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Endoscopic transorbital approach bone pillars: a comprehensive stepwise anatomical appraisal

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OBJECTIVE The endoscopic superior eyelid transorbital approach has garnered significant consideration and gained popularity in recent years. Detailed anatomical knowledge along with clinical experience has allowed refinement of the technique as well as expansion of its indications. Using bone as a consistent reference, the authors identified five main bone pillars that offer access to the different intracranial targeted areas for different pathologies of the skull base, with the aim of enhancing the understanding of the intracranial areas accessible through this corridor.

METHODS The authors present a bone-oriented review of the anatomy of the transorbital approach in which they conducted a 3D analysis using Brainlab software and performed dry skull and subsequent cadaveric dissections.

RESULTS Five bone pillars of the transorbital approach were identified: the lesser sphenoid wing, the sagittal crest (medial aspect of the greater sphenoid wing), the anterior clinoid, the middle cranial fossa, and the petrous apex. The associations of these bone targets with their respective intracranial areas are reported in detail.

CONCLUSIONS Identification of consistent bone references after the skin incision has been made and the working space is determined allows a comprehensive understanding of the anatomy of the approach in order to safely and effectively perform transorbital endoscopic surgery in the skull base.

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KEYWORDS endoscopic superior eyelid transorbital approach; endoscopic transorbital; skull base surgery; transorbital surgery

In recent years, transorbital surgery has garnered considerable consideration and gained popularity.[1–19] The notable evolution of this technique underscores the significance of detailed anatomical knowledge and clinical experience. These factors are instrumental in refining the procedure and broadening its indications within the armamentarium of skull base neurosurgeons.[20–27]

We propose retaining the previously described phases for the endoscopic superior eyelid transorbital approach, namely the 1) skin, 2) working space, 3) lesion removal, and 4) reconstruction phases.[28] After completing the initial phases, one must recognize the crucial role of bone as a consistent reference point. Using bone structures as a reference during the approach allows enhancement of the understanding of the anatomy of all the intracranial areas accessible through this corridor.

Therefore, in this purely anatomical bone-based study, a detailed and comprehensive review of the transorbital approach via a bone-oriented roadmap is provided, with five bone pillars and their corresponding intracranial areas described. Dedicated cadaveric dissection along with dry skull drilling and specific 3D reconstruction has been used.

Methods

Anatomical dissections were performed at the Laboratory of Surgical Neuroanatomy of the University of Bar-

ABBREVIATIONS LSW = lesser sphenoid wing.
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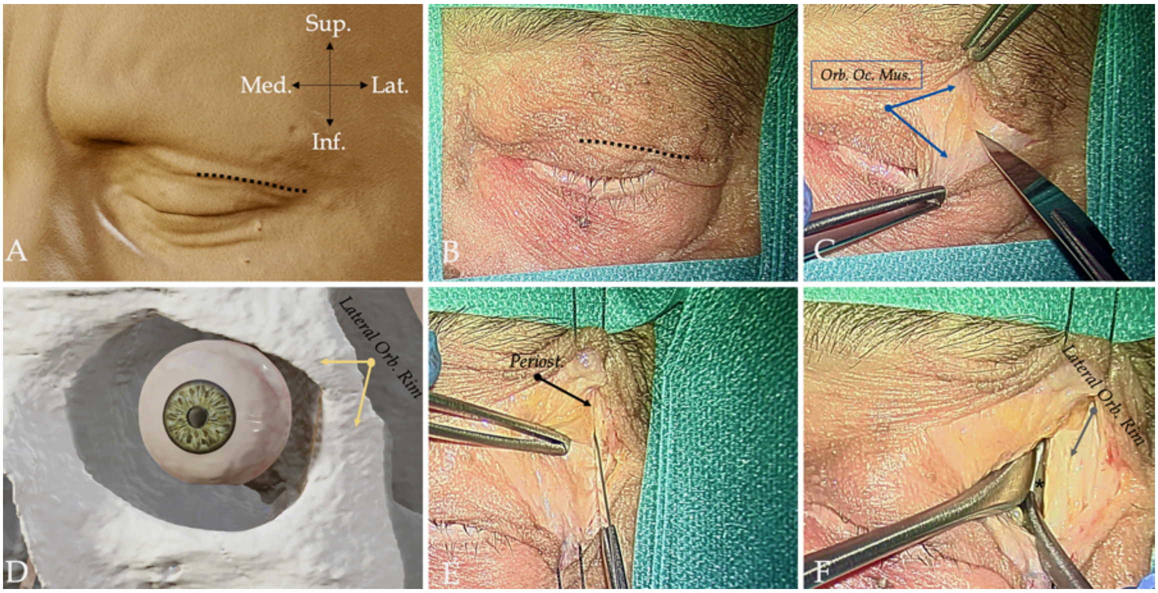

FIG. 1. Skin phase. A superior eyelid incision is performed 8 mm from the palpebral fissure. Dissection through the orbicularis oculi muscle is performed until identification of the superolateral orbital rim. **A:** A 3D skin analysis with Brainlab software showing the incision (*black dotted line*) for the superior eyelid transorbital approach. **B:** Cadaveric dissection showing the planned skin incision (*black dotted line*) for the superior eyelid transorbital approach. **C:** Cadaveric dissection showing the incision of the palpebral portion of the orbicularis oculi muscle. **D:** A 3D bone analysis with Brainlab software showing the lateral orbital rim. **E:** Cadaveric dissection through the orbicularis oculi muscle at the junction between the pretarsal and preseptal planes until identification of the periosteum. **F:** Cadaveric dissection showing identification of the superolateral orbital rim so that dissection can progress inside the orbit cavity. The *asterisk* represents the space created in the orbit cavity after dissection of the periorbital layer. Inf. = inferior; Lat. = lateral; Lateral Orb. Rim = lateral orbital rim; Med. = medial; Orb. Oc. Mus. = orbicularis oculi muscle; Periost. = periosteum; Sup. = superior.

celona. First, a 3D analysis using Brainlab software was conducted, involving the fusion of CT and MR images to achieve segmentation.

