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**Open-Door Extended Endoscopic Transorbital
Technique to the Paramedian Anterior and Middle
Cranial Fossae. Technical Notes, Anatomical-
Morphometric Quantitative Analysis**

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Abstract

BACKGROUND. The superior eyelid endoscopic transorbital approach (SETOA) provides a direct and short minimally invasive route to the paramedian aspect of anterior and middle skull base. Nevertheless, it uses a narrow corridor that limits its angles of attack.

OBJECTIVE. The aim of this study was to evaluate the feasibility and potential benefits of an “extended” conservative variant of the “standard” endoscopic transorbital approach - termed “open-door” - to enhance the exposure of lesions affecting the paramedian aspect of the anterior and middle cranial fossae.

METHODS. First, the authors described the technical nuances of the open-door extended transorbital approach (ODETA). Next, they documented its morphometric advantages over standard SETOA. Finally, they provided a clinical - anatomical application to demonstrate enhanced exposure and better angles of attack to treat lesions occupying the paramedian anterior and middle cranial fossae. Five adult cadaveric specimens (10 sides) initially underwent standard SETOA and then extended open-door SETOA (ODETA) to the paramedian anterior and middle fossae. The adjunct of hinge-orbitotomy, through three surgical steps and straddling the frontozygomatic suture, converted conventional SETOA to its extended open-door variant. CT scans were performed before dissection and uploaded to the neuronavigation system for quantitative analysis. The angles of attack on the axial plane that addressed four key landmarks, namely the tip of the anterior clinoid process (ACP), foramen rotundum (FR), foramen ovale (FO), and trigeminal impression (TI), were calculated for both operative techniques and compared.

RESULTS. Hinge-orbitotomy of the extended open-door SETOA resulted in several surgical, functional, and esthetic advantages: it provided wider

axial angles of attack for each of the target points, with a gain angle of $26.68^{\circ} \pm 1.31^{\circ}$ for addressing the ACP ($p < 0.001$), $29.50^{\circ} \pm 2.46^{\circ}$ for addressing the FR ($p < 0.001$), $19.86^{\circ} \pm 1.98^{\circ}$ for addressing the FO ($p < 0.001$), and $17.44^{\circ} \pm 2.21^{\circ}$ for addressing the lateral aspect of the TI ($p < 0.001$), while hiding the skin scar, avoiding temporalis muscle dissection, preserving flap vascularization, and decreasing the rate of bone infection and degree of orbital content retraction.

CONCLUSIONS. The extended open-door technique may be specifically suited for selected patients affected by paramedian anterior and middle fossae lesions, with prevalent anteromedial extension toward the anterior clinoid, the foremost compartment of the cavernous sinus and FR and not completely controlled with the pure endoscopic transorbital approach.

INTRODUCTION

Over the last fifty years, minimally invasive surgery (MIS) has become the driving paradigm in several branches of surgery, mainly in the neurosurgical field. Particularly, the advent and the continuous refinements of the endoscopes, have led to the progressive and rapid diffusion of its adoption, first in endoscope-assisted and then in purely endoscopic procedures, mainly among pathologies involving median skull base, as witnessed in the surgical management of sellar region lesions, in which the endoscopic endonasal transsphenoidal (EEA) route has become the gold standard^{1,2}.

The surgical freedom represents one of the main drawbacks among the endoscopic approaches. To overcome this limit Kassam et al^{3,4}. provided some basic rules which allowed, through different additional bony resections, to expand the surgical corridor converting the “standard” into the “extended” endoscopic endonasal transsphenoidal approaches (EEEEA), and consequently to expand the surgical indications of this route to lesions extending over the boundaries of the sellar region, from the frontal sinus to the second cervical vertebra in the sagittal plane, and from midline to mid-orbit meridian for anterior cranial fossa, to the floor of middle cranial fossa, and to the jugular foramen for the posterior cranial fossa, in the coronal plane^{1,3,4}. Despite EEAs provide an excellent surgical corridor to access the ventral midline skull base, the mantra “*Do not cross the plane of cranial nerve and major vessels*” contraindicates their adoption for pathologies with lateral extension to or primarily affecting the paramedian skull base. To fill this gap and following the way showed by EEAs, by using the same technology and adopting the same principles, the superior eyelid endoscopic transorbital approach (SETOA) has becoming very popular among neurosurgeons over the last two decades thanks to its peculiar advantages. Indeed, it allows to deal with

heterogeneous pathologies spreading from the paramedian aspect of anterior skull base up to the petrous apex⁵⁻¹², in isolated or combined manner^{13,14}, in a minimally invasive nature, with minimal or no brain retraction, without crossing plane of cranial nerves and major vessels, with short distance and direct route to the target, small bony defect, satisfactory aesthetic outcome, short hospital stay and rapid patient recovery^{15,16}.

