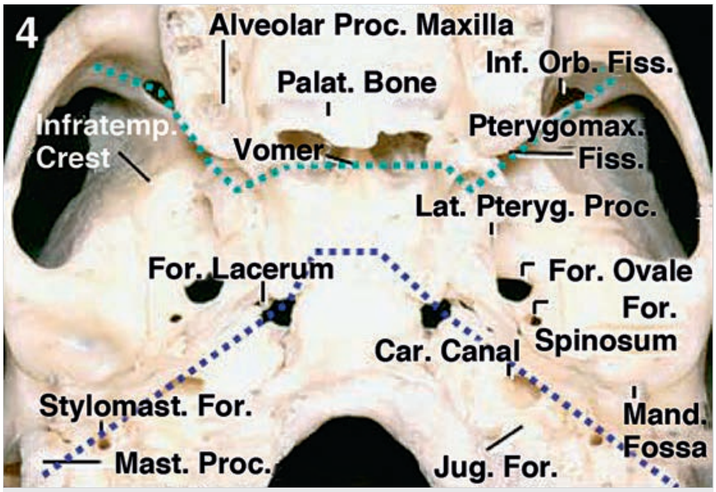

Fig. 1.4 On the exocranial side, the anterior and middle fossae are divided by a transverse line, extending through the pterygomaxillary fissures and pterygopalatine fossae at the upper level, and the posterior edge of the alveolar processes of maxillae at a lower level. Medially, this corresponds to the attachment of vomer to the sphenoid bone (*dotted light blue line*). The middle and posterior cranial fossae are separated on each side, by a transverse line crossing near the posterior border of vomer–sphenoid junction, foramen lacerum, carotid canal, jugular foramen, styloid process, and mastoid tip (*dotted dark blue line*). Car.: carotid; Fiss.: fissure; For.: foramen; Inf.: inferior; Infratemp.: infratemporal; Jug.: jugular; Lat.: lateral; Mand.: mandibular; Mast.: mastoid; Orb.: orbital; Palat.: palatine; Proc.: process; Pteryg.: pterygoid; Pterygomax.: pterygomaxillary; Stylomast.: stylomastoid.

