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## INTRODUCTION

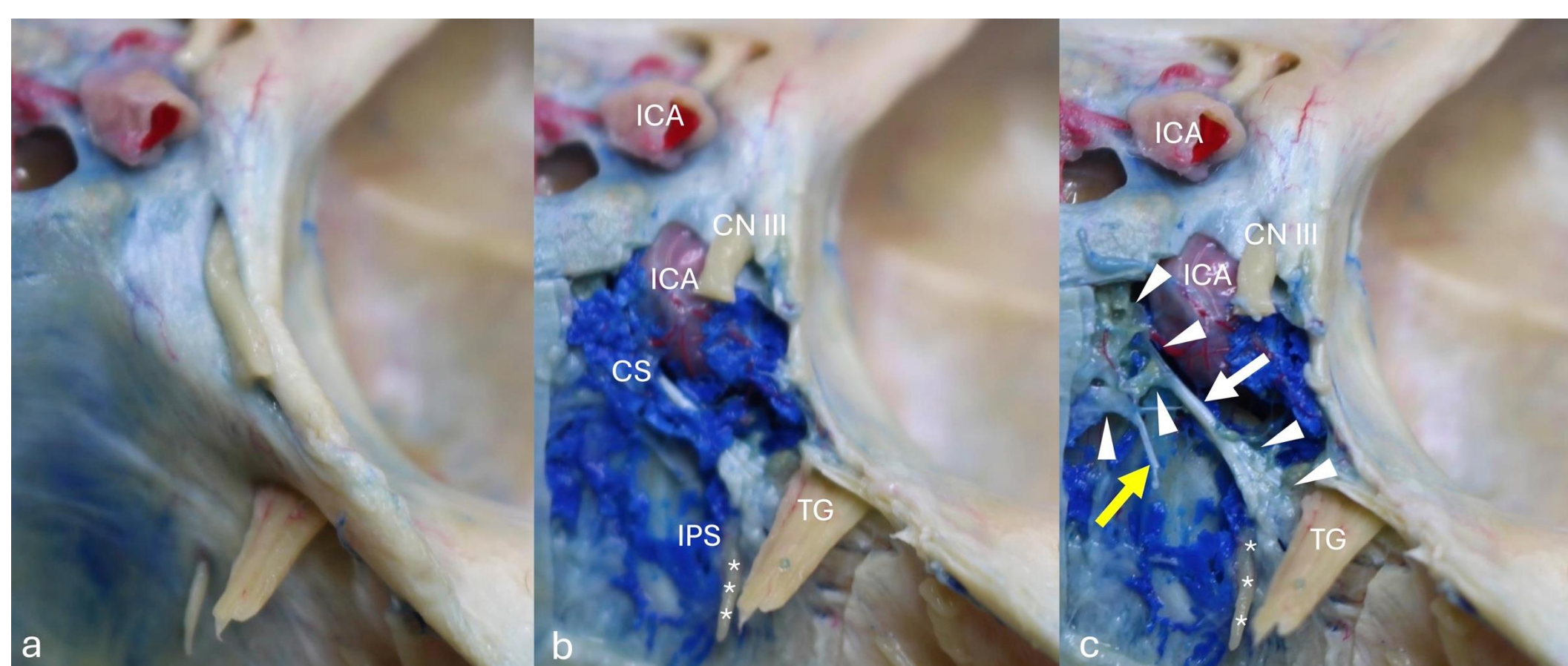
Gruber's ligament, also known as the petroclinoid ligament, petrosphenoidal ligament, or petroclival ligament (PCL), is a fibrous structure in the clival region of the skull base that has been used as a surgical landmark by skull base surgeons. Gruber's ligament, within the inferomedial paraclival triangle, is said to form the roof of Dorello's canal, through which the abducens nerve (CN VI), dorsal meningeal artery, and inferior petrosal sinus (IPS) travel. Gruber's ligament attaches posteriorly to the apex of the petrous part of the temporal bone and anteriorly to the posterior clinoid process or lateral border of the clivus. A previous study found that the anterior attachment of Gruber's ligament was onto the clivus, not the posterior clinoid process, and suggested using "petroclival ligament" as a preferred term for this structure. Although many studies have focused on Gruber's ligament and Dorello's canal, even those with a histological component did not sufficiently evaluate these structures and their surrounding anatomical relationships. Therefore, this study aims to assess the comprehensive morphology of Gruber's ligament and Dorello's canal to understand them better.