For dry skull dissection, two dry skulls (four sides) were used. Each preestablished bone pillar was sequentially removed using a high-speed drill. Images were obtained with an external camera (Canon Rebel T5i).

For the cadaveric dissection, three heads (six sides) were used. Dissections started macroscopically and then continued endoscopically using a rigid 4-mm-diameter endoscope (Stryker) connected to a light source. A high-speed drill was used for bone removal.

Results

Prior to the identification of the forthcoming bone pillars, the transorbital approach was initiated following the preliminary stages of the skin incision and working space phases. These initial phases of the approach were performed as previously described.[1,17,18,29]

In this study, we performed an analysis of the superior eyelid skin incision (Video 1).

VIDEO 1. Step-by-step dissection of a left transorbital approach. The procedure starts with a skin incision over the superior eyelid, and then the appropriate working space is achieved. Subsequently, the LSW is removed, followed by the sagittal crest and anterior clinoid. Finally, the middle fossa and the most superolateral portion of the greater sphenoid wing are reached, as well as the posterior fossa, via dedicated drilling of the petrous apex. © Alberto Di Somma, published with permission. Click here to view.

Accordingly, for the skin phase, the incision was made in the superior eyelid crease. Dissection through the orbicularis oculi muscle proceeded until the lateral orbital rim was discerned, and then further progressed between the periosteum and periorbita using a malleable retractor to retract the orbital contents medially until identification of the inferior and superior orbital fissure (Fig. 1).

For the working space phase, the drilling process was initiated by removing the body of the zygoma (orbital surface of the zygomatic bone) until the temporalis deep fascia was exposed and then further progressed along the greater sphenoid wing (Fig. 2). It may become necessary to remove the lateral orbital rim to achieve an increased working space and optimal angulation, thereby facilitating greater maneuverability and more extensive exposure.[30]

From this point, an adequate working space was obtained and the procedure followed our sequential bone-oriented proposal. Drilling of each bone pillar was conducted sequentially, providing access to each intracranial area.

Lesser Sphenoid Wing

After the skin incision is made and a working space is achieved, the first bone pillar that is encountered is the lesser sphenoid wing (LSW). Initially, this structure needs to be exposed via removal of the greater sphenoid wing (thus continuing the drilling of the working space phase) and the frontobasal bone. Exposure of the temporal dura mater and frontal dura mater permits identification and