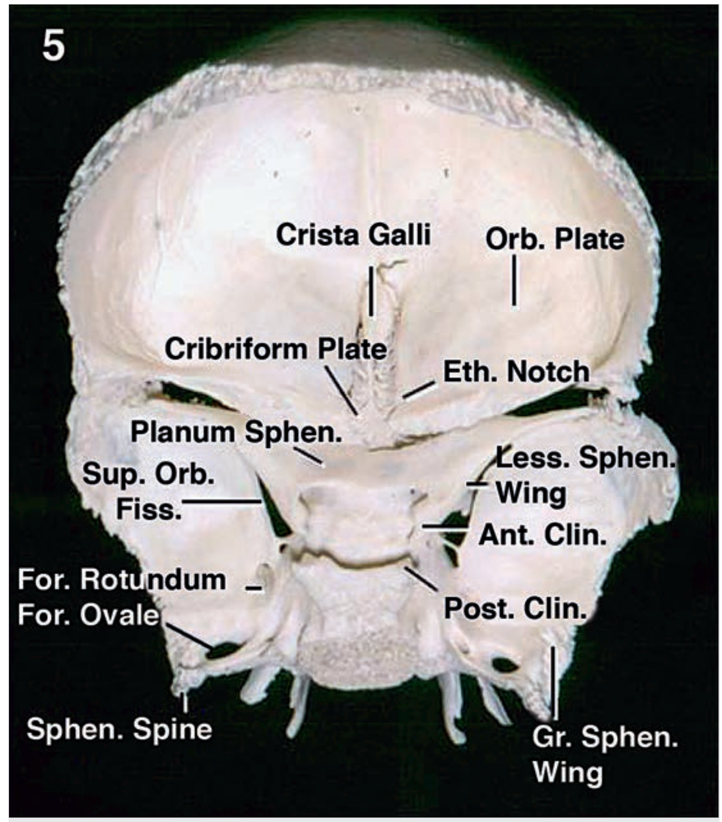

Fig. 1.5 The frontal, ethmoid, and sphenoid bones combine to form the anterior fossa, which is divided into medial and lateral portions. The medial part, covering the upper nasal cavity and sphenoid sinus, is formed by the crista galli and the cribriform plate of the ethmoid bone anteriorly and the planum of the sphenoid body posteriorly. The lateral part, which covers the orbit and the optic canal, is formed by the frontal bone and the lesser wing of the sphenoid bone, which blends medially into the anterior clinoid processes and points toward the middle fossa. Ant.: anterior; Clin.: clinoid; Eth.: ethmoid, ethmoidal; Fiss.: fissure; For.: foramen; Gr.: greater; Less.: lesser; Orb.: orbital; Post.: posterior; Sphen.: spheno, sphenoid, sphenoidal; Sup.: superior.

whereas the lateral plates of the ethmoid bones separate the nasal cavity from each orbit (▶ Fig. 1.7 and ▶ Fig. 1.8).

Some foramina and grooves connect the endocranial and exocranial surfaces and transmit vascular and neural structures in this area. The foramen cecum in the midline serves as the site of passage of an emissary vein; the cribriform plate is pierced by the filaments of the olfactory nerve; the supraorbital grooves, on the superior orbital limits, are related to the frontal branch of the first trigeminal division; the anterior and posterior ethmoidal canals, located along the suture line formed by the frontal and ethmoid bones, transmit the anterior and posterior ethmoidal nerves and arteries; the superior orbital fissure, located between the lesser and greater sphenoidal wings, transmits the superior ophthalmic vein and the first division of the trigeminal, oculomotor, trochlear, and abducens nerves; and the optic canals between the anterior and posterior roots of the anterior clinoid processes transmit the optic nerve and the ophthalmic artery.

1.4 Anatomy of the Middle Skull Base

The endocranial surface of the middle fossa is formed by the sphenoid and temporal bones. The division between these bones usually is not easy to see unless one is focusing on the sphenoid spine, the most posterior prominence of the sphenoid bone, just posterolateral to the foramen spinosum. From this point, it is possible to follow the sphenopetrosal and sphenosquamosal sutures (▶ Fig. 1.9).

The middle cranial base has medial and lateral parts. The medial part is formed by the body of the sphenoid, whereas the lateral parts result from the combination of lesser and greater sphenoid wings and squamous and petrous parts of the temporal bone. The medial portion of the middle cranial base is the sellae, whereas the most lateral portions are the temporal fossae. Between these two areas, on each side, are the parasellar regions. The parasellar regions are probably the smallest areas of the skull base with the highest concentration of important neural and vascular structures, as they house the cavernous sinuses.

The sphenoid contributes to the middle fossa mainly with its body, the greater and lesser wings. Laterally, the lesser sphenoid wings form the sphenoid ridges. Medially, the lesser wings are connected to the sphenoid body through the anterior root, and they form the roof of the optic canal and are continuous with the sphenoid planum. At the center of the planum is the sphenoid jugum, a faint ridge, which is the remnant of the fusion of the ossification centers. The posterior root of the anterior clinoid process, also called the optic strut, separates the optic canals above from the superior orbital fissure below. The chiasmatic sulcus is located posterior to the planum. On each side of the chiasmatic sulcus are the endocranial openings of the optic canals. Posteriorly, the chiasmatic sulcus is separated from the sellar cavity by the tuberculum sellae. The posterior limit of the sellae is composed of the dorsum and posterior clinoid processes, which