## MATERIALS AND METHODS

Gross anatomical dissection using microscope: Eight sides (six for conventional approach and two for inferior approach), mean age 82.6 years (58 to 98 years).

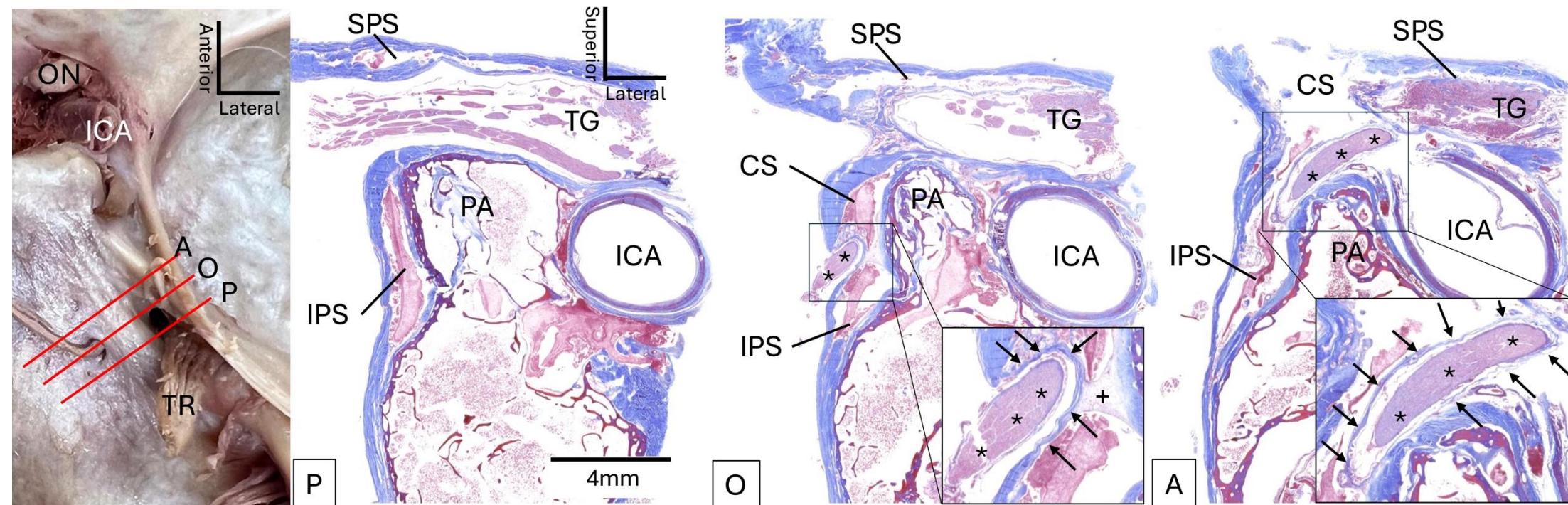
Histological observations: Seven sides (five coronal and two sagittal sections), mean age 79.3 years (67 to 91 years). Masson Trichrome staining.

