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Photographic atlas

Unusual foramina of the skull base: Petrosphenoidal, Pterygoalar, Pterygospinous, Caroticoclinoid and Interclinoid. Findings in dried skulls.

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The anatomical variations are a chapter of major importance in the practice of human macroscopy due to their high clinical and surgical implications. Many of these variations, in all body segments, are biological atavisms or phylogenetic remnants and result from narrow osteofibrous formations in association with neurovascular structures - in part of their pathways.

In the skull, due to its structural and developmental complexities, one notices several foraminal formations, complete or incomplete, which originate, in great part, from idiopathic calcifications of ligaments or fibrous laminae in the exocranium as well as in the endocranium. These foramen, sometimes denominated canals, are formed from ossifications or calcifications of ligaments and are intimately related to neurovascular structures, causing, on the one hand, compressive neuropathies and, on the other hand, making surgical access difficult. Thus, we indicate as relevant the following variant foramina in their completely ossified presentations: petrosphenoidal, pterygoalar, pterygospinous, caroticoclinoid, and interclinoid.

The petrosphenoidal foramen (or the Dorello's canal) is a generally osteofibrous formation delimited by the superior petrosphenoidal ligament (or the Gruber's ligament) between the apex of the petrous part of the temporal bone (petrous tubercle) and the occipital clivus. Therefore, connecting the posterior and middle cranial fossae. The superior petroesphenoidal ligament constitutes one of the limits of the inferomedial paraclival triangle and can ossify to varying degrees, forming a completely osseous passage in rare cases (**figures 01 and 02**). The petrosphenoidal foramen is responsible for the transition of structures - the abducens nerve, the inferior petrosal sinus, and the dorsal meningeal branch of the meningohypophyseal trunk. Historically, what justifies the eponym, is considered the first description of the foramen by the Italian anatomist Primo Dorello (1872-1963) in the work "*Considerazioni sopra la causa della paralisi transitoria dell'abducente nelle flogosi dell'orecchio medio*" [1].

The foramen pterigoalar (porus crotaphitico-buccinatorius or the foramen of Hyrtl) is a resistant osteofibrous formation and, evolutionarily, atavistic. Thus, the foramen is formed, in part, by the homonymous ligament of the skull base - the pterygoalar ligament. However, this ligament can, to varying degrees, and for unknown reasons, be ossified and, when completely mineralized, becomes a relatively dense bony bar (**Figures 03 and 04**) that interposes between the foramen ovale and the infratemporal fossa. This complicates the course of mandibular nerve branches and extracranial surgical access to the foramen ovale and the parapharyngeal

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and retropharyngeal spaces. The pterygoalar ligament is disposed from the anterolateral border of the foramen spinosum to the root of the lateral lamina of the pterygoid process. The foramen pterygoalar was described by Hyrtl in 1862 [2, 4].

The foramen pterygospinous (or the foramen of Civinini) was originally described by the Italian anatomist Filippo Civinini. The disposition of the pterygospinous ligament, near the pterygoalar ligament, occurs from the lateral lamina of the pterygoid process to the spine of the sphenoid bone, immediately superior to the foramen ovale. Thus, topographically, the foramen pterygospinous, formed from the complete ossification of the homonymous ligament, is located medially to the foramen ovale between the superior margin of the ossified pterygospinous ligament (also referred to as the pterygospinous bony bar) and the base of the skull (**figures 05, 06, and 07**). The Pterygospinous ligament, which forms from the thickening of the fascia between the pterygoid muscles, can undergo ossification to varying extents forming the characteristic Civinini's spine - a bony "spur" present on the posterior margin of the lateral lamina of the pterygoid process. This foramen is filled by an extension of the interpterygoid fascia and is crossed by the tensor veli palatini muscle, the accessory middle meningeal artery, the medial pterygoid nerve, and sometimes by part of the pterygoid venous plexus [2,5].

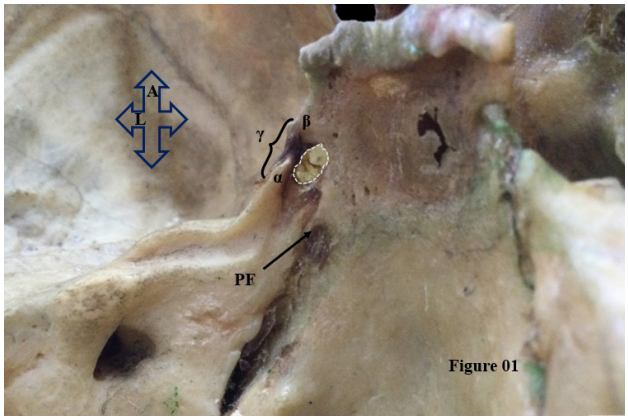

Fig. 01 - Complete petrosphenoidal foramen internally delimited by the translucent area. The osseous bar (γ) by ossification of the petrosphenoidal ligament with the α and β identification of its attachment extremes - from the petrous tubercle to the margin of the dorsum of the hypophyseal fossa (or sella turcica), respectively. PF: petro-occipital fissure; A: anterior and L: lateral.