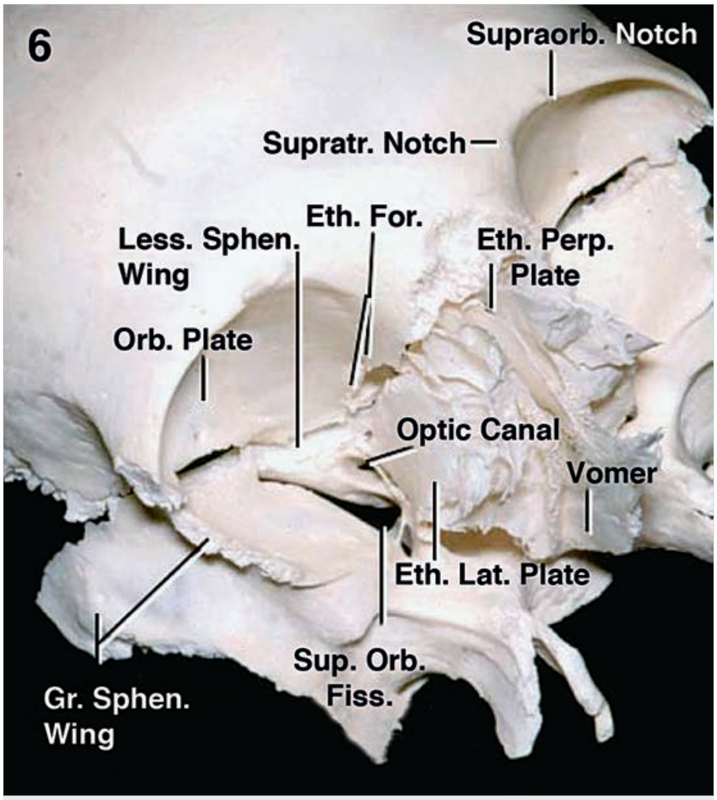

Fig. 1.6 On the exocranial side, the anterior cranial base is divided into a medial part related to the ethmoidal and sphenoidal sinuses and nasal cavity below, and a lateral part that corresponds to the orbit and maxilla. The ethmoid bone forms the anterior and middle thirds of the exocranial surface, and the sphenoid body forms the posterior third of the medial part. The ethmoid presents the perpendicular plate that joins the vomer in forming the nasal septum and two lateral plates located in the medial wall of the orbits. The lateral plates separate the lateral wall of the nasal cavity and the orbit. The main foramina of the region are the anterior and posterior ethmoidal foramina located in the superomedial orbital wall, along the frontoethmoidal suture, which transmit the ethmoidal nerves and arteries; the supraorbital and supratrochlear notches or foramina, transmitting the arteries and nerves of the same name; and the optic canal, which transmits the optic nerve and ophthalmic artery. The superior orbital fissure is located between the lesser and greater sphenoidal wings on the lateral side of the optic canal. It transmits the oculomotor, trochlear, ophthalmic, and abducens nerves, a recurrent meningeal artery, and the superior and inferior ophthalmic veins. Eth.: ethmoid, ethmoidal; Fiss.: fissure; For.: foramen; Gr.: greater; Lat.: lateral; Less.: lesser; Orb.: orbital; Perp.: perpendicular; Sphen.: spheno, sphenoid, sphenoidal; Sup.: superior; Supraorb.: supraorbital; Supratr.: supratrochlear.

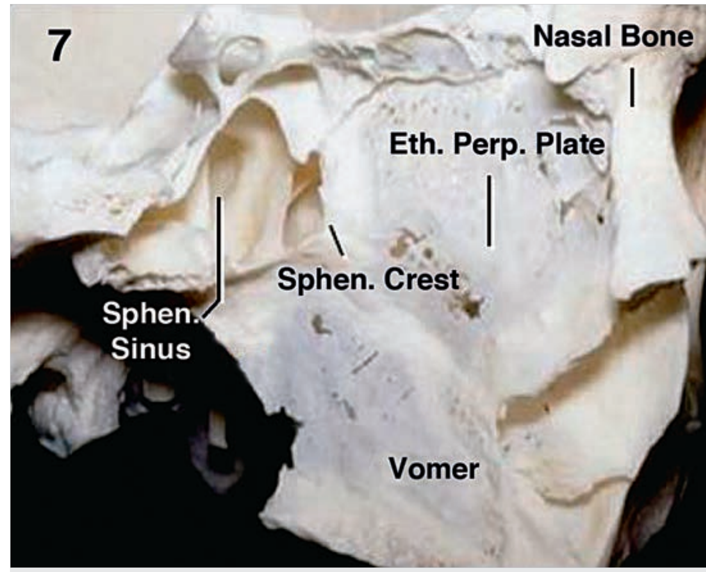

Fig. 1.7 The osseous nasal septum is formed by the attachment of the perpendicular plate of the ethmoid and vomer at the sphenoidal crest. Eth.: ethmoid, ethmoidal; Perp.: perpendicular; Sphen.: spheno, sphenoid, sphenoidal.