## RESULTS



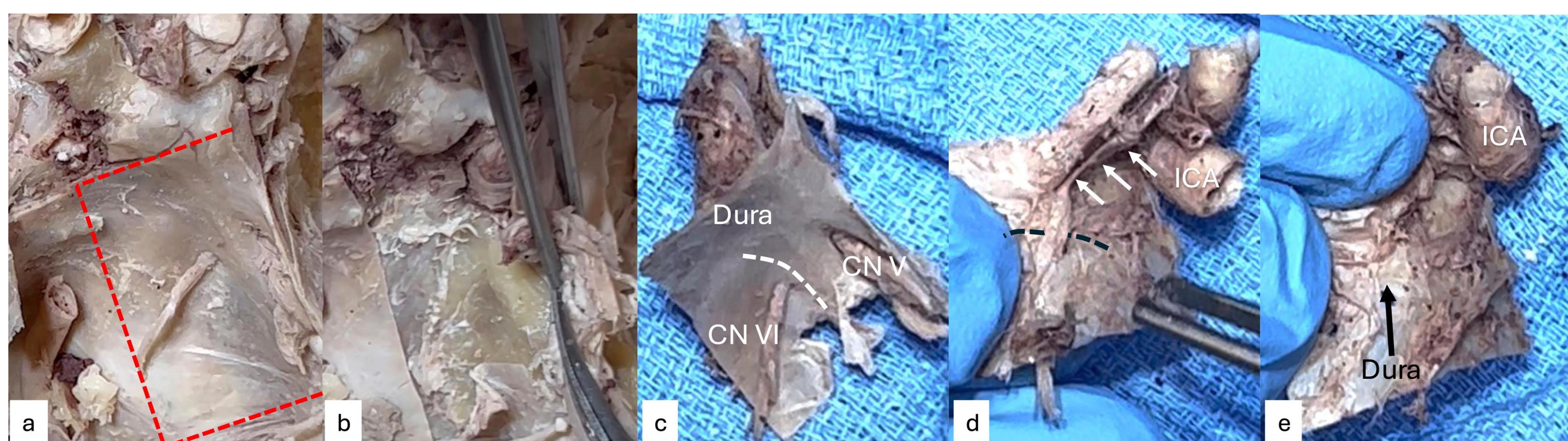
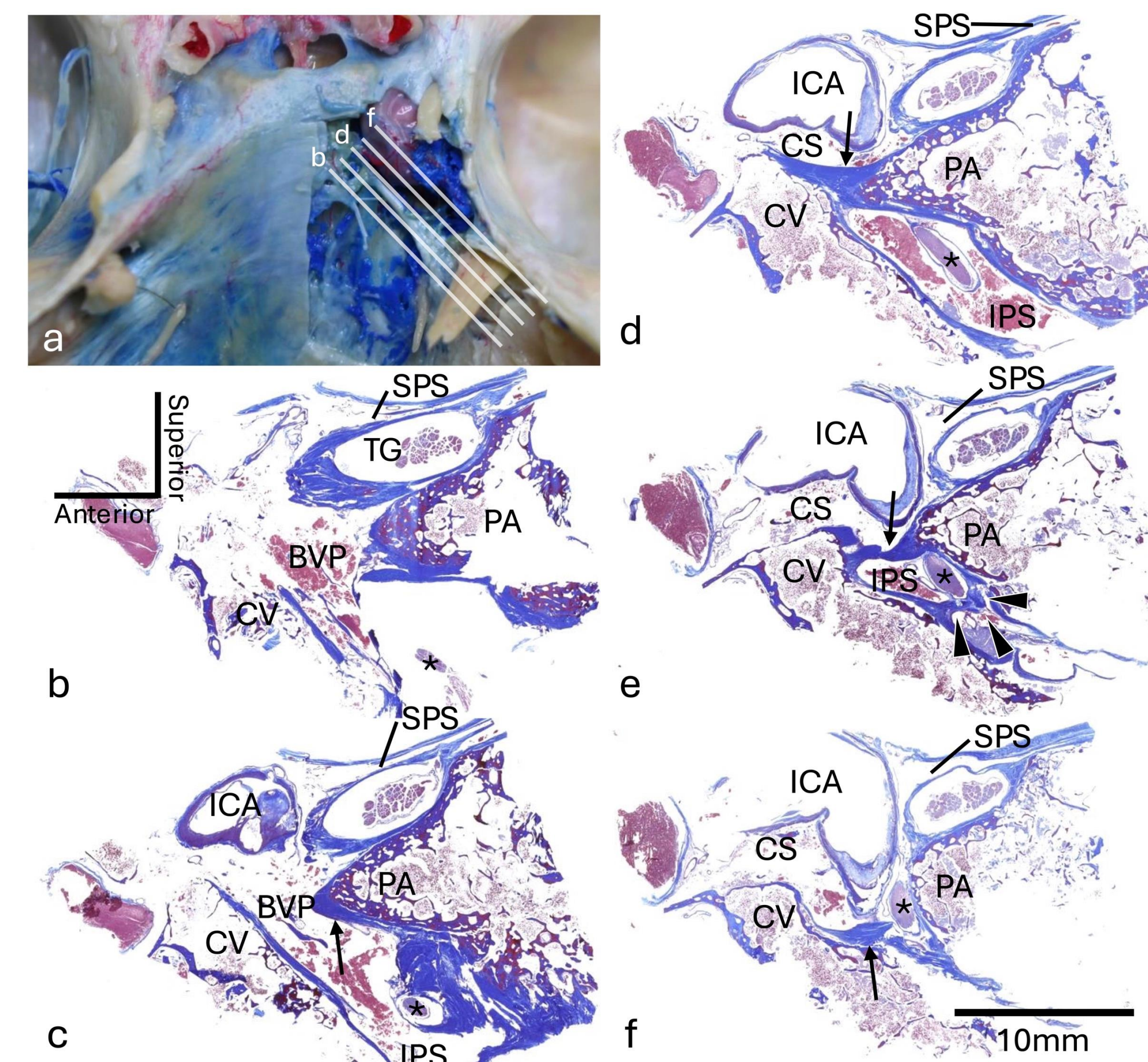
**Figure 1** Step-by-step conventional dissection of right Dorello's canal and abducens nerve (\*).