The caroticoclinoid foramen was first mentioned in the literature by the pathologist and anatomist Friedrich Gustav Jakob Henle in 1855, and is formed by the ossification or mineralization, to varying degrees, of the ligament of the same name - the caroticoclinoid ligament. This ligament extends from the anterior clinoid process to the middle clinoid process, under the dura mater lining. Thus, depending on the extent of its mineralization, the caroticoclinoid foramen is categorized as complete or incomplete (figures 08 and 8.1). In addition, the caroticoclinoid foramen is related in most of the findings to another formation - the interclinoid foramen. The caroticoclinoid foramen constitutes the anterior part of the cavernous sinus roof and this is an barrier to an anterior clinoidectomy for treatments of paraclinoid aneurysms and cavernous sinus meningiomas [3,6].

The interclinoid foramen occurs by ossification of the homonymous ligament - the interclinoid ligament, existing between the anterior and posterior clinoid processes. However, occasionally, the ossification between the middle and posterior clinoid processes can occur (**figure 09**). The interclinoid ligament is positioned under the fold of the same name (interclinoid fold) and delimits anteromedially the oculomotor trigone [3,6].

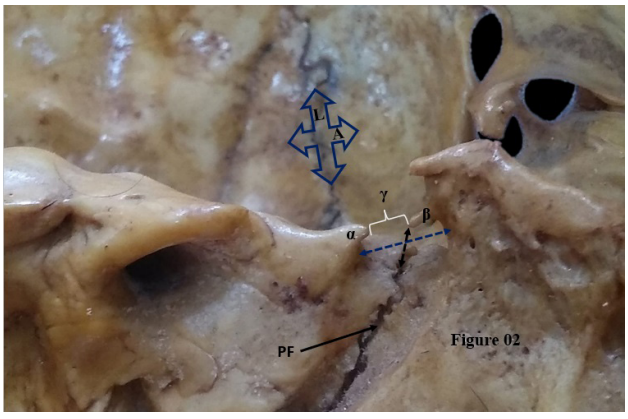

Fig. 02 - Incomplete petrosphenoidal foramen (for comparison with the complete form), classified as type VI (Oliveira et al., 2022). In this finding, we represent two diameters: the maximum transverse diameter (blue dotted line) and the oblique diameter (black dotted line). α: petrous tubercle; β: osseous prominence of the dorsum of the sella turcica; γ: distance or opening of the petrosphenoidal foramen - local of the part of the non-mineralized ligament; PF: petro-occipital fissure; A: anterior and L: lateral.

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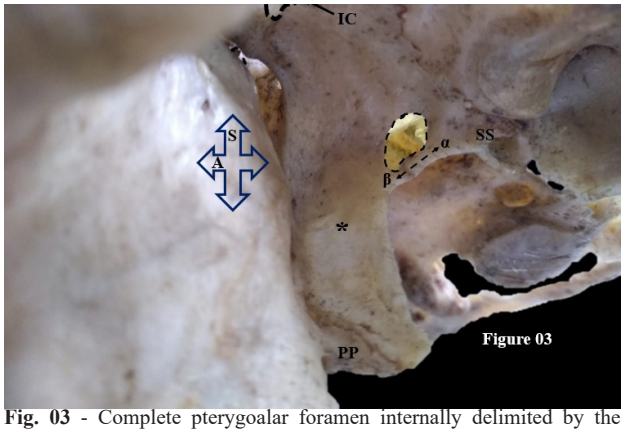

Fig. 03 - Complete pterygoalar foramen internally delimited by the translucent area. The pterygoalar osseous bar that results from the ossification of the homonymous ligament is represented by the dotted arrow. β: osseous spine (of Civinini); α: anterior segment of the spine of the sphenoid bone; SS: sphenoidal spine; PP: pyramidal process of the palatine bone; IC: infratemporal crest and the asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone; S: superior and A: anterior.