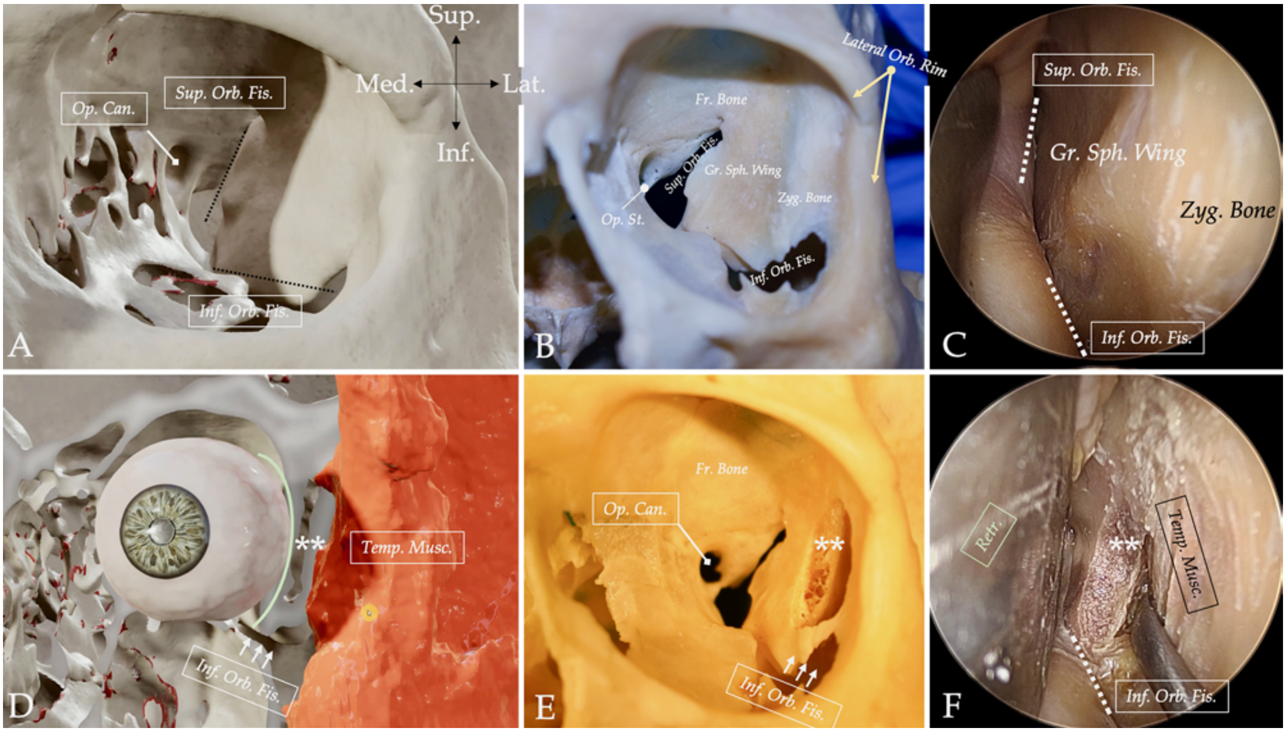

FIG. 2. Working space phase. A malleable retractor (*green line* in panel D) is placed to separate the orbital contents medially from the posterolateral wall of the orbit until the superior and inferior orbital fissures (*white dotted lines* in panels C and F) are identified. The orbital surface of the zygomatic bone and greater sphenoid wing (*asterisks* in panels D–F) are drilled until the temporalis deep fascia and temporal dura mater are exposed. **A and D:** A 3D analysis using Brainlab software. **B and E:** Bone analysis in dry skull. **C and F:** Cadaveric dissection. Fr. Bone = frontal bone; Gr. Sph. Wing = greater sphenoid wing; Inf. Orb. Fis. = inferior orbital fissure; Op. Can. = optic canal; Op. St. = optic strut; Retr. = retractor; Sup. Orb. Fis. = superior orbital fissure; Temp. Musc. = temporalis muscle; Zyg. Bone = zygomatic bone. See Fig. 1 legend for other abbreviations.

dissection of the LSW. Hence, the LSW can be drilled to facilitate exposure of the frontal and temporal dura, which is generally necessary when treating spheno-orbital meningiomas via a transorbital route. Dural opening at this location leads to identification of the frontobasal and temporal lobes, as well as the sylvian fissure and possibly its contents (Fig. 3).[31] The LSW (first bone pillar) is a key bone landmark of the transorbital approach because it is connected to the other bone pillars. In fact, the next bone pillar, the newly described sagittal crest[32] (second bone pillar), is located just inferiorly in the medial aspect of the surgical field. The anterior clinoid (third bone pillar) is the medial and deep prolongation of the LSW. The most superolateral portion of the greater sphenoid wing, which continues inferiorly with the middle fossa floor (fourth bone pillar), also represents the most lateral aspect of the LSW (its origin). Finally, following the middle fossa floor, the posterior fossa can be approached after removing the petrous apex (fifth bone pillar).

Sagittal Crest (medial aspect of the greater sphenoid wing)

The newly described sagittal crest, represented by a triangular bony ridge consisting of the residual medial portion of the greater sphenoid wing after its initial drilling, serves as the second bone pillar and constitutes a very important surgical landmark during the transorbital approach.[32]

The complete drilling of this structure is performed from its apical part to its base until reaching the maxillary strut and the foramen rotundum. Its removal facilitates the extension of the dissection, allowing an interdural peeling of the lateral wall of the cavernous sinus, thereby enabling identification of the following critical structures: oculomotor nerve, trochlear nerve, trigeminal branches up to the gasserian ganglion, trigeminal root, and the intracavernous segment of the internal carotid artery, as well as the intracavernous sixth cranial nerve (Fig. 4).[10,32–34] Moreover, the dura mater covering the temporal pole also becomes visible; it can be opened to explore the temporal lobe and reach the temporomesial regions up to the temporal horn of the lateral ventricle.

Anterior Clinoid Process

After drilling of the LSW medially through the roof of the superior orbital fissure in a horizontal plane, it is possible to identify the next bone pillar, the anterior clinoid process. Correct visualization and unroofing of the optic canal are followed by drilling posteriorly toward the center of the anterior clinoid process base, until careful detachment and complete removal in an extradural manner can be achieved. The opening of the dura mater and subsequent intracranial evaluation of this area shows the following structures inside the opticocarotid region: the intracranial portion of the optic nerve running posteriorly