a: Before dissection b: After removal of the surface dura of the paraclival area. c: After removal of the superficial latex. The white band seen here has traditionally been recognized as Gruber's ligament (white arrow), which clearly connects to the dura on the cavernous sinus and petrous apex (white arrowheads). Note that another fibrous band (yellow arrow, cut during dissection) is also observed, extending from the dura on the cavernous sinus.



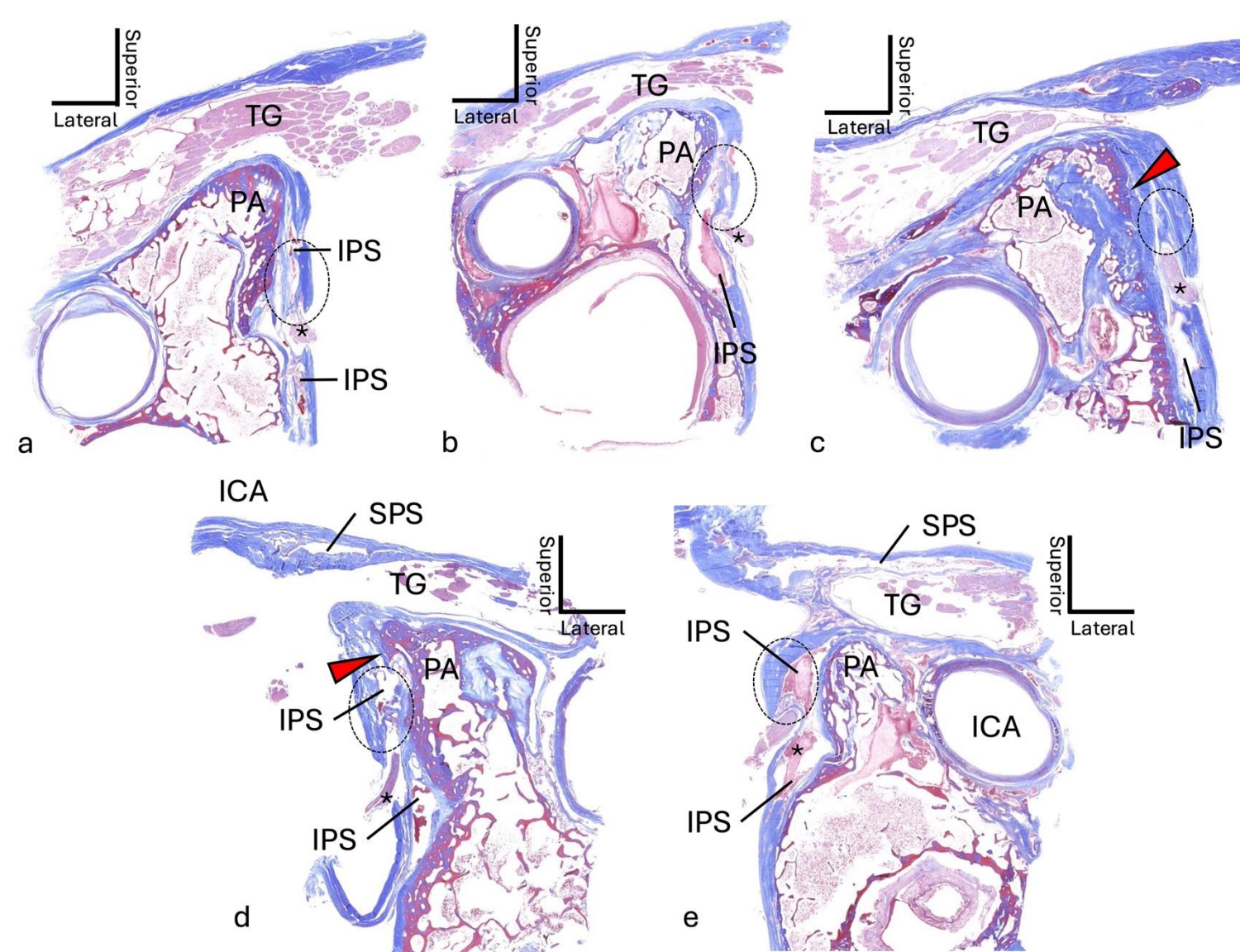
**Figure 3** Histological observation of Dorello's canal (coronal sections).