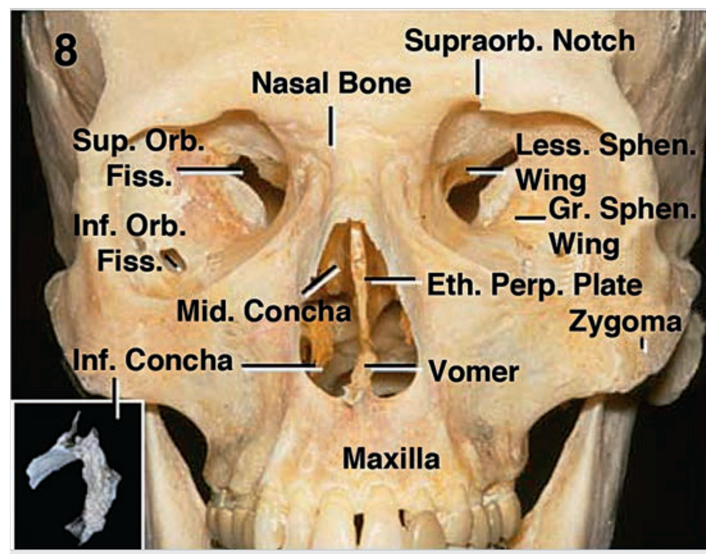

Fig. 1.8 Anterior norma. The orbital rim is formed by the frontal bone, zygoma, and maxilla. The nasal bone is interposed above the anterior nasal aperture, between the maxillae. The nasal cavity is located between the ethmoid bone above and the maxillae, palatine bones, and pterygoid processes of the sphenoid below. It is roofed by the frontal and ethmoid bones, and the floor is formed by the maxillae and palatine bones. The nasal septum forms the medial wall of the nasal cavities. The nasal conchae are located on the lateral walls of the nasal cavity. The inferior concha (*inset*) is a separate bone, and the middle and superior concha are appendages of the ethmoid bone. Eth.: ethmoid, ethmoidal; Fiss.: fissure; Gr.: greater; Inf.: inferior; Less.: lesser; Mid.: middle; Orb.: orbital; Perp.: perpendicular; Sphen.: spheno, sphenoid, sphenoidal; Sup.: superior; Supraorb.: supraorbital.

are the medial boundaries between the middle and posterior cranial fossae (▶ Fig. 1.10).

The greater sphenoid wings contribute to the temporal fossae. Anteriorly, it forms the lateral limit of the superior orbital fissure. The foramen rotundum, which transmits the maxillary division of the trigeminal nerve, is separated from the superior orbital fissure by a bridge of bone, the maxillary strut. The largest opening at the greater sphenoid wing is the foramen ovale, which transmits the third trigeminal division and, in most cases, the accessory meningeal artery. Lateral to this opening is the foramen spinosum for the middle meningeal artery. Occasionally, there may be an opening medial to the foramen ovale—the emissary sphenoid foramen (foramen of Vesalius), which transmits a vein connecting the pterygoid venous plexus and the cavernous sinus and, in some cases, might transmit the accessory meningeal artery. The lingula is a protrusion of the sphenoid bone located at the junction of the body and the greater wing. As soon as the carotid artery leaves its canal on the petrous portion of the temporal bone, it is embraced by the lingula, which holds the artery in place and enables it to run along the carotid sulcus on each side of sellae. Anteriorly, the carotid artery rests against the optic strut, in close relationship with the anterior clinoid. The lingula gives attachment to the

