Comprehensive and Clinical Anatomy of the Middle Ear

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Stéphane Louryan

Second Edition

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To my wife, Ruth, for her constant love and support; for my three sons, grandchildren, and all the Mansour family.

Salah Mansour

Preface

Following the great success of the first edition of *Comprehensive and Clinical Anatomy of the Middle Ear*, our publisher invited the team of authors to produce a second edition. We worked diligently to present new anatomical facts and concepts, which build upon continuing surgical experience and advanced correlated endoscopic and imaging acquisitions.

Although human anatomy is a stable basic knowledge, when it concerns the ear, it remains a dynamic discipline where nothing is set in stone. This second edition reports the latest observations to enable better otology training and enhance surgical approaches.

Most of the anatomy described in the first edition is still valid and pertinent. However, additional anatomical details and their functional importance are reported in this second edition. These additions and other refinements provide improved diagnostic orientations and suggest more precise surgical procedures in the middle ear.

In every chapter of this second edition, subchapters and subdivisions report and illustrate updated elements of embryology and anatomy, as well as relevant modern endoscopic and imaging illustrations to better perform otological surgery. Additional knowledge concerning the mechanics of middle ear anatomical content is introduced to assist in the understanding of its clinical significance and its importance to the surgical setting.

We have also added a new chapter to explain the fragile structure of the middle ear as an organ and its comparative evolution during phylogenesis, aiming to offer a holistic vision for handling the middle ear.

Most illustrations, anatomical plate dissections, endoscopic and microscopic pictures, and imaging demonstrations were revisited for the purposes of this second edition. This allows us to better highlight normal middle ear anatomical details, congenital abnormalities, and conflictual pathological presentations. We wish to offer students and teachers a complete and up-to-date reference book concerning the functional anatomy of the middle ear. To do so, we not only draw from our knowledge and experience as practitioners but also discuss current modern otology research. This second edition reviews the recent literature relative to the discipline and references many new and interesting sources.

This second edition is the result of close collaboration among good friends and colleagues. It is a tribute to their dedication to medical teaching and their desire to expand the knowledge of practitioners everywhere.

Beirut, Lebanon Salah Mansour

Preface

A second edition gives the opportunity to revisit our knowledge, expand upon our experiences, and offers an updated presentation. I also think of it as confirmation that the Comprehensive and Clinical Anatomy of the Middle Ear met the expectations of our fellow specialists. So, again under the guidance of Prof. Salah Mansour, it was a great pleasure to work with the same enthusiastic team. New anatomical pictures have been added. This edition reconfirms the notion that temporal bone dissection is an indispensable step for the theoretical teaching of surgery.

Colombiers, France

Jacques Magnan

Preface

The great success of the first edition of this book motivates us to go further in depth digging for a complete and most interesting knowledge concerning middle ear anatomy and its complex functional architecture. Our aim was to update advances recently found following correlated disciplines, especially ear endoscopy, in order to make available a complete reference book for learners and teachers.

I am thankful for the active collaboration between all members of the team of authors; their central collaboration and conjugate efforts render the present work most enjoyable and informative.

Doha, Qatar — Hassan Haidar

Preface

Computed tomography is the most precise radiologic modality available for the study of the anatomy of the middle ear. The otologist's practice and teaching during clinical, preoperative, and postoperative work are supported by the knowledge of the usual CT aspects of the walls, contents, and compartments neighboring the noble anatomic structures of the temporal bone. Such knowledge should be a baseline for any otology candidate.

This second edition showcases new CT images to illustrate the detailed anatomy of middle ear structures. Anatomical variants and pathological aspects have been added to enlarge the imaging spectrum in several sections.

I want to thank Professor Mansour and my coauthors for their constructive and active collaboration: their contribution was essential to the orientation of imaging studies to the needs of the otologist.

I hope this book will encourage continued dialogue among radiologists and surgeons in their daily practice. I firmly believe such collaboration is key to advancing both disciplines.

Mount Lebanon, Lebanon Karen Nicolas

Preface

This second edition adds data concerning the developmental genetics and comparative anatomy of the middle ear structures.

Embryology progressively gives place to developmental biology, which offers ways to understand congenital malformations. Some of these abnormalities can be understood in the light of evolution and comparative anatomy. The close relationships of middle ear ossicles with the temporo-mandibular joint are also discussed and can explain some pathological signs, such as tinnitus.

The precise embryological origin of middle ear ossicles is still debated, and this second edition takes account of such controversy.

The human embryo histological sections come from collections of the Louis Deroubaix anatomy and embryology Museum, Université libre de Bruxelles.

Brussels, Belgium — Stéphane Louryan

Contents

Temporal Bone

1

Contents

The temporal bone is situated at the inferior and lateral part of the skull and lateral to the temporal cortex. It is the center of anatomy knowledge to the otologist because it contains the hearing organ and equilibrium with various cavities and recesses associated with the ear.

The temporal bone is the most complex bone in the human body and further complicated by the small size and three-dimensional orientation of associated structures.