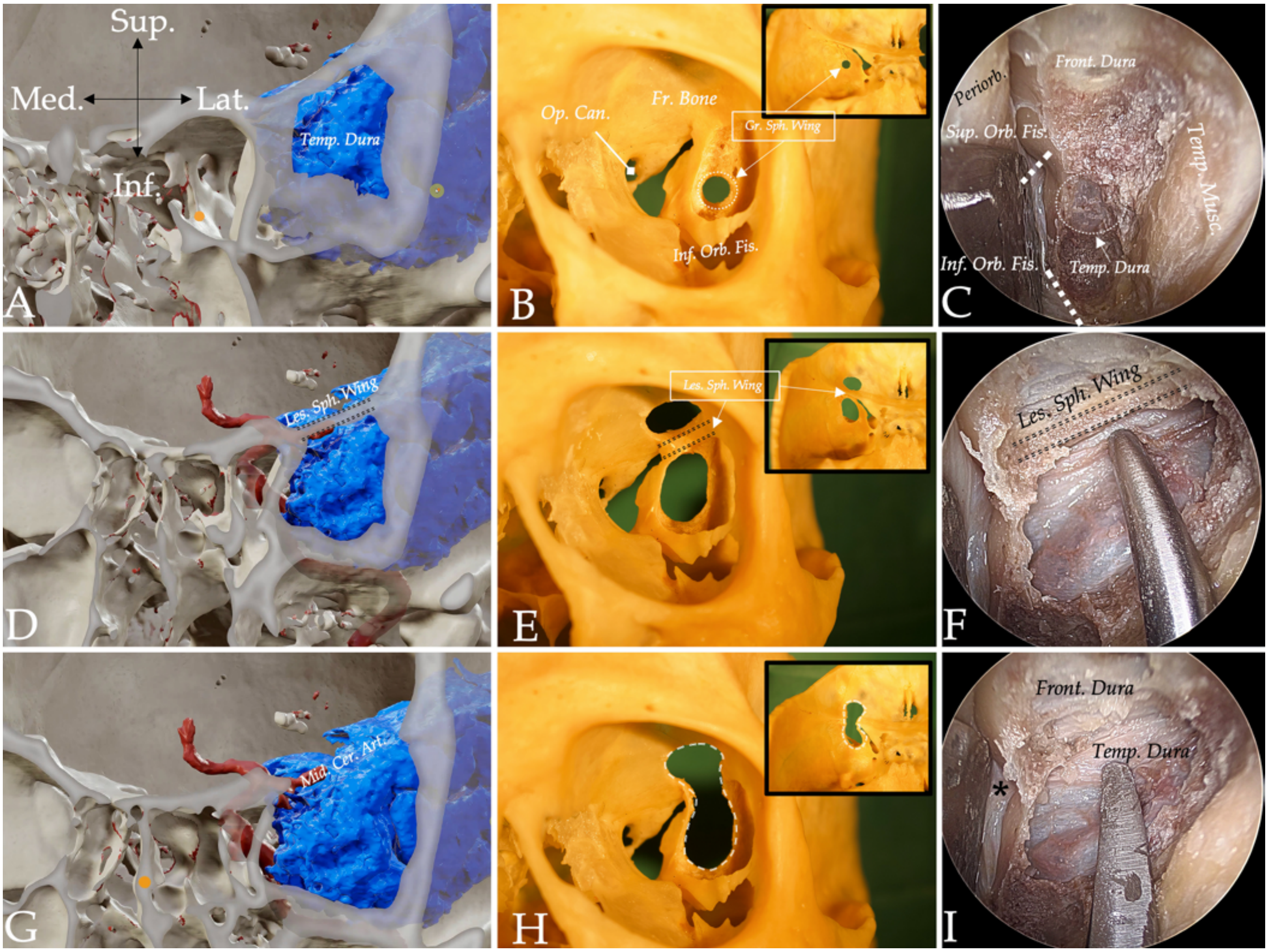

FIG. 3. LSW bone pillar. The upper and lateral portions of the LSW are drilled until the frontal dura and anterior clinoid process are exposed. **A, D, G:** A 3D analysis using Brainlab software. **B, E, H:** Bone analysis in dry skull from the transorbital and transcranial (**insets**) perspectives. **C, F, I:** Cadaveric dissection. The *asterisk* represents the periorbita, and the *white dotted lines* represent the superior and inferior orbital fissures. Front. Dura. = frontal dura; Les. Sph. Wing = LSW; Mid. Cer. Art. = middle cerebral artery; Periorb. = periorbit; Temp. Dura = temporal dura. See previous figure legends for other abbreviations.

to form the optic chiasm, the clinoid portion of the internal carotid artery, the frontobasal lobe, and the olfactory tract (Fig. 5).[14,35]

Middle Fossa Floor

The middle fossa floor is described as the next bone pillar of the superior eyelid transorbital approach. Upon exposure of the temporal dura of the temporal lobe, the dura and lobe can be elevated extradurally until proper visualization of the middle meningeal artery exiting the spinous foramen and of the entire floor of the middle cranial fossa with the mid-subtemporal ridge or crista ovale.[26] Removal of the cranial middle fossa floor is performed respecting the following anatomical boundaries: the lateral wall of the cavernous sinus medially, the limit of the squama temporalis laterally, the lateral pterygoid muscle covering the infratemporal fossa inferiorly, the LSW superiorly, the greater sphenoid wing anteriorly, and the greater superficial petrosal nerve as well as petrous portion of the internal carotid artery and anterior surface of the petrous segment of the temporal bone posteriorly.

Removal of the middle fossa floor also allows access to the infratemporal fossa. In order to facilitate access to the next and last bone pillar, the petrous apex, the most superolateral part of the greater sphenoid wing (directed toward the pterion) has to be drilled (Fig. 6).[36]

Petrous Apex

The petrous apex is the deepest bone structure of the skull base that can be reached via a transorbital route, representing the fifth and last bone pillar of this approach. Its drilling allows exposure of the main neurovascular structures of the posterior fossa.