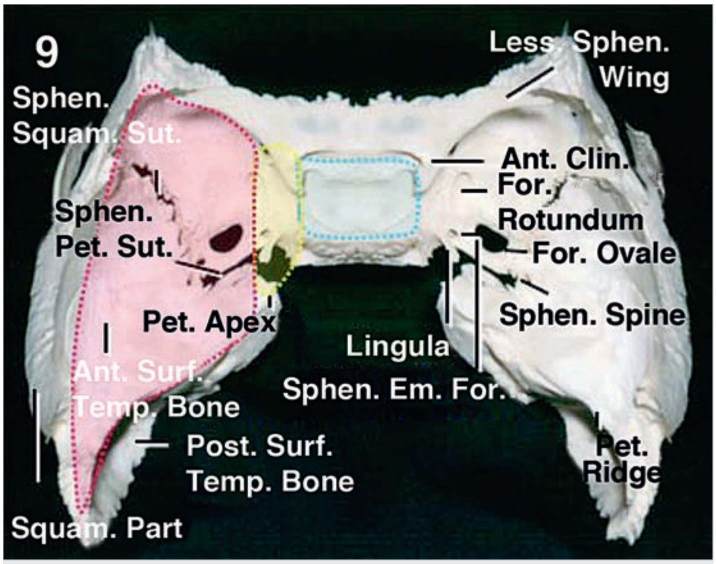

Fig. 1.9 The endocranial surface of the middle cranial base is formed by the sphenoid and temporal bones and can be divided into three regions: a medial part, the sellar region (*blue shaded area*), formed by the sphenoid body; a lateral part, the temporal fossa (*pink shaded area*), formed by the sphenoidal wings and the cerebral surface of the squamosal and petrous parts of the temporal bone; and an intermediate part, the parasellar area (*yellow shaded area*), formed by the transitional part of the sphenoid bone between the greater wing and body and receiving posteriorly a small contribution of the petrous apex of the temporal bone. The greater wing forms the largest part of the endocranial surface of the middle fossa, with the squamosal and the petrosal parts of the temporal bone completing this surface. Ant.: anterior; Clin.: clinoid; Em.: emissary; For.: foramen; Less.: lesser; Pet.: petrosal, petrous; Post.: posterior; Sphen.: spheno, sphenoid, sphenoidal; Squam.: squamosal, squamous; Surf.: surface; Sut.: suture; Temp.: temporal.

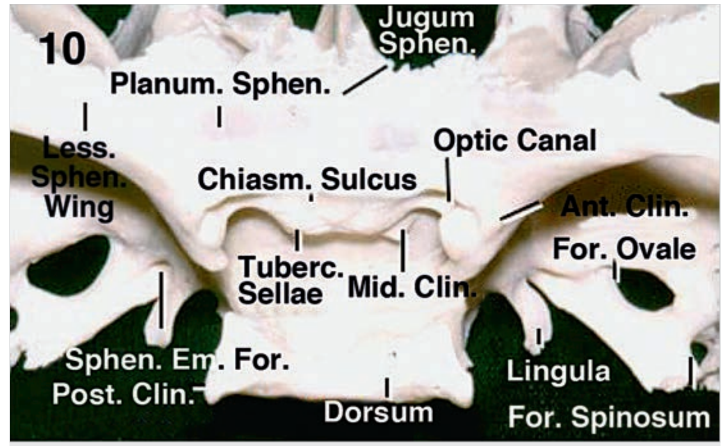

Fig. 1.10 Enlarged view of the medial part of the middle fossa, formed by the body of the sphenoid bone. Ant.: anterior; Chiasm.: chiasmatic; Clin.: clinoid; Em.: emissary; For.: foramen; Less.: lesser; Post.: posterior; Mid.: middle; Sphen.: spheno, sphenoid, sphenoidal; Tuberc.: tuberculum.