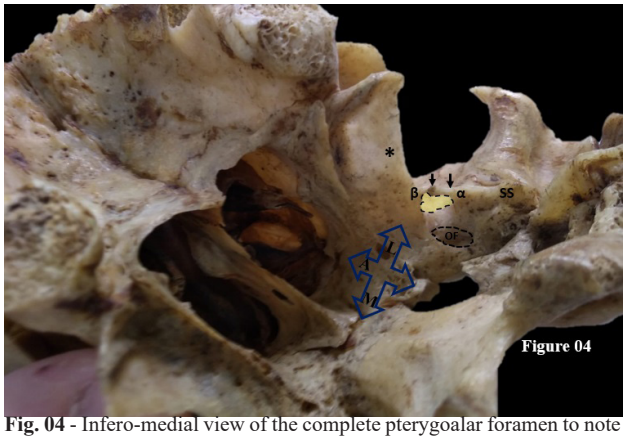

Fig. 04 - Infero-medial view of the complete pterygoalar foramen to note the lateral relationship with the foramen ovale (OF); β: osseous spine (of Civinini); α: anterior segment of the spine of the sphenoid bone; black arrows: pterygoalar osseous bar; SS: sphenoidal spine; asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone; L: lateral; A: anterior and M: medial.

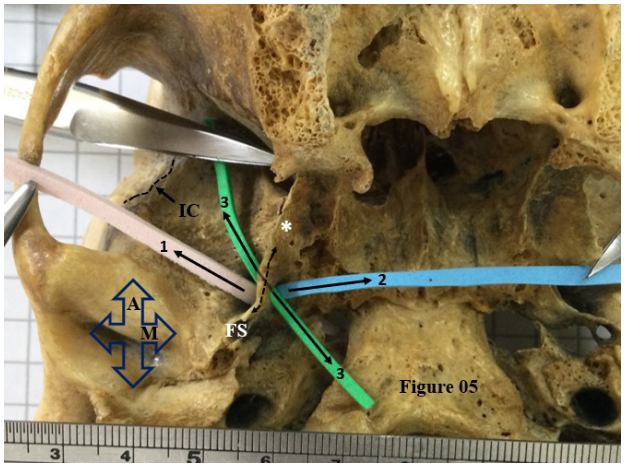

Fig. 05 - Pterygospinous osseous bar (dotted black arrow) forming the inferior limit of the foramen pterygospinous (crossed by the arrow identified with the number 3 and in an anteroposterior oblique disposition) and superposed on the foramen ovale. The emergencies of the foramen ovale occur lateral and medial to the superposition of the pterygospinous osseous bar. This is demonstrated by the arrows identified with the numbers 1 and 2, respectively. FS: foramen spinosum; asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone; IC: infratemporal crest; A: anterior and M: medial.

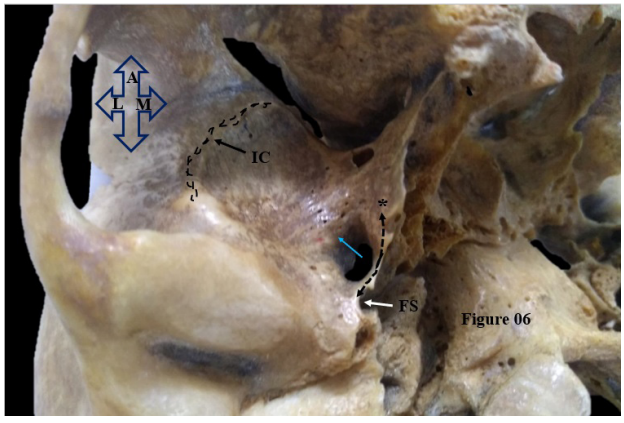

Fig. 06 - Pterygospinous osseous bar (dotted black arrow), in lateral view, showing the superposition to the foramen ovale (blue arrow - in direction to the infratemporal fossa). SF: foramen spinosum; asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone; IC: infratemporal crest; L: lateral; A: anterior and M: medial.