Temporal bone has multiple embryological origins and shows adverse developmental aspects. It houses several important structures such as the outer ear, the *middle ear* and internal ear apparatus, the facial nerve (VII), the vestibulocochlear nerve (VIII), the internal carotid artery, and the jugular vein, which contract major impacts on the ME surgical anatomy.

This chapter will be mostly oriented, not to study the temporal bone as such but to address it in a specific and restricted scope aiming to describe precisely the developmental and anatomical environment in which the middle ear achieves its final architecture.

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Our target will be to demonstrate the relationship of critical structures around and inside the middle ear. Knowledge about the anatomical details of the temporal bone surfaces is a milestone for any surgical approach, which will be briefly illustrated when the corresponding anatomic area is described.

1.1 Embryology of the Temporal Bone

Temporal bone formation results from the fusion and growth of four bones: the squamous, the petrous, the tympanic, and the styloid bone. These bones interact to build up the final temporal bone.

Being a part of the skull, the temporal bone development is an integral part in the process of skull development. The human skull is developed from three components:

1. *The cartilaginous neurocranium or chondrocranium* is the part of the skull formed by endochondral ossification; it constitutes the majority of the skull base (ethmoid bone and portions of the occipital, temporal, and sphenoid bones). Endochondral ossification takes place in a cartilaginous anlage; chondroblasts become hypertrophied and progressively change into osteoblasts, which elaborate the bony matrix. The corresponding area is the "ossification center."
2. *The membranous neurocranium or neuroskull* is the part of the skull formed by intramembranous ossification; it constitutes the vault of the skull (frontal, parietal portions of the temporal, occipital, and sphenoid bone). Intramembranous ossification happens when a cluster of mesenchymal cells in a membranous structure gives rise to osteoblasts, in the absence of any cartilaginous matrix.
3. *The viscerocranium or visceroskull* is the part of the skull derived from the visceral (branchial) arches and is suspended to the rest of the cranium [1]. It includes the facial bones.

These three components of the skull contribute actively in the formation of the temporal bone in the following way:

The deep part of the petrous bone is derived from the cartilaginous neurocranium, but the more superficial parts are derived from the membranous neurocranium. The squamous bone is derived from the membranous neurocranium, and the tympanic bone is a part of the visceral skull [2].

1.1.1 Cartilaginous Neurocranium

The majority of the skull base develops from the cartilaginous neurocranium. The formation of the human skull base is a complex process that begins during the fourth week of fetal development. Neural crest cells and paraxial mesoderm derived from occipital somites migrate to sit between the emerging brain and foregut. These cells migrate around and in front of the notochord to form condensations accumulating within the emerging cranial base. The chondrocranium begins to form when these cells condense into cartilage early in the seventh week; these cells are named parachordal cartilages and contribute to the creation of the basal plate. These parachordal cartilages give rise to the body, greater and lesser wings of the sphenoid bones as well as the perpendicular plate of the ethmoid and the crista galli. These embryonic cartilages fuse around the existing cranial nerves and blood vessels to create the primordia of neural foramina.

1.1.1.1 The Cartilaginous Otic Capsule

Between the eighth and ninth week of gestation, the cartilaginous otic capsule appears as budge in the base of the cartilaginous cranium. It develops from the mesenchymal tissue that surrounds the otic vesicle. Later, the otic capsule becomes surrounded by membranous layers (internal and external periosteal layers); these layers will become the extracapsular part of the petrous bone [3] (Fig. 1.1).

Shortly after this process, the lateral and superior boundaries of the otic capsule begin to appear with the earliest development of the mastoid

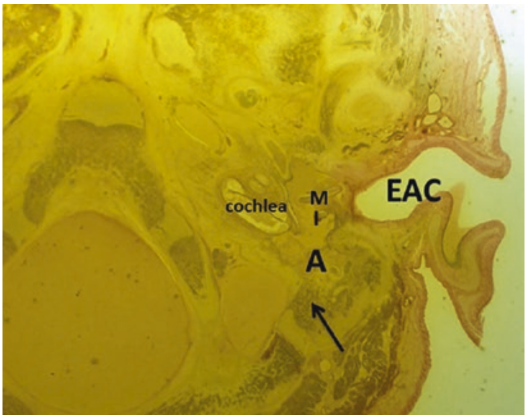

Fig. 1.1 The left temporal bone in a 6-month, 250 mm, human fetus. The mastoid area contains external periosteal layer bone (arrow) and will transform into the mastoid bone. Notice that the mastoid antrum (A) and the cochlea are already developed. *M* malleus, *I* incus, *EAC* external auditory canal