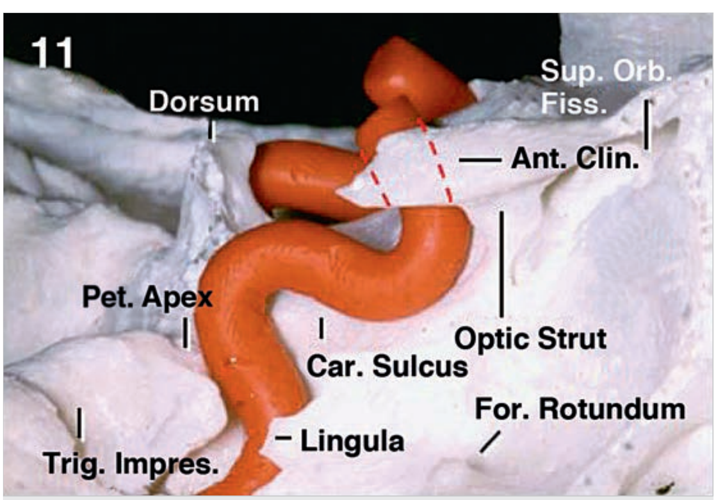

Fig. 1.11 Lateral view of the parasellar region. The courses of the petrous, cavernous, and supraclinoid carotid have been represented. The cavernous sinus sits on the lateral aspect of the body of the sphenoid bone. The carotid sulcus is the shallow groove on the lateral aspect of the body of the sphenoid bone along which the cavernous carotid courses. The cavernous carotid sits against and is separated from the carotid sulcus by the dura of the medial sinus wall. The carotid sulcus starts on a position inferior and lateral to the dorsum sellae at the intracranial end of the carotid canal, turns forward to groove the body of the sphenoid immediately below the lateral edge of the floor of the sella, and turns upward to end on a position medial to the anterior clinoid process. Ant.: anterior; Car.: carotid; Clin.: clinoid; Fiss.: fissure; For.: foramen; Impres.: impression; Orb.: orbital; Pet.: petrous; Sup.: superior; Trig.: trigeminal.

petrolingual ligament, which separates the petrous carotid from the vertical cavernous carotid segment (▶ Fig. 1.11).

The endocranial surfaces of the petrolingual petrous and squamosal parts of the temporal bone also form the middle fossa (▶ Fig. 1.12 and ▶ Fig. 1.13). In this area, the greater petrosal nerve runs into the facial hiatus just medial to the tensor tympani muscle and lateral to the carotid canal. The trigeminal impression, which houses the trigeminal ganglion, is lateral to the petrous apex and posterosuperior to the superior opening of the carotid canal.

The exocranial surface of the middle cranial base is also divided into medial and lateral parts (▶ Fig. 1.14 and ▶ Fig. 1.15). The medial part encompasses the sphenoid body and the upper portion of the basal part of the occipital bone and corresponds to the sphenoid sinus and the nasopharynx. The lateral part is formed by the greater sphenoid wing and the lateral pterygoid plate; the petrous, tympanic, squamous, and styloid parts of the temporal bone; and the zygomatic, palatine, and maxillary bones. Between the lateral and medial parts of the middle cranial base, an intermediate part corresponds to the area between the pterygoid plates. This area is inferior to each cavernous sinus and extends from the pterygopalatine fossa anteriorly to the pterygoid fossa posteriorly. The pterygopalatine fossa is located between the posterior wall of the maxillary sinus in the front, the pterygoid process behind, the palatine bone medially, and the body of the sphenoid bone above. The fossa opens laterally through the pterygomaxillary fissure into the infratemporal fossa and medially through the sphenopalatine foramen to the nasal cavity. Both the foramen rotundum for the maxillary nerve and the pterygoid canal for the vidian nerve open through the posterior wall of the fossae formed by the pterygoid process of the sphenoid bone. The palatovaginal canal carrying the pharyngeal nerve and artery and the greater and lesser palatine canals conveying the greater and lesser palatine arteries also open into the pterygopalatine fossa. The inferior orbital fissure, across which the orbital muscle stretches, lies in front of the pterygopalatine fossa.