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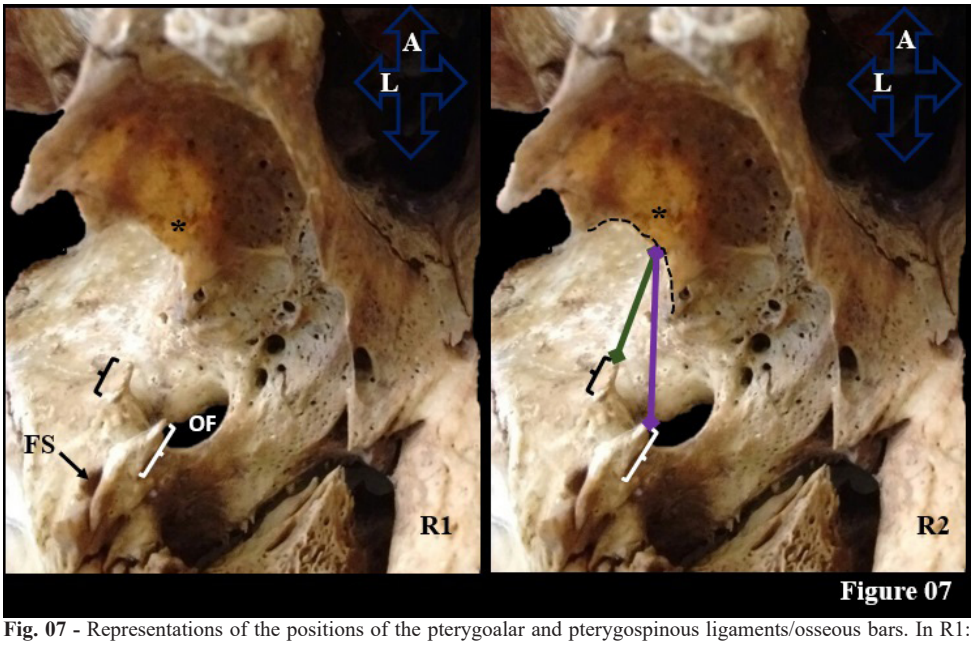

Fig. 07 - Representations of the positions of the pterygoalar and pterygospinous ligaments/osseous bars. In R1: black bracket - spicule or osseous prominence indicative of the fixation point of the pterygoalar ligament; white bracket - spicule or osseous prominence indicative of the fixation point of the pterygospinous ligament; SF: foramen spinosum; OF: foramen ovale; asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone; L: lateral and A: anterior. In R2: black bracket - spicule or osseous prominence indicative of the fixation point of the pterygoalar ligament; white bracket - spicule or osseous prominence indicative of the fixation point of the pterygospinous ligament; green arrow: representation of the pterygoalar ligament disposition; purple arrow: representation of the disposition of the pterygospinous ligament; asterisk (*): lateral lamina of the pterygoid process of the sphenoid bone and dotted black line: free margin of the lateral lamina of the pterygoid process - probable extent for the occurrence of Civinini's spine; L: lateral and A: anterior.

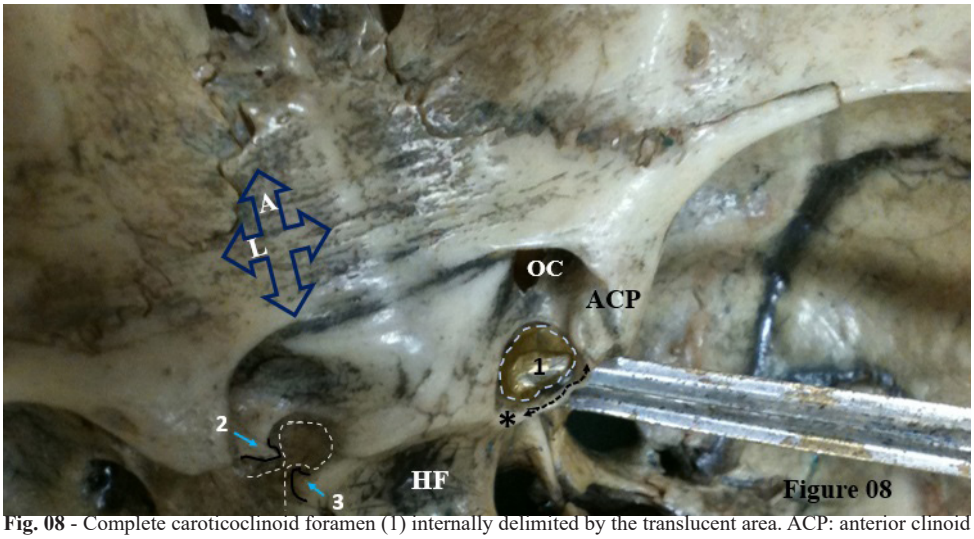

Fig. 08 - Complete caroticoclinoid foramen (1) internally delimited by the translucent area. ACP: anterior clinoid process; OC: optic canal; asterisk (*): middle clinoid process; dotted black arrow: caroticoclinoid osseous bar by ossification of the homonymous ligament; HF: hypophyseal fossa; 2: anterior clinoid process and 3: middle clinoid process - both forming, by partial ossification, the incomplete caroticoclinoid foramen; L: lateral and A: anterior.