Multiple structures should be identified as safe boundaries before drilling of the petrous apex: inferiorly, the greater superficial petrosal nerve and the petrous region of the internal carotid artery; medially, the lateral border of the mandibular division of the trigeminal nerve and the

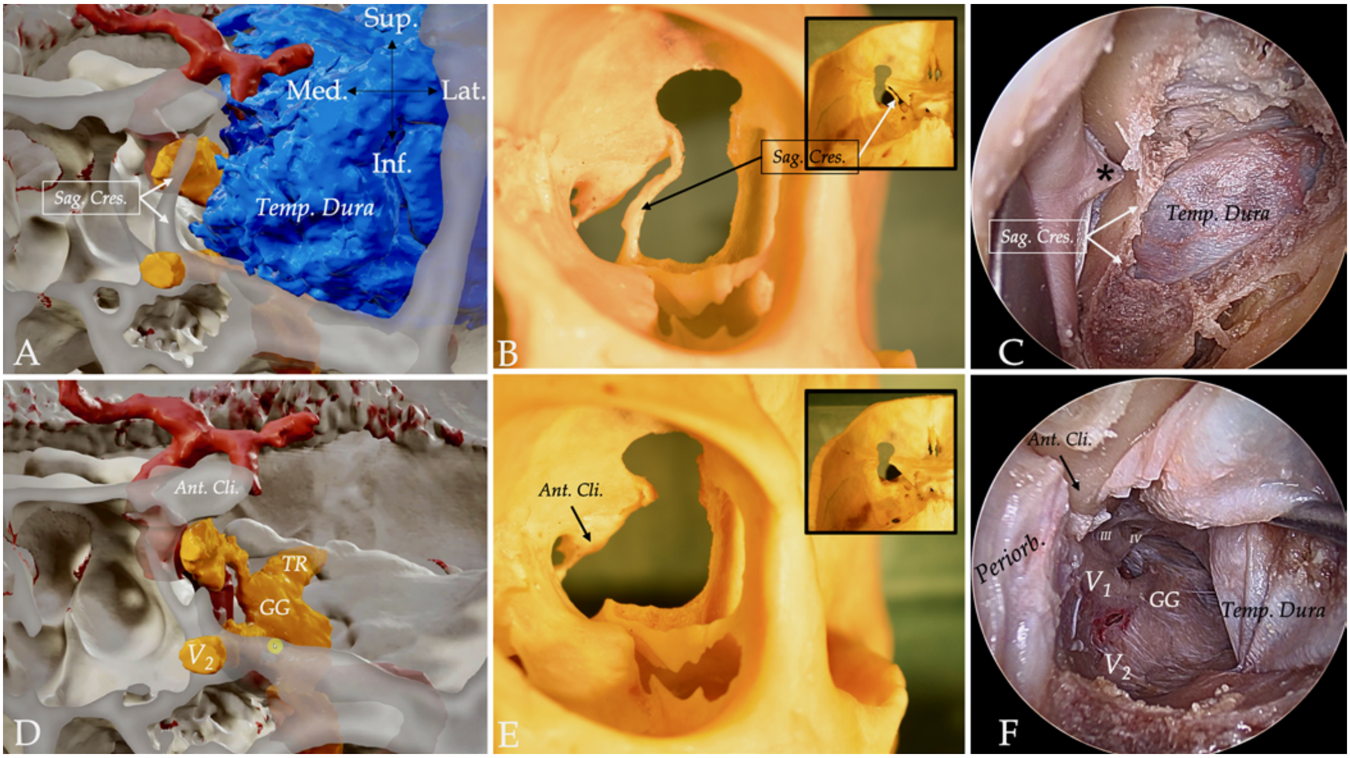

FIG. 4. Sagittal crest (medial aspect of the greater sphenoid wing) bone pillar. The sagittal crest is identified and drilled and the cavernous sinus is peeled interdurally. **A and D:** A 3D analysis using Brainlab software. **B and E:** Bone analysis in dry skull from the transorbital and transcranial (**insets**) perspectives. **C and F:** Cadaveric dissection. The *asterisk* represents the meningo-orbital band. Ant. Cli. = anterior clinoid; GG = gasserian ganglion; III = oculomotor nerve; IV = trochlear nerve; MOB = meningo-orbital band; Sag. Cres. = sagittal crest; TR = trigeminal root; V1 = ophthalmic branch of the trigeminal nerve; V2 = maxillary branch of the trigeminal nerve. See previous figure legends for other abbreviations.

gasserian ganglion; laterally, the beginning of the inner ear; and superiorly, the tentorium, petrous ridge, and superior petrosal sinus.

After recognition of these crucial landmarks, drilling of the petrous apex proceeds in the medial to lateral direction, allowing exposure of the internal carotid artery and posterior cranial fossa. The opening of the dura mater at this location permits exploration of the following intradural spaces and visualization of the following structures: the cerebellopontine angle, with visualization of the anterolateral portion of the pons, the petrous surface of the cerebellum, the origin of the trigeminal nerve, the facial and vestibulocochlear nerves, the superior petrosal vein draining to the superior petrosal sinus, the anterior inferior cerebellar artery, and the labyrinthine arteries; the middle incisural space, with visualization of the ambient and crural cisterns, the cerebellar mesencephalic fissure, the anterolateral portion of the mesencephalon, the superior cerebellar artery, and the oculomotor and trochlear nerves; and the ventral brainstem space, with visualization (normally only by means of an angulated lens) of the abducens nerve entering the cavernous sinus from Dorello's canal and the basilar trunk at the midline (Fig. 7).[37–40]

Discussion

The endoscopic transorbital approach has undergone significant evolution and has gained acceptance and popularity in recent years, proving to be an excellent route to access critical, mainly lateral, skull base regions. An extensive number of anatomical studies demonstrating its safeness and feasibility have allowed its progressive growth, leading to an increasing number of indications for its use and clinical reports.[1–18,29,30,32,38,41–53] Utilization of consistent anatomical landmarks in relation to the orbital contents facilitates a comprehensive systematization of the approach. This systematic framework allows for more effective treatment of diverse surgical pathologies within the confines of the operating room.