The main drawback is its narrow, and single corridor if compared to the binostril of endoscopic endonasal approach, bounded by the not-expandable bony tissue of the orbital rims superiorly, inferiorly, and laterally, and the vulnerable orbital content, medially, which limit its surgical freedom and angles of attack.

OBJECTIVE

In line with the concept of ideal approach – to provide adequate exposure of the lesion and facilitate its complete and safe resection, through the identification and protection of the adjacent critical neurovascular structures - to improve the maneuverability of the surgical instruments at the entry point and at the surgical target area, and accordingly to provide a better control on the lesions involving the paramedian aspect of the anterior and middle skull base, through better angles of attack and exposure of the adjacent neurovascular structures, we tried to expand, in a minimally invasive fashion, through additional two bony cuts in a “hinge-orbitotomy”, the orbital access of the “standard” SETOA to the middle fossa converting it in its “extended Open-Door” variant. Through an anatomical-morphometric quantitative analysis we compared the horizontal angles of attack between two considered approaches. Finally, we added an illustrative clinical case of a patient affected by cavernous sinus meningioma and treated with the above-cited technique.

MATERIAL AND METHODS

Five adult cadaveric specimens (10 sides), embalmed and injected with red latex for the arteriosus blood vessels, were dissected. All dissections were performed in adherence with regulations governing the use of human cadaveric tissues. No Institutional Review Board was required because this study was performed in deidentified cadaveric specimens.

The SETOA, after the initial step under exoscopic visualization, proceeded with endoscopic assistance. The osteofibrosus flap which converted the “conventional” SETOA into its Extended Open-Door variant, was harvested under exoscopic visualization. Both operative techniques were performed on each side for each specimen; to validate our comparison, the approaches were performed in a sequence from the approach with the least tissue removal (standard SETOA) to the most extensive one (Extended Open-Door).

As previously reported in the pertinent literature¹⁶, the orbital retraction was set at <10 mm. The axial angles of attack were the analyzed and compared between two surgical techniques considered.

Anatomical dissections

- “Standard” Superior Eyelid Transorbital Endoscopic Approach (SETOA)

A SETOA to the petrous apex was performed as previously reported in the pertinent literature¹¹.

A skin incision was placed in a superior eyelid crease, the subperiosteal/periorbital dissection continued within the orbit until to identify the inferior (IOF) and superior orbital fissures (SOF)¹⁷. At this point, the zygomatic body and the intraorbital part of the greater sphenoid wing (GSW) were drilled from the anterior end of the SOF, proximally, until to identify and remove the sagittal crest and to expose the temporal pole

dura mater, distally. Then, an interperiosteal-dural dissection via meningo-orbital band (MOB)¹⁸ was performed to unlock the lateral wall of the CS up to the gasserian ganglion (GG). After cutting middle meningeal artery (MMA), the temporal pole was elevated in extradural fashion, and the exposure of the greater superior petrosal nerve (GSPN) and the petrous apex, completed the dissection procedure (Figure 1).