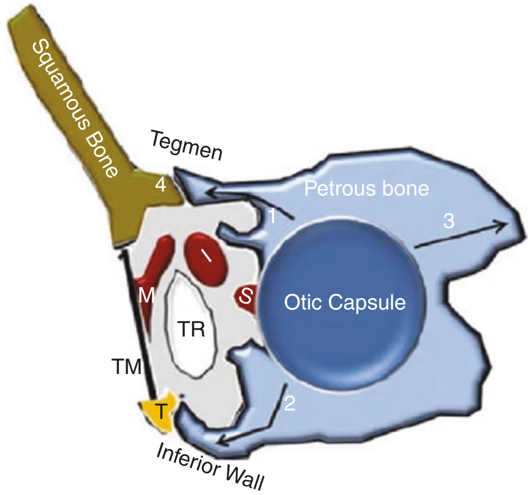

Fig. 1.2 Schematic drawing, frontal plane (34-week-old fetus). Schema showing the cartilaginous flanges running out from the otic capsule: (1) Lateral and superior flange or the tegmental plate growing from the otic capsule superior to the tubotympanic recess (TR) to form part of the tegmen tympani and the walls of the Eustachian tube. (2) Lateral and inferior cartilage flange, growing from the otic capsule to form the jugular plate and the floor of the tympanic cavity. (3) Anteromedial flange growing from the otic capsule anteromedially to form the petrous apex. The inferior wall of the middle ear is built up by the inferior plate of the petrous bone (2) which runs laterally to join the tympanic bone (T); the plane of fusion constitutes the hypotympanic fissure(*). The tympanic bone (T) and the tympanic membrane (TM) form the lateral wall of the middle ear cavity. The tegmen tympani is formed by fusion of the tegmental process of the petrous bone (2) and the transverse plate of the squamous bone (4). *M* malleus, *I* incus, and *S* stapes

process and tegmen tympani [4]. A cartilaginous flange grows from the lateral and superior part of the otic capsule and goes downward and outward superior to the tubotympanic recess and above the Meckel's cartilage to form the tegmen tympani and the lateral wall of the Eustachian tube (ET) (Fig. 1.2) (see Sect. 2.5.1). Thus, *the tympanic cavity and the bony part of the ET originate from the petrous bone.* Furthermore, from the lateral and inferior part of the cartilaginous otic capsule, another flange grows below the tubotympanic recess to form the jugular plate and the floor of the tympanic cavity. Anteromedially, another periosteal layer grows to form the petrous apex (Fig. 1.2).

By the 16th week, the labyrinth reaches its adult size. Only at this time, the first part of the petrous bone starts to ossify by the endochondral ossification process. There are 14 different ossification centers in the otic capsule, which progressively fuse during the fetal period [4].

The ossification proceeds and continues in the remaining part of the petrous bone to gain its final aspect by about midterm. By the 23rd week of gestation, the rest of the ossification process of the extracapsular parts of the temporal bone continues by extension of the surrounding periosteum forming the mastoid process, the tegmen tympani, the middle ear floor, and the walls of the Eustachian tube (Figs. 1.2 and 1.3). The floor of the middle ear ossifies between the 24th and 29thweek from an extension of the jugular plate ossification center [5]. Ossification of the otic capsule is completed only shortly before birth [5]. A delay or a focal lack of the ossification process may explain the dehiscence of the superior semicircular canal [6, 7].

1.1.2 Membranous Neurocranium and the Squamous Bone

The squamous part of the temporal bone develops from intramembranous ossification; it is formed from one ossification center that appears

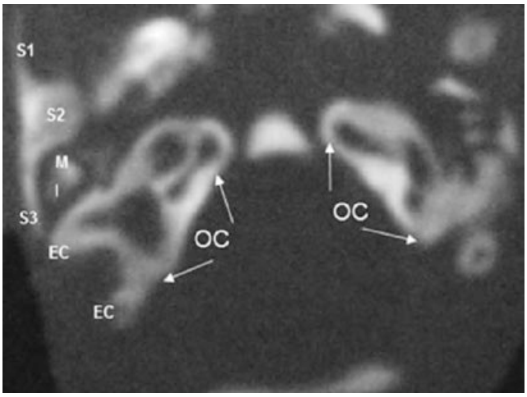

Fig. 1.3 Transversal CT scan of a 22-week-old 220 mm fetus, showing ossification of the otic capsule (OC) and beginning of the ossification process in the extracapsular parts of the petrous bone (EC) extending to form the mastoid process. The inferior part of the squamous bone with its three parts: S1 anterior part forming the zygomatic process, S2 middle part forming the roof of the EAC and part of the tegmen, and S3 the posterior part forming the anterior part of the mastoid process. Notice that the petrous bone and the squamous bone are not yet fused. *M* malleus, *I* incus

during the eighth week of gestation [8]. The development of the upper and lower halves of the bone primordium differs:

- The upper part is flat and thin; it becomes the vertical portion.
- The lower part, due to the presence of the tympanic bone by the 16th week, bulges and grows rapidly into three directions (Fig. 1.2):
  1. *The anterior part* extends anteriorly around the tympanic ring toward the zygomatic bone primordium. It is fixed to the anterior-superior part of the tympanic bone. It forms the zygomatic process of the squamous bone and is involved in the formation of the roof of the temporomandibular joint.
  2. *The middle part* sinks medially above the tympanic ring to form the superior wall of the external auditory canal, the attic outer wall, and the lateral part of the tegmen tympani [9].
  3. *The posterior part* extends posteriorly behind the tympanic ring to cover a major part of the base of the petrous bone. It forms the anterior portion of the mastoid process.