The proposed bone-oriented anatomical review of the anatomy of the transorbital approach describes five bone pillars with their corresponding intracranial areas.

Emphasizing the importance of individualizing each case, it is imperative that each procedure be tailored in accordance with the specific targeted area and the underlying pathology inherent to the surgical case. In this manner, it is not always necessary to remove all the mentioned bone pillars or the entirety of each of them.

The removal of the LSW allows access to the frontal and temporal lobes as well as to the sylvian fissure and middle cerebral artery.[31] In the majority of cases when the transorbital route is used, the LSW bone pillar is removed. This is particularly noteworthy in extradural lesions of the middle and anterior cranial fossae and spheno-orbital meningiomas, for which the approaches have

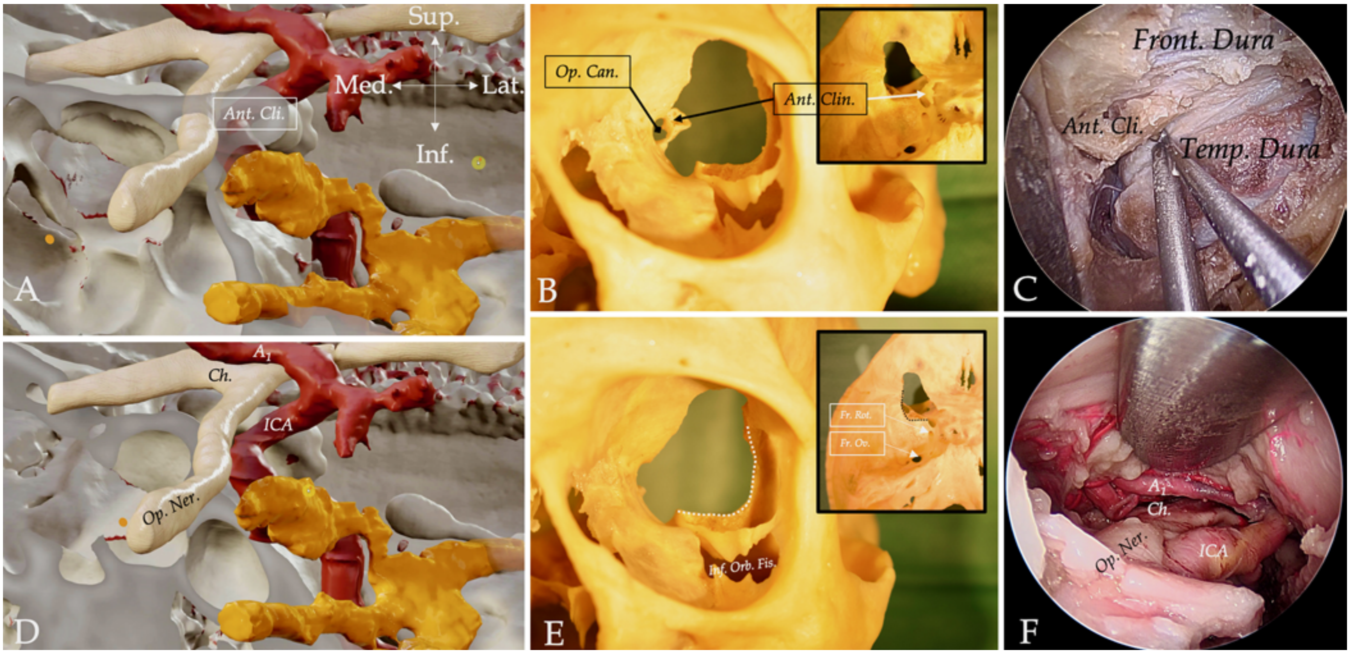

FIG. 5. Anterior clinoid bone pillar. The anterior clinoid process is removed extradurally to expose the opticocarotid region. **A and D:** A 3D analysis using Brainlab software. **B and E:** Bone analysis in dry skull from the transorbital and transcranial (**insets**) perspectives. **C and F:** Cadaveric dissection. The *white dotted line* (E) and *black dotted line* (**inset** in E) represent the middle fossa floor and superolateral portion of the greater sphenoid wing from the transorbital and transcranial perspectives, respectively. A1 = A1 segment of the anterior cerebral artery; Ch. = chiasma; Front. Dura = frontal dura; Fr. Ov. = foramen ovale; Fr. Rot. = foramen rotundum; ICA = internal carotid artery; Op. Ner. = optic nerve; Temp. Dura = temporal dura. See previous figure legends for other abbreviations.