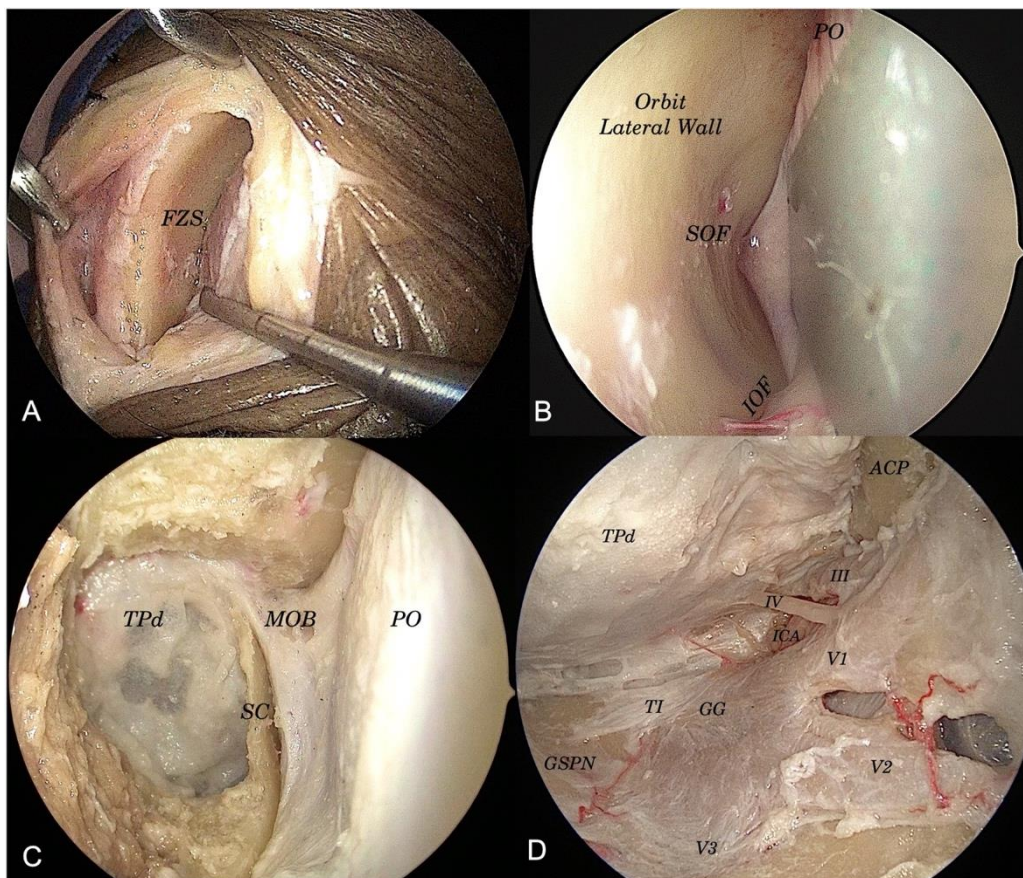


Figure 1. Common steps during “Standard” and “Extended Open-Door” Superior Eyelid Endoscopic Trans-Orbital Approach (SETOA). Right side.

A. Superior eyelid skin incision and identification of the subperiosteum/periorbital plane of dissection within the orbit and the frontozygomatic suture; **B.** Intraorbital subperiosteal dissection with identification of anatomical landmarks; **C.** The drilling of the orbit lateral wall discovers temporal pole dura mater, sagittal crest and meningo-orbital band **D.**

Exposure of the lateral wall of cavernous sinus after interperiosteal-dural dissection via meningo-orbital band. (FZS: Fronto-Zygomatic Suture; SOF: Superior Orbital Fissure; IOF: Inferior Orbital Fissure; TPd: Temporal Pole dura; MOB: Meningo-Orbital Band; SC: Sagittal Crest; PO: Periorbit; ACP: Anterior Clinoid Process; ICA: Internal Carotid Artery; GG: Gasserian Ganglion).

- “Extended Open-door” Superior Eyelid Transorbital Endoscopic Approach

The harvesting of an osteofibrosus flap straddling the frontozygomatic suture and involving the superior and lateral orbital rims, in a hinge-orbitotomy based on the overlying pericranium, converted through three surgical steps, the “standard” SETOA into its “Extended Open-Door” variant (Figures 2).

In detail, the first step involved the widening of the lateral orbital wall removal (Figures 2c and 2f): the drilling of the inner surface of frontal process of the zygomatic bone and the GSW forming the lateral wall of the orbit was extended laterally from the most anterior end of the superior orbital fissure (SOF), until to reach the most anterior insertion of the temporalis muscle at the McCarty keyhole^{19,20} (Figure 2c, superior yellow dotted line), then, it was carried vertically inferiorly following the anterior border of the temporalis muscle up to the level of the inferior orbital fissure (IOF) (Figure 2c, vertical yellow dotted line); finally it was directed medially to reach the most anterior opening of the inferior orbital fissure (Figure 2c, inferior yellow dotted line).