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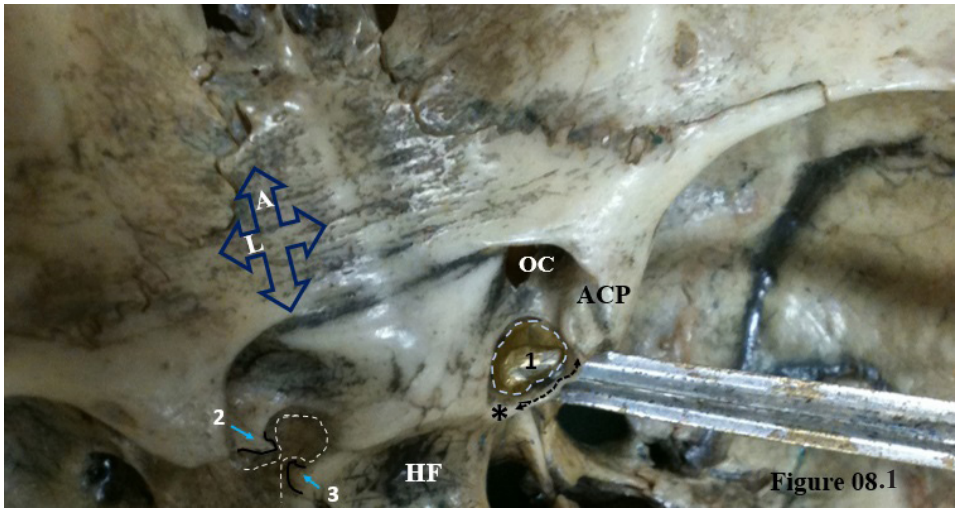

Fig. 8.1 - Bilateral complete caroticoclinoid foramina (1) internally delimited by the translucent area. ACP: anterior clinoid process; OC: optic canal; asterisk (*): middle clinoid process; dotted black arrow: caroticoclinoid osseous bar by ossification of the homonymous ligament; HF: hypophyseal fossa; L: lateral and A: anterior.

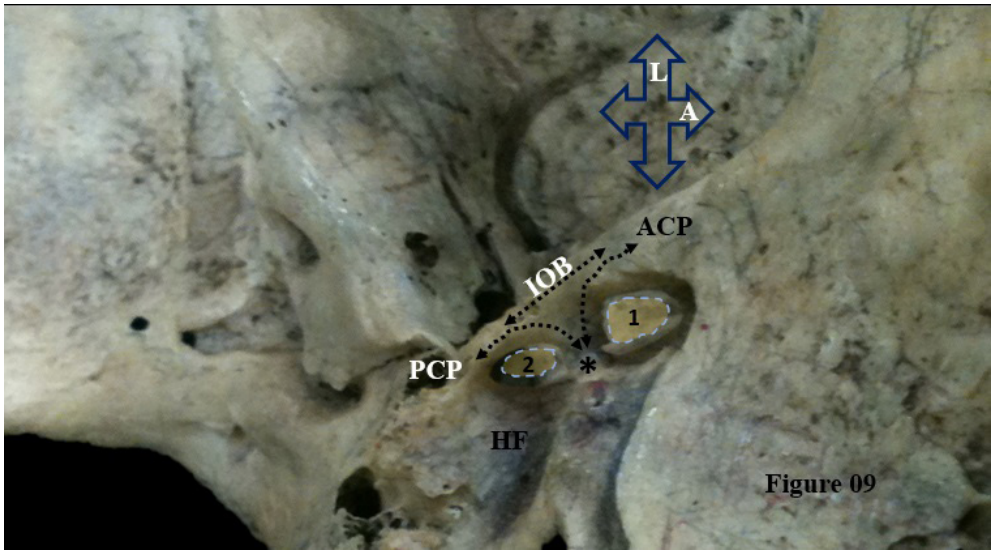

Fig. 09 - Interclinoid foramen (2) from the complete ossification of the interclinoid ligament with the formation of the interclinoid osseous bar or bridge (IOB). In this specimen, the interclinoid osseous bar ossified in association as the middle clinoid process (*) - curved dotted black arrows, forming, in addition to the interclinoid foramen, the carotoclinoid foramen (1). ACP: anterior clinoid process; PCP: posterior clinoid process; HF: hypophyseal fossa; L: lateral and A: anterior.

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