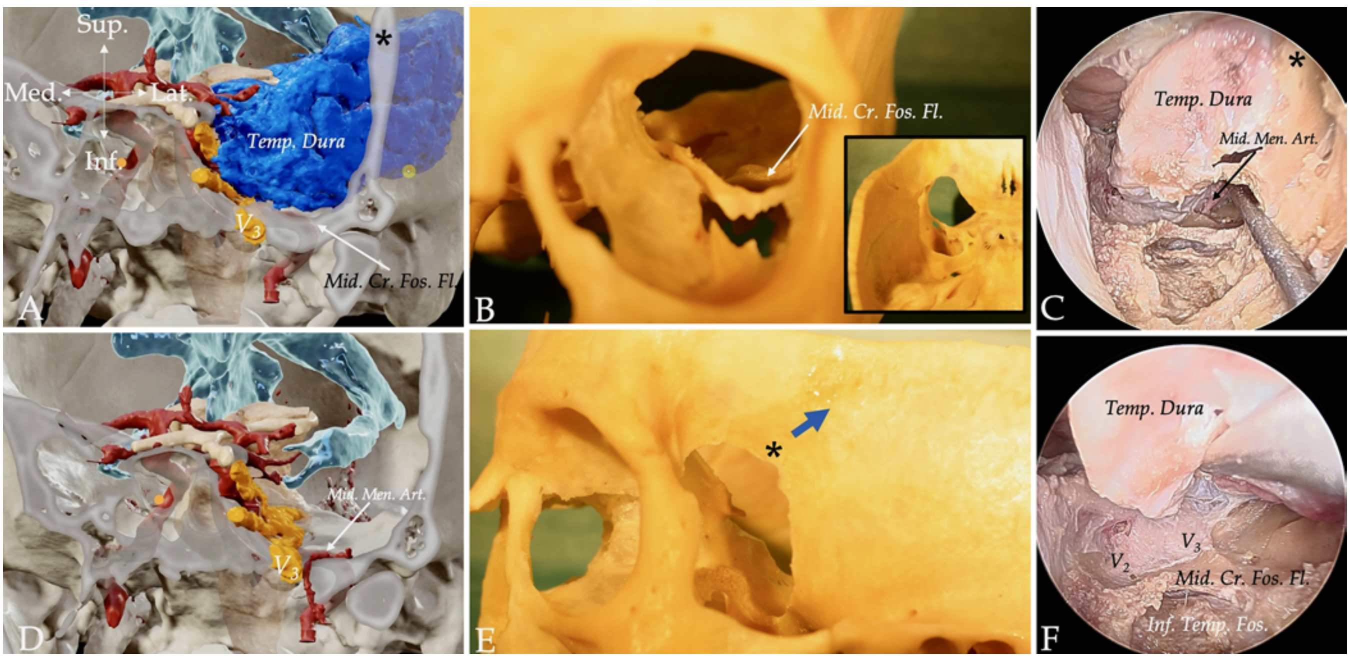

FIG. 6. Middle fossa floor bone pillar. The floor of the middle fossa floor is drilled and the temporal lobe is extradurally elevated to allow access to the infratemporal fossa. **A and D:** A 3D analysis using Brainlab software. **B and E:** Bone analysis in dry skull from the transorbital (B), lateral (E), and transcranial (**inset** in B) perspectives. **C and F:** Cadaveric dissection. The *asterisk* represents the superolateral portion of the greater sphenoid wing, and the *blue arrow* represents the pterion. Inf. Temp. Fos. = inferior temporal fossa; Mid. Cr. Fos. Fl. = middle cranial fossa floor; Mid. Men. Art. = middle meningeal artery; V3 = mandibular branch of the trigeminal nerve. See previous figure legends for other abbreviations.