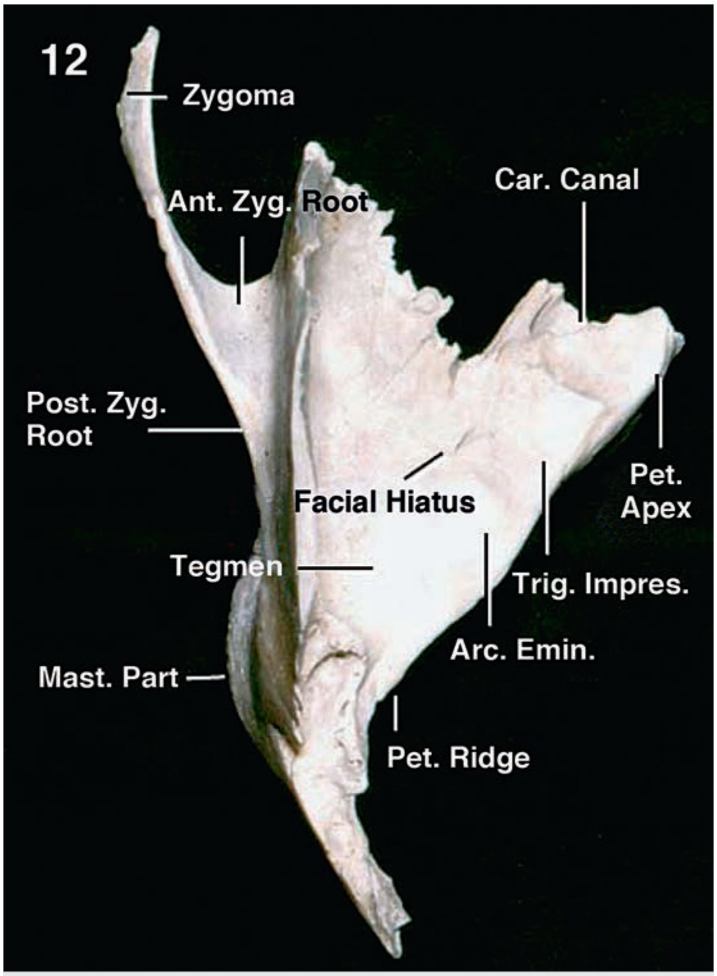

Fig. 1.12 The upper surface of the petrous bone is grooved along the course of the greater and lesser petrosal nerves. The lesser petrosal nerve, from the tympanic plexus, passes through the tympanic canaliculus, which is located anterior to the facial hiatus and courses in an anteromedial direction parallel to the greater petrosal nerve, which courses along the facial hiatus. The carotid canal extends upward and medially and provides passage to the internal carotid artery and carotid sympathetic nerves in their course to the cavernous sinus. The posterior trigeminal root, the semilunar ganglion, and Meckel's cave occupy the middle fossa on the upper surface of the petrous bone at the site of the trigeminal impression. The arcuate eminence approximates the position of the semicircular canals. The internal auditory canal can be identified below the floor of the middle fossa by drilling along a line approximately 60 degrees medial to the arcuate eminence, near the middle portion of the angle between the greater petrosal nerve and arcuate eminence. The petrous apex, medial to the internal acoustic meatus, is free of important structures. A thin lamina of bone, the tegmen tympani, extends laterally from the arcuate eminence and roofs the mastoid antrum, the tympanic cavities, and the canal for the tensor tympani muscle. Opening the tegmen from above exposes the heads of the malleus, incus, the tympanic segment of the facial nerve, and the superior and lateral semicircular canals. Ant.: anterior; Arc.: arcuate; Car.: carotid; Emin.: eminence; Impres.: impression; Mast.: mastoid; Pet.: petrous; Post.: posterior; Trig.: trigeminal; Zyg.: zygomatic.