1.1.3 The Viscerocranium

1.1.3.1 The Styloid Process

The styloid process derives directly from the Reichert's cartilage of the second visceral arch. It develops from two parts:

1. The proximal part or the base, also named *the tympanohyale*, is situated close to the tympanic bone. Its ossification center appears before birth and continues to grow until the age of 4 years. It fuses with the petromastoid component during the first year of life [10].
2. The distal part, *the stylohyale*, starts its ossification only after birth. It fuses with the proximal part only after puberty.
3. The stylohyoid ligament can ossify, which causes dysphagia (Eagle's syndrome) (Fig. 1.9).

1.1.3.2 The Tympanic Bone

The tympanic ring is a C-shaped bone that provides physical support to the tympanic membrane. It is formed by intramembranous ossification (Fig. 1.4).

At the eighth week of gestation, the tympanic ring appears as a condensation in the cephalic part of the mandibular part of the first branchial arch, which is situated ventral to the first pharyngeal cleft and lateral to Meckel's cartilage.

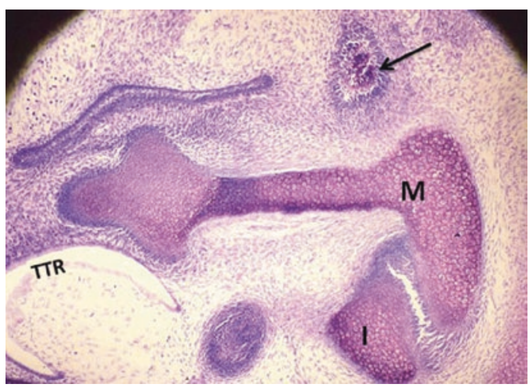

Fig. 1.4 An intramembranous area of ossification (arrow) corresponding to the tympanic bone in an E17 mouse embryo (sagittal section, toluidine blue). The cartilaginous primordial of the malleus (M) and incus (I) are also visible. Tubotympanic recess (TTR). Toluidine blue staining at pH4

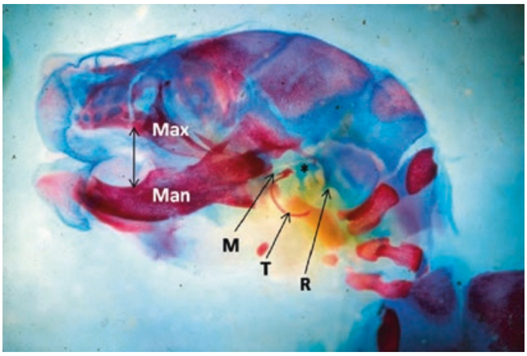

Fig. 1.5 Skeletal staining of a mouse E 16 embryo. In blue, the Meckel's (M) and Reichert's (R) cartilages appear in close relationship with the ossicles rudiment (*). In red, we can see maxillary (Max) and mandibular (Man) bones around the oral cavity (double arrow). The tympanic ring (T) is also red and ossifies following intramembranous process

This condensation will extend in a circumferential fashion around the first pharyngeal cleft resulting in the C-shaped structure [11]. Within 2 weeks, the ossification is first detected in the part of the condensation adjacent to Meckel's cartilage, and then, it progresses through the rest of the condensation to form a fully developed tympanic ring that is well recognized by the 11th week of gestation (Fig. 1.5).

At 12th week, growth of the tympanic ring proceeds rapidly with a consequent increase in its overall size. The tympanic ring is never closed superiorly, giving rise to the incisura tympanica (*notch of Rivinus*) where the pars flaccida of the tympanic membrane will insert.

Fusion of the tympanic ring with the other components of the temporal bone starts first at 31st week in the posterior part. The anteromedial segment of the tympanic bone does not join the temporal bone until 37th week. Its fixation to the temporal bone is complete at birth.

The tympanic bone is 9 mm in diameter at birth, almost its definitive size. At this time, it is ring shaped and is open superiorly [12–16].

The formation of the external auditory meatus and the formation of the manubrium are in close association with the tympanic ring formation [11]. The tympanic ring plays an instructive role for the external auditory canal development. Very likely, aural atresia results from the failure of the tympanic ring to develop [17]. In addition, the formation of the tympanic ring is essential for the insertion of the manubrium of the malleus into the tympanic membrane [18]. Several experimental conditions leading to a lack of external auditory meatus formation also result in a severe underdevelopment of the manubrium with a normal aspect of the rest of the malleus. This fact is confirmed in cases of major aural atresia, showing an absence of the manubrium with otherwise normal looking of the rest of the malleus [18, 19].