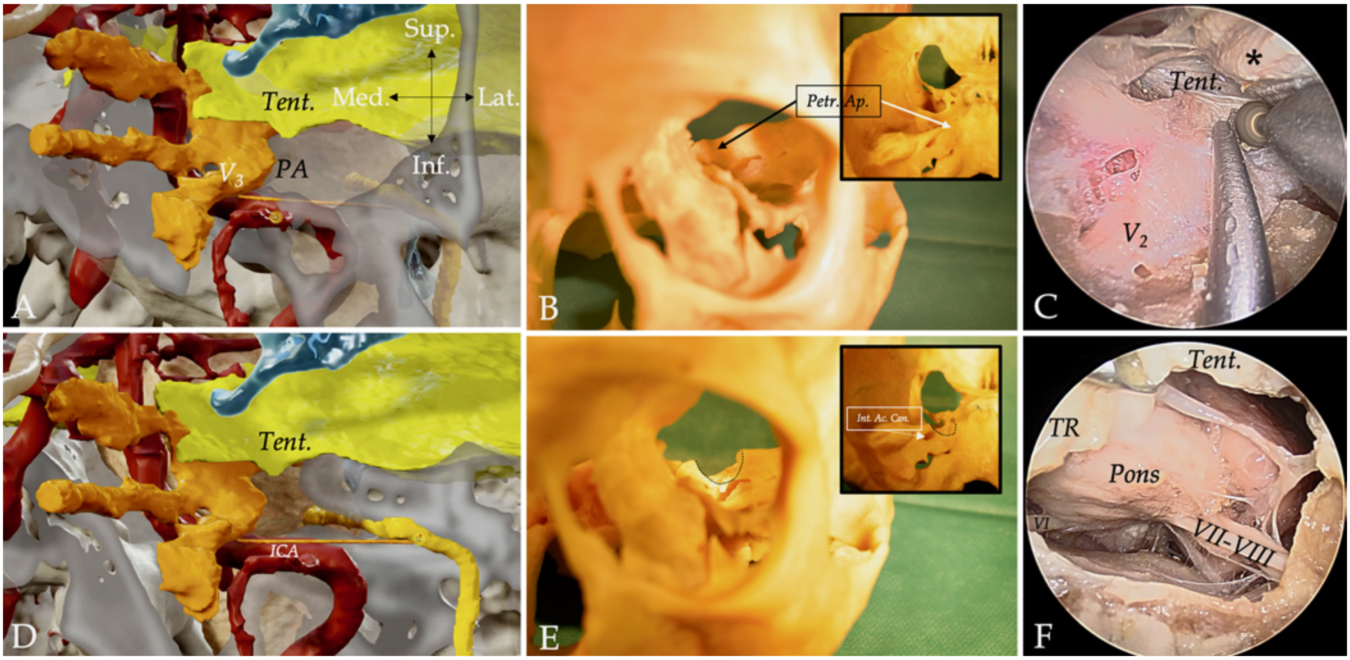

FIG. 7. Petrous apex bone pillar. The petrous apex is exposed via the transorbital approach and the posterior cranial fossa structures are identified. **A and D:** A 3D analysis using Brainlab software. **B and E:** Bone analysis in dry skull from the transorbital and transcranial (**insets**) perspectives. **C and F:** Cadaveric dissection. The *asterisk* represents the temporal dura, and the *black dotted line* represents where the petrous apex is drilled. Int. Ac. Can. = internal acoustic canal; PA, Petr. Ap. = petrous apex; Tent. = tentorium cerebelli; VII–VIII = facial and vestibulocochlear nerves. See previous figure legends for other abbreviations.

previously been classified as stages 1 and 2 of difficulty, respectively.[2,31,54]

The excision of the sagittal crest allows access to the cavernous sinus and more extensive exposure of the temporal lobe.[10,32–34] This phase of bone removal permits treatment of lesions in Meckel's cave and the cavernous sinus, for which the approaches have previously been classified as stages 3 and 4 of difficulty, respectively.[7,54,55]

The removal of the anterior clinoid process permits exposure of the opticocarotid region.[14,35] Drilling of its base might be sufficient for most of the pathologies in this area, but complete excision must be achieved to treat anterior clinoid meningiomas, for which the approach has previously been classified as stage 4 of difficulty.[54]

Drilling of the middle cranial fossa and most superolateral portion of the greater sphenoid wing becomes the cardinal pillar for petrous lesions, for which the approach has previously been classified as stage 5 of difficulty.[54] It also allows access to the infratemporal fossa.[26,36]

Removal of the petrous apex permits entrance to the posterior cranial fossa and its main neurovascular structures.[37–40] Drilling of the petrous apex is necessary for the treatment of posterior cranial fossa lesions such as petroclival meningiomas, for which the approach has also been classified as stage 5 of difficulty.[54] However, a thorough comprehension of the anatomy in this area facilitates the resection of other pathologies such as trigeminal schwannoma involving the trigeminal pore.

Study Limitations

One limitation of this study is that we used cadaveric specimens. While they serve as valuable models for the investigation of surgical approaches, they cannot entirely replicate the complexities of the clinical environment. The proposed anatomical review serves as a theoretical and systematized model oriented around consistent bone pillars during the approach, which must be individualized in each surgical case and tailored to the specific needs of the pathology being treated. Because the anatomical landmarks used consist of bony structures, they may be altered in cases of significant hyperostosis, as well as in instances of pneumatization of the lateral recess of the sphenoidal sinus.

Conclusions

After completion of the initial phases of the transorbital approach, namely the skin phase and working space phase, identification of consistent bone references allows a comprehensive understanding of the anatomy of the transorbital corridor in order to safely and effectively perform transorbital endoscopic surgery in the skull base.

We identified five main bone pillars that offer access to the different intracranial targeted areas for different pathologies of the skull base. We believe that the identification of these structures enhances our understanding of the anatomy of the transorbital approach, thus facilitating a more accurate and precise representation in the operating room.

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Disclosures

Dr. Alobid reported personal fees from Sanofi, GSK, AstraZeneca, and Menarini outside the submitted work. Dr. Di Somma reported being a consultant for Brainlab.

Author Contributions

Conception and design: Enseñat, Codes, Tafuto, Gomez, Alobid, Di Somma. Acquisition of data: Mosteiro, Tafuto, Gomez, Alobid, Di Somma. Analysis and interpretation of data: Enseñat, Mosteiro, Tafuto, Prats-Galino, Di Somma. Drafting the article: Codes, Tafuto, Alobid, Di Somma. Critically revising the article: Enseñat, Codes, Matas, Alobid, Lopez, Prats-Galino, Di Somma. Reviewed submitted version of manuscript: Mosteiro, Matas, Alobid, Lopez, Prats-Galino, Di Somma. Approved the final version of the manuscript on behalf of all authors: Enseñat. Administrative/technical/material support: Tafuto, Lopez. Study supervision: Enseñat, Tafuto, Di Somma.

Supplemental Information

Videos

Video 1. https://vimeo.com/910910362.

Previous Presentations

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