P, O, and A show a section posterior to, on, and anterior to the opening of Dorello's canal. P: The inferior petrosal sinus runs medial to the petrous apex and inferior to the trigeminal ganglion. O: The abducens nerve (\*) enters the opening of Dorello's canal and courses within the IPS. The abducens nerve remains enveloped by the dura (indicated by arrows in the magnified image in the lower-right corner). The dura surrounding the nerve is connected to the dura on the medial surface of the petrous apex by loose connective tissue (+ in the magnified image in the lower-right corner). A: The abducens nerve (\*) is entirely in Dorello's canal. The abducens nerve continued to be enveloped by the dura (arrows in the magnified image in the lower-right corner). Note this image also shows the confluence of the cavernous sinus.

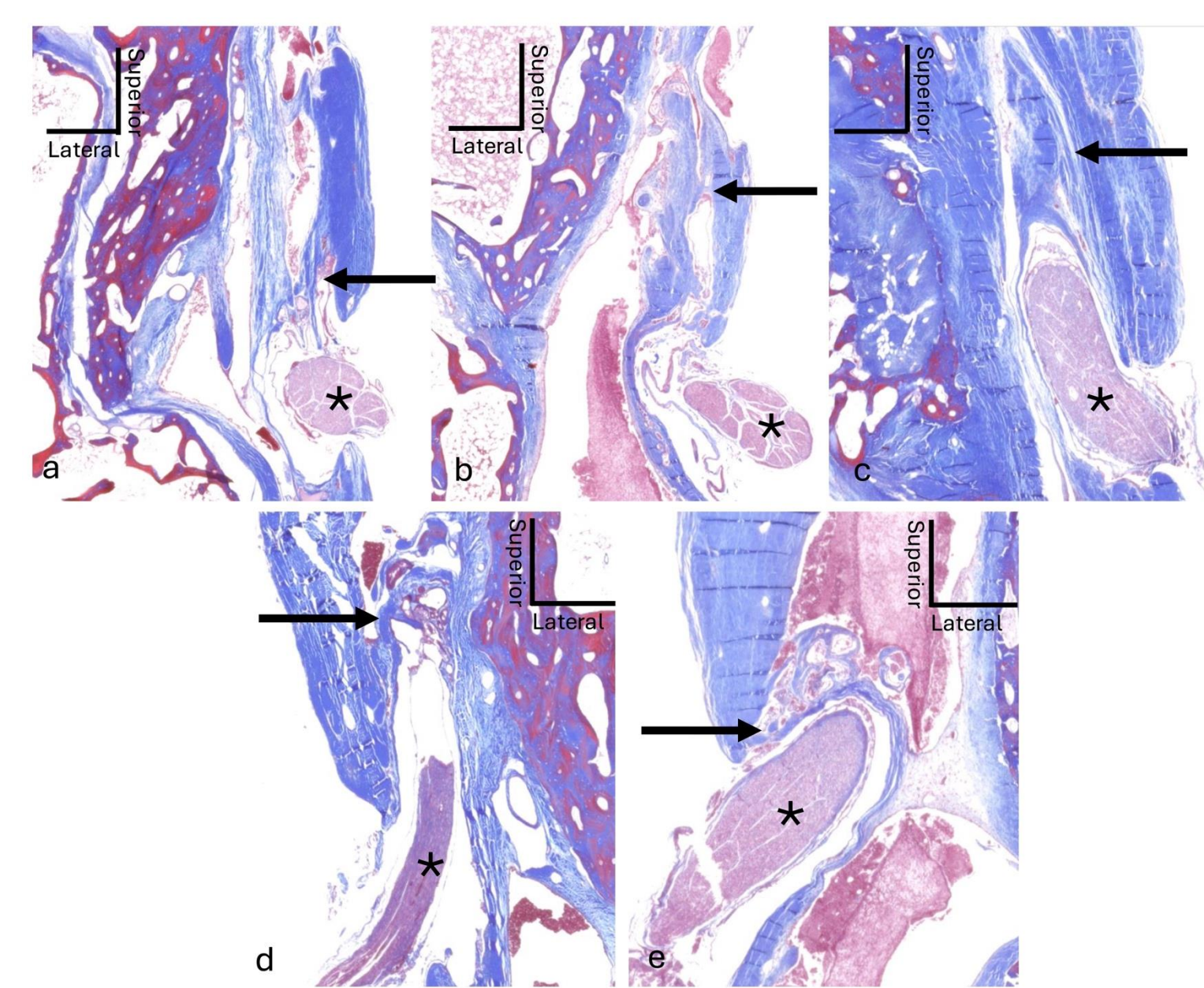


**Figure 2** Inferior approach to Dorello's canal

a: Incision line (rectangular area). b: After elevation of the periosteum. c: Dorello's canal and its contents are harvested en bloc. d: Observation of Dorello's canal from the periosteal (endosteal) side. CN VI is shown at the arrows. The location of where the traditionally described Gruber's ligament should be is indicated by the dotted line. e: After removal of CN VI. No specific ligamentous structures are seen; only dura is observed.



**Figure 4** Coronally sectioned images at the opening (O section in Figure 3) of Dorello's canal in five samples (a-c: left side, d,e: right side). Note that there is no distinct ligamentous structure in any sample. The only structure superior to the abducens nerve (asterisk) is the laterally folded dura and dural wall of the IPS (circles). Also note that the bony spine (arrowhead, hook-like structure) is observed far from but above the abducens nerve in Figures C and D. These could represent dural ossifications.



**Figure 5** Magnified images from Figure 5 focus on the abducens nerve (\*) and surrounding tissue. Figure 5a-e corresponds to Figure 4a-e, respectively. Note that the connective tissue superior to the abducens nerve at the opening of Dorello's canal connects to the dura, forming the medial wall of the IPS, with its thickness varying between individuals.

**Figure 6** Sagittal histological images of the right Dorello's canal.