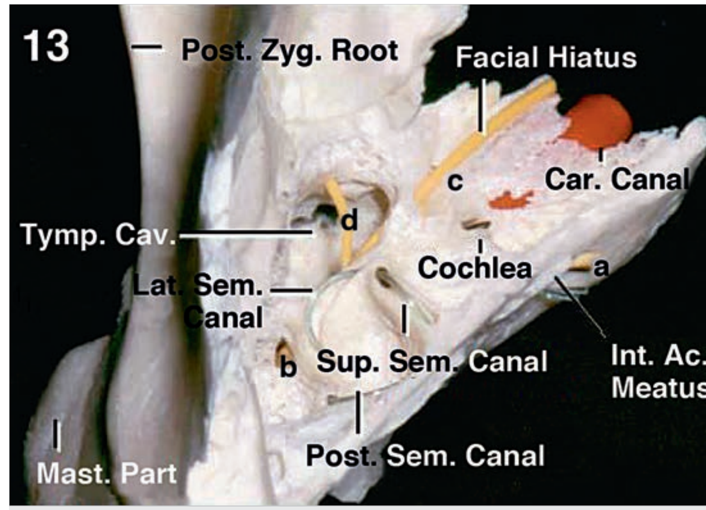

Fig. 1.13 The anterior surface of the temporal bone has been drilled to expose the internal structure of the temporal bone. The carotid artery is represented in red, the facial nerve in yellow, the cochlear nerve in black, and the vestibular nerves in green. The arcuate eminence approximates the position of the superior semicircular canal; however, the relationship between these two structures is greater at their anterior end, from which their main axis diverges. From the brainstem to its peripheral branches, the facial nerve can be divided into six portions: cisternal, meatal (a), labyrinthine, tympanic, mastoid (b), and extracranial. The labyrinthine segment, which is located in the petrous part, extends from the meatal fundus to the geniculate ganglion and is situated between the cochlea anteromedially and the semicircular canals posterolaterally. The labyrinthine segment ends at the site at which the greater superficial petrosal nerve arises from the facial nerve at the level of the geniculate ganglion. From there, the nerve turns laterally and posteriorly along the medial surface of the tympanic cavity, thus giving the name tympanic segment to that part of the nerve. The tympanic segment runs between the lateral semicircular canal above and the oval window below. As the nerve passes below the midpoint of the lateral semicircular canal, it turns vertically downward and courses through the petrous part adjacent to the mastoid part of the temporal bone. Thus, the third segment, which ends at the stylomastoid foramen, is called the mastoid or vertical segment. Into the temporal bone, the facial nerve gives off the greater petrosal (c) and chorda tympani (d) nerves. The chorda tympani nerve, which arises from the mastoid part, runs upward, passes along the roof of the tympanic cavity, and exits the cavity through the anterior canaliculus. The greater petrosal nerve runs initially along the facial hiatus and beneath the dura of the middle fossa, reaches the sphenopetrosal groove formed by the junction of the petrous and sphenoid bones, immediately superior and anterolateral to the horizontal segment of the petrous carotid, and joins the sympathetic carotid nerves to help form the vidian nerve into the pterygoid canal. The cochlea lies below the floor of the middle fossa in the angle between the labyrinthine segment of the facial nerve and the greater petrosal nerve, just medial to the geniculate ganglion, anterior to the fundus of the internal acoustic meatus, and posterosuperior to the lateral genu of the petrous carotid artery. Ac.: acoustic; Car.: carotid; Cav.: cavity; Int.: internal; Lat.: lateral; Mast.: mastoid; Post.: posterior; Sem.: semicircular; Sup.: superior; Tymp.: tympanic; Zyg.: zygomatic.

The lateral part of the middle cranial base that corresponds endocranially to the temporal fossa includes the infratemporal fossa, mandibular fossa, and the parapharyngeal space (▶ Fig. 1.16). The infratemporal fossa is bounded anteriorly by the posterolateral surface of the maxilla and the infratemporal crest, which separates the infratemporal from the superolaterally located temporal fossa. The infratemporal fossa is bounded anteromedially by the lateral pterygoid plate, laterally by the mandibular ramus, and posteriorly by the tympanic part of the temporal bone and styloid process. The pterygomaxillary and inferior orbital fissures, the alveolar canals, the foramen spinosum, the ovale, and the emissary sphenoid foramen open into the infratemporal