1.2 Perinatal Changes of the Temporal Bone

At the time of the perinatal period, the squamous and tympanic bones have already fused together; but the resultant segment is still separated from the petrous segment [20]. Early in the perinatal period, these two segments begin to fuse simultaneously at several locations, beginning with the medial surface of the squamous part to the lateral edge of the tegmental process of the petrous bone. This zone of fusion becomes the internal petrosquamous suture [7]. The fusion continues posteriorly between the petrous and squamous parts of the mastoid process; failure of complete fusion of the two parts leads to formation of a bony septum inside the mastoid process, called *Koerner's septum* [21] (see Sect. 5.1). The external petrosquamous suture present on the outer surface of the mastoid process marks the plane of fusion between these two parts.

Finally, the inferior portion of the tympanic ring fuses medially to the inferior process of the petrous bone, thus forming the inferior wall of the tympanic cavity.

1.3 Postnatal Changes of the Temporal Bone

Expansion pressures and antagonist forces exerted by the cephalic neuroskull and the muscular visceroskull, in addition to the pneumatization

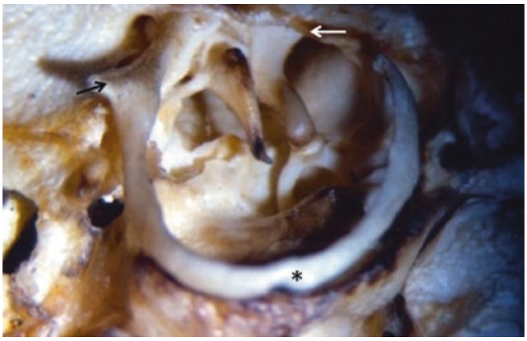

Fig. 1.6 Neonate skull with tympanic annulus bone (*) with its anterior tubercle (white arrow) and posterior tubercle (black arrow). The external auditory meatus is short and ossicles are completely visible

process, are the main factors for the remodeling process and postnatal changes of the temporal bone.

Bone growth around the tympanic ring following its fusion to the petrous bone proceeds laterally around its circumference. This results in the development of the bony external auditory canal [22]. This lateral extension of the tympanic ring results from the growth of two tympanic tubercles, one from the anterior aspect of the ring and the second from the posterior aspect (Fig. 1.6). These projections grow laterally and then toward each other inferiorly to form the inferior wall of the external auditory canal. By doing so, these projections delimit two openings: the first is in the upper part, *the notch of Rivinus*, and the second is inferior, *the foramen of Huschke* [23].

Clinical Pearl

Usually the foramen of Huschke closes by the age of 5 years by additional bone growth. This foramen remains patent in about 7% of adults; in such cases, the skin of the external auditory canal may invaginate into the residual foramen and migrate under the inferior wall of the external bony canal, leading to the formation of a canal cholesteatoma (Fig. 1.7).

Enclosure of the base of the styloid process occurs simultaneously with the lateral extension of the tympanic bone as well. In addition, the tympanic ring changes its orientation relative to the rest of the cranium.

At birth, the tympanic ring lies beneath the skull in an almost horizontal plane. By the third month, because of the upward and lateral rotation of the petrous bone caused by a rapid enlargement of the forebrain, the tympanic ring appears on the inferolateral aspect of the skull; few months later, it attains its final near vertical orientation [21].

The mastoid process is flat at birth. The stylomastoid foramen is superficial with the facial nerve lying on the lateral surface behind the tympanic bone. Due to pneumatization process in the mastoid process, its lateral portion grows downward and forward so that the stylomastoid foramen is pushed medially onto the undersurface of the temporal bone (see Sect. 5.2).

The styloid process does not make its appearance until after birth. It becomes attached to the tympanic bone during its lateral extension. The progression by which the styloid process grows and ossifies is variable, explaining the variable size and shape of the styloid process in adult skulls [24].

The squamous part of the temporal bone grows rapidly along with the cranial vault during the first 4 years of life and continues at a much slower pace until adulthood [7, 20].

Clinical Pearl

Parallel to the orientation changes of the tympanic bone, changes also occur in tympanic membrane orientation. At birth, the tympanic membrane is in almost horizontal plane; this explains the difficulty of exposure of the tympanic membrane in newborns during otoscopy for paracentesis. Associated to the tympanic ring changes of orientation, the inferior tympanic sulcus lateralizes accordingly so the tympanic membrane becomes more vertical and more accessible for examination.