a: Imaginary section lines for images b through f. Note that the dura in image a is removed to highlight the anatomical structures depth of the dura, but the histological images from b to f are produced with the dura intact. b: The abducens nerve (\*) before entering Dorello's canal. The basilar venous plexus (BVP) is located between the petrous apex (PA) and clivus (CV). c: The abducens nerve (\*) entering Dorello's canal. The confluence of the BVP, superior petrosal sinus (SPS), and inferior petrosal sinus (IPS) is observed. The PA is protruding, and the BVP between the PA and CV becomes narrower compared to image b. The dura on the anterior surface of the PA extends anteriorly (arrow). d: The abducens nerve (\*) traveling inferior to the PA. The PA remains protruding, and the BVP between the PA and CV becomes narrower than in image c. The dura on the anterior surface of the PA and posterior surface of the CV extends and fuses, forming a single fibrous band (arrow). e: The abducens nerve (\*) traveling inferior to the fibrous band (arrow), which is an extension of the dura from the anterior surface of the PA and posterior surface of the CV. This band is thinner than the fibrous band in image d. The PA is less prominent than in image d, and the BVP between the PA and CV is wider than in image d. Note that another fibrous band, also an extension of the dura (arrowheads), is observed inferior to the abducens nerve (\*) between the PA and CV. f: No fibrous band is observed, but there is a thickening of the dura (arrow).

## ABBREVIATIONS

CN VI, abducens nerve; CS, cavernous sinus; CV, clivus; ICA, internal carotid artery; IPS, inferior petrosal sinus ON, optic nerve; PA, petrous apex; SPS, superior petrosal sinus; TG, trigeminal ganglion; TR, trigeminal root

## CONCLUSIONS

The dural tissue at the confluence of the SPS, IPS, CS, and BVP forms a mesh-like structure. At the point where the clivus (CV) and petrous apex (PA) come closest, the dura on the CV and PA fuse to form a single fibrous band (as observed in both dissection and sagittal histology). We found that this fibrous band is not separate from the medial dural wall at its PA end (as shown in coronal section histology). Although connected at the PA end, there is a sinus space between the fibrous band and the medial dural wall. During gross anatomical dissection, the connection between these two structures is severed, resulting in an independent band. Therefore, the extension of the dura, which is part of a mesh-like structure rather than a distinct ligament, has been referred to as Gruber's ligament. This tissue morphology varied across specimens but was consistently identified as part of the dura.