At that point the orbital rim, including the zygomatic process of the frontal bone and the frontal process of the zygomatic bone, was completely freed from the GSW.

The second and third surgical steps involved performing two osteotomies: using a reciprocating saw or a craniotome without the footplate, we placed two cuts on the exposed superior and lateral orbital rims, straddling the

FZS, starting from inside the orbit and preserving the overlying periosteum: the first-one at the level of McCarty keyhole, at the anterior-superior limit of the lateral orbit wall drilling (Figure 2d, 1th cut red dotted line, and Figure 2G), and second-one at the level of anterior opening of the IOF, at anterior-inferior limit of the lateral orbit wall drilling (Figure 2d, 2nd cut red dotted line, and Figure 2G). An additional practical technique for these osteotomies involves first accurately locating the frontozygomatic suture. Once this landmark is identified, a superior cut is made 1 cm above it, and a second cut is placed 1 cm below it, ensuring precision in the osteotomies and minimizing the risk of structural compromise or injury to adjacent tissues.

As the periorbita along the superior and lateral orbital rims is contiguous with the pericranium, the resulted island bone flap is now completely disconnected from the skull bone, but it is retained in situ, in a floating fashion, through the overlying pericranium which acts as hinge allowing to the flap to be dynamically or statically reflected laterally (Figure 2H).

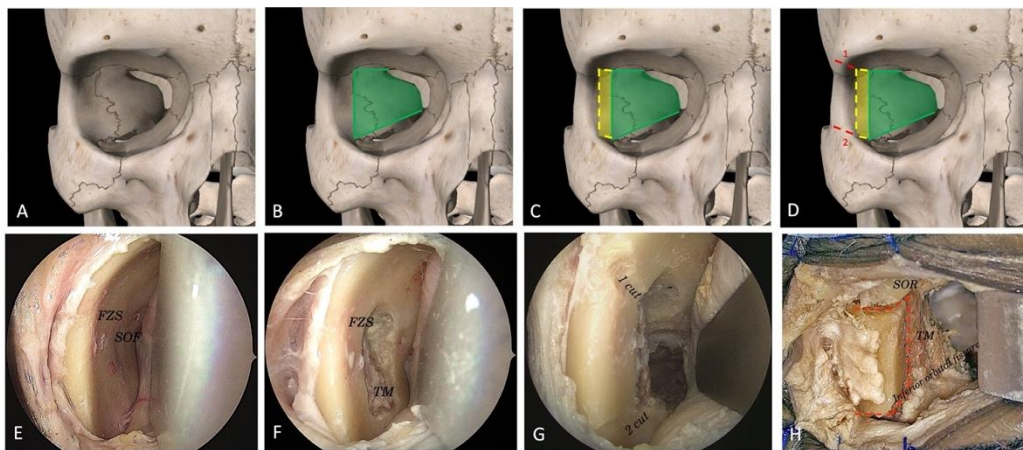


Figure 2. (A-I) Steps converting the “Standard” into the “Extended Open-Door Transorbital Endoscopic (ODETA) Approach. A-D: Schematic draw; E-H: Cadaveric dissection (right side). A) Bony anatomy of the orbit; B) Green lines define the boundaries of the orbit lateral wall drilling during a conventional superior eyelid endoscopic transorbital approach (standard SETOA); C) yellow

dotted lines delimit the further orbit lateral wall drilling during the proposed extended Open-Door superior eyelid endoscopic transorbital approach (first step); **D**) finally, the two red dotted lines (1-2) represent the two bony cuts on the lateral and superior orbit rims, straddling the frontozygomatic suture, realizing an hinge-orbitotomy based of the pericranial flap (second and third steps). **E**. Dissection along the subperiosteum/periorbital plane within the orbit and identification of anatomical landmarks; **F**. The drilling of the orbit lateral wall discovers the inner surface of the temporalis muscle in the homonymous fossa; **G**. Further anterior extension of the orbit lateral wall drilling until to identify the anterior margin of temporalis muscle and performing of two shallow-groove which identify the site of two bony cuts for the supero-lateral orbitotomy. **H**. Hinge orbitotomy based on pericranial flap. The yellow circle delimits the osteo-fibrosus flap. (FZS: Fronto-Zygomatic Suture; SOF: Superior Orbital Fissure; TM: Temporalis Muscle, SOR: Superior Orbital Rim).