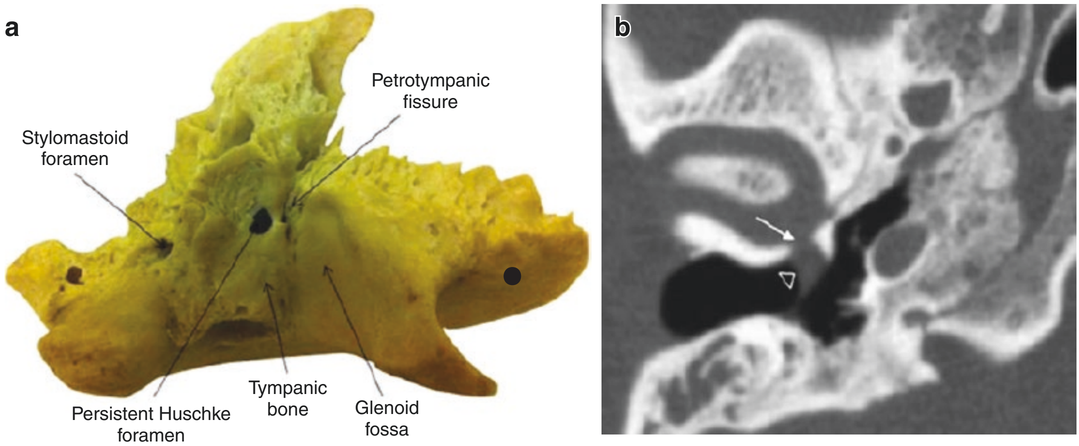

Fig. 1.7 Persistent foramen of Huschke. (**a**) Cadaveric temporal bone, inferior surface, showing a persistent foramen of Huschke. (**b**) Transversal computed tomography of the external auditory canal of a right ear, showing a persistent foramen of Huschke (white arrow) with a secondary cholesteatoma (arrowhead)

1.4 Anatomy of the Temporal Bone

The temporal bone, a paired and symmetrical bone, participates in the formation of the base and the calvarium of the skull. It is formed from the fusion of four different embryological bones: **the petrous bone, the squamous bone, the tympanic bone, and the styloid bone**.

The auditory system is disposed on two axes: the yellow text is original from the introduction.

1. *Anteroposterior air axis* consisting of the Eustachian tube, middle ear, and mastoid antrum.
2. *Latero-medial sensorial axis* consisting of the external and internal auditory canals.

These two axes intersect at the level of the middle ear cavity (Fig. 1.8).

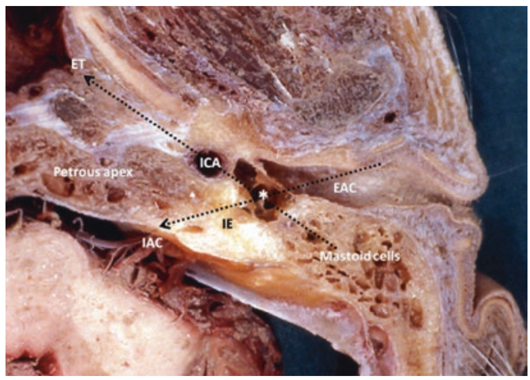

Fig. 1.8 Transverse cut through a left (view from below) temporal bone showing the middle ear cavity (*) hollowed out in the center of the temporal bone between the external auditory canal (EAC) and the inner ear (IE). The middle ear lies at the intersection of two axes (black dotted arrows), external - internal auditory canal (EAC-IAC) axis and mastoid - Eustachian tube (Mastoid cells - ET) axis. *ICA* internal carotid artery

The temporal bone connects with four bones: the occipital bone posteriorly and laterally, the parietal bone superiorly, the sphenoid bone anteriorly and the zygomatic bone laterally.

1.4.1 The Petrous Bone

Petrous comes from the Latin word "petra" meaning rock; it is the hardest bone of the human skull. It houses the inner ear, the internal carotid artery, the Fallopian canal, and the major part of the middle ear. It results from the ossification of the otic capsule and its flanges.

The petrous bone is shaped like a pyramid that project anteromedially forming a 45° angle with the transverse axis. This pyramid has a posterolateral base (the mastoid) and an anteromedial summit (the petrous apex). It is wedged between the basioccipital and the greater wing of the sphenoid. Its anterosuperior surface is endocranial and participates in the formation of middle cranial fossa floor. Its posterosuperior surface is also endocranial and forms the anterolateral wall of the posterior cranial fossa. Its inferior surface is exocranial and corresponds to the posteromedial part of the mastoid process.

1.4.2 The Squamous Bone

The squamous bone constitutes the major part of the lateral surface of the temporal bone. The squamous bone presents two parts:

1. *The vertical part* is a flat and a thin plate of bone that extends upward to form part of the lateral wall of the middle cranial fossa.
2. *The horizontal part* is prolonged anteriorly as the zygomatic process, which originates from two roots: a sagittal posteroexternal root that overhangs the external auditory canal forming its superior part and a transversal anterointernal root that forms the condyle of the temporomandibular joint.

1.4.3 The Tympanic Bone

The tympanic portion of the temporal bone is a gutter-shaped plate of the bone. It is situated below the squamous bone between the glenoid fossa anteriorly and the mastoid process posteriorly. The inferior surface of the tympanic bone presents a plate of bone called the vaginal process, which surrounds the styloid process and merges with the petrous bone near the carotid canal.

The tympanic bone forms the anterior, inferior, and posterior walls of the bony external auditory canal. Its attachment to the mastoid and the squamous delineates two suture lines: the tympanosquamous suture anterosuperiorly and the tympanomastoid suture posteroinferiorly. Medially, the tympanic bone articulates with the petrous bone to form the *petrotympanic fissure*.

The junction between the tympanic bone and the squamous bone superiorly corresponds to *the notch of Rivinus.*

Medially, the tympanic bone presents a narrow furrow: the *tympanic sulcus* to which the tympanic membrane annulus is inserted.

1.4.4 The Styloid Bone

The styloid process is a long, slender, and pointed bone of variable length averaging from 20 to 25 mm. It lies anteromedial to the stylomastoid foramen.

The tip of the styloid bone is located between the external and internal carotid arteries, lateral to the pharyngeal wall, and immediately behind the tonsillar fossa.

Three muscles and two ligaments are attached to the styloid process: the stylopharyngeus muscle, the stylohyoid muscle, and the styloglossus muscle. The stylohyoid ligament extends from the tip of the styloid process to the lesser horn of the hyoid bone and the stylomandibular ligament, which starts under the attachment of the styloglossus muscle and ends on the mandibular angle [10, 22, 25–27].

Clinical Pearl
The ossification process of the styloid ligament may involve the whole length of the ligament, giving rise to a bony prolongation between the skull and the hyoid bone; this may manifest clinically by odynophagia, Eagle's syndrome (Fig. 1.9).

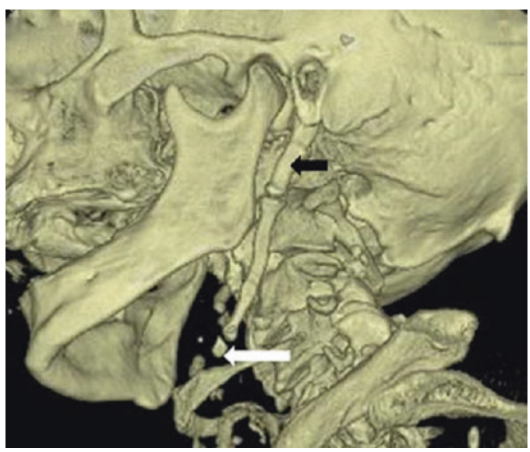

Fig. 1.9 Computed tomography with 3D reformation showing complete ossification of the stylohyoid ligament from the styloid process (upper arrow) to its insertion on the hyoid bone (lower arrow)

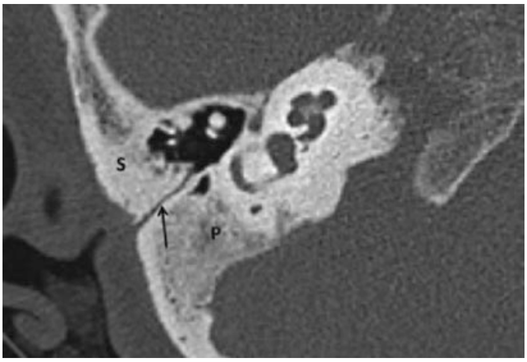

Fig. 1.10 Transversal computed tomography of the right temporal bone of a child with hereditary cleidocranial dysostosis: prominent petrosquamous suture (black arrow) that could be misinterpreted as a temporal bone fracture. *S* squamous bone, *P* petrous bone

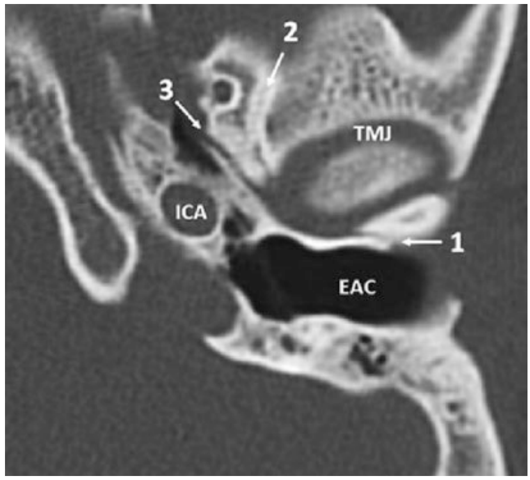

Fig. 1.11 Transversal computed tomography of a left ear, showing the three different sutures appearing with a Y shape. They form together the Glaserian fissure, (1) the tympanosquamous fissure, (2) the anterior petrosquamous fissure, and (3) the posterior petrotympanic fissure. *ICA* internal carotid artery, *EAC* external auditory canal, *TMJ* temporomandibular joint

1.4.5 Temporal Bone Fissures

Four intrinsic fissures form at the fusion lines of the four bones forming the temporal bone.

1.4.5.1 The Petrosquamous Fissure

The petrosquamous fissure or suture connects the petrous bone and the squamous bone and opens directly into the mastoid antrum. It is a narrow fissure and continuous with the petrotympanic fissure.

The external petrosquamous fissure, which links the squamous and the petrous parts of the mastoid process, is sometimes visible on the outer surface of the mastoid process (Fig. 1.10). The internal petrosquamous fissure is located in the tegmen tympani and joins its squamous and petrous portions.

1.4.5.2 Tympanomastoid Fissure

The tympanomastoid fissure or suture anchors the tympanic bone to the mastoid process. This suture is situated in the posteroinferior part of the external auditory canal (see Fig. 1.12).

The auricular branch of the vagus nerve, Arnold's nerve, emerges through the tympanomastoid suture to innervate part of the external auditory canal skin.

1.4.5.3 Tympanosquamous Fissure

The tympanosquamous fissure connects the tympanic bone to the squamous bone. The tympanosquamous fissure is seen in the anterosuperior part of the external auditory canal and continues medially into the petrotympanic and petrosquamous fissures (see Figs. 1.11 and 1.12).

1.4.5.4 The Petrotympanic Fissure

The petrotympanic fissure or Glaserian fissure is situated between the medial aspect of the tympanic bone and the mandibular fossa. It transmits the chorda tympani, the anterior tympanic artery, and the anterior malleal ligament (Fig. 1.11).

Clinical Pearl

In the context of trauma, these normal fissures, especially if evident, may be misinterpreted as temporal bone fractures (Figs. 1.10 and 1.11).

The petrosquamous fissure may remain open until the age of 20 years, providing a route for a spread of infection from the middle ear to the intracranial cavity.

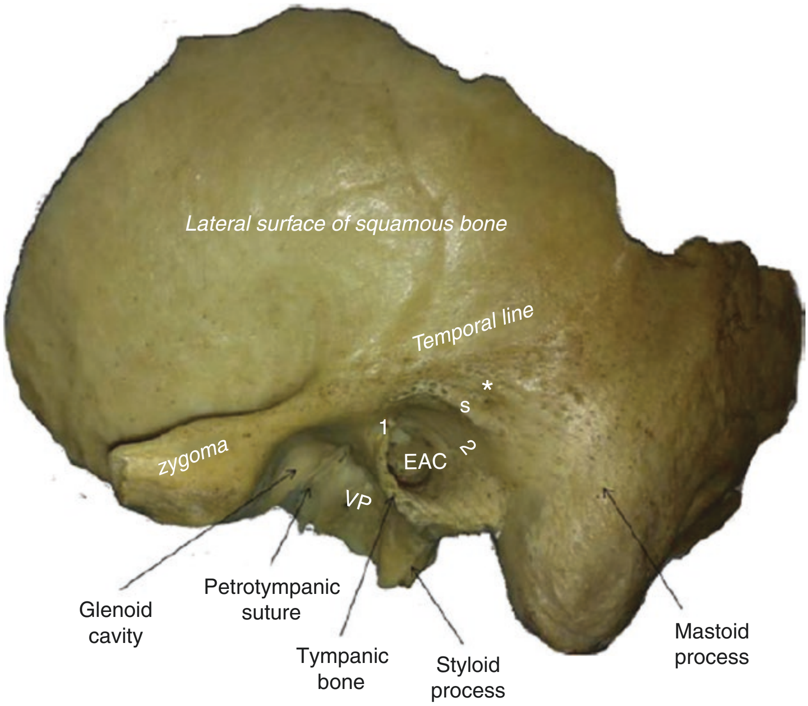

Fig. 1.12 Lateral surface of a left temporal bone. *1* tympanosquamous fissure, *2* tympanomastoid fissure, *EAC* external auditory canal, *S* Henle's spine, * suprameatal triangle, *VP* vaginal process

1.4.6 Temporal Bone Surfaces

The temporal bone exhibits four surfaces: the lateral, posterior, superior, and inferior surface.

1.4.6.1 The Lateral Surface (Fig. 1.12)

The squama constitutes the major part of the lateral surface of the temporal bone and extends upward as a flat bone to cover part of the temporal lobe of the cerebrum.

The lateral surface of the squama shows a vertical groove for the middle temporal artery and serves as an area of attachment for the temporalis muscle. The medial surface of squama is grooved for the branches of the middle meningeal artery. Inferior to the squama, the external auditory canal is located. The tympanic bone forms the anterior, inferior, and posterior walls of the bony external auditory canal. The hiatus between the tympanic bone and the squamous bone corresponds to *the notch of Rivinus.* Anterior to the external auditory canal is the temporomandibular joint; a thin bony shell separates them from each other.

Several important landmarks characterize the lateral surface of the temporal bone:

- *The mastoid process* refers to the bony process located on the posteroinferior border of the lateral surface of the temporal bone. Two distinct bones contribute to the formation of the mastoid process: the anterosuperior portion is formed by squamous bone, and the petrous bone forms the posteroinferior portion. These processes serve laterally for the attachment of the sternocleidomastoid muscle and medially to the posterior belly of the digastric muscle (see Sect. 5.2).
- *The zygomatic process* originates above the external auditory canal. It leaves the squama and projects anteriorly to unite the zygomatic bone. On the inferior surface of the zygomatic process is the mandibular or glenoid fossa, which accommodates the condyle of the mandible. The anterior limit of the glenoid fossa is demarcated by the articular eminence; the postglenoid process demarcates its posterior limit. The glenoid fossa communicates with the middle ear through the petrotympanic fissure.
- *The temporal line or supramastoid crest*: posterior to the external auditory canal, the zygomatic process prolongs as a faint line or the supramastoid crest. This crest serves for the attachment of the temporal muscle. It is an