Anatomical-Morphometric Quantitative Analysis

- **Axial angles of Attack**

CT scan was performed on each head specimen before dissections and then uploaded on a Medtronic neuronavigation system. Four target points were identified: the tip of anterior clinoid process (ACP), foramen rotundum (FR), foramen ovale (FO) and the lateral margin of the trigeminal impression (TI). The angles of attack on the axial plane were measured by fixing the distal tip of the probe on the anatomical target and moving the proximal end of the probe at the orbital content (1 cm retracted), medially, and, at the frontozygomatic suture on the orbital rim, laterally, for the standard SETOA. The lateral boundary of the axial angles for the extended open-door approach was the maximum lateral reflection of the harvested osteofibrosus flap without injury of the pericranium and temporalis muscle detachment. These measurements were obtained while positioning the endoscope at 12 hours in the surgical field providing a full view of the target and confirmed on the specimen CT scan appearing on the neuronavigation system monitor (Figure 3).

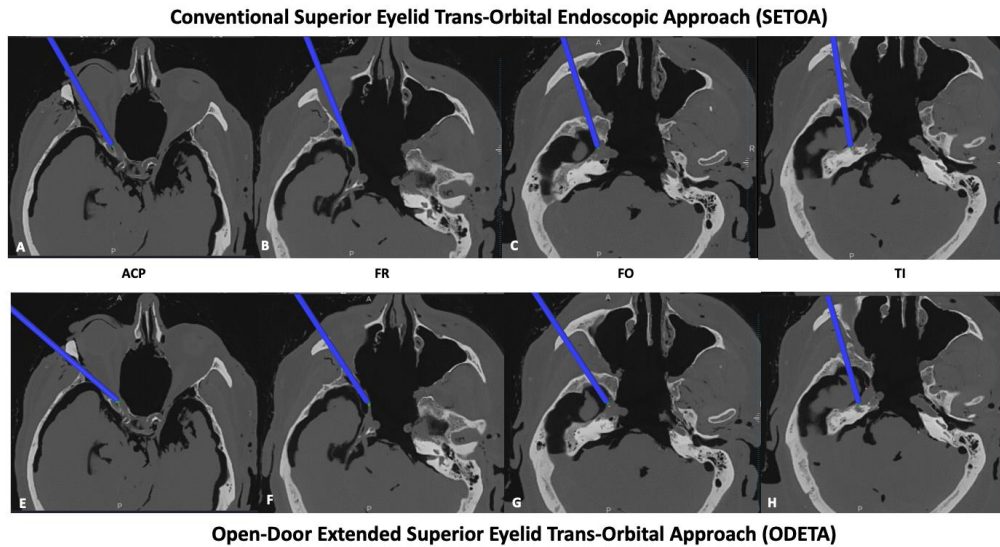


Figure 3. Neuro-navigated CT scan: axial images of horizontal angles of attack provided by “standard” superior eyelid trans-orbital approach in addressing the tip of anterior clinoid process (A), the foramen rotundum (B), the foramen ovale (C) and trigeminal impression (D); axial images of horizontal angles of attack provided by “Extended Open-Door” superior eyelid trans-orbital approach in addressing the tip of anterior clinoid process (E), the foramen rotundum (F), the foramen ovale (G) and trigeminal impression (H). (ACP: Anterior Clinoid Process; FR: Foramen Rotundum; FO: Foramen Ovale; TI: Trigeminal Impression).

Statistical analysis

The data of axial angles of attack related to ACP tip, FR, FO and most lateral part of TI resulting from standard transorbital approach and from its extended conservative variant were compared using student *t* test; *p* values < 0,05 were considered statistically significant.

RESULTS

- Axial angles of Attack

The angles of attack on axial plane for each of the considered target were wider in the Extended Open-Door technique than in the conventional transorbital approach. In details, the angles described by the conventional SETOA were $11,05 \pm 1,81^\circ$, $10,82 \pm 1,65^\circ$, $7,14 \pm 1,43^\circ$ and $6,23 \pm 1,32^\circ$ in addressing the ACP, the FR, FO and TI, respectively, versus $37,73 \pm 2,42^\circ$, $40,32 \pm 2,89^\circ$, $27 \pm 2,12^\circ$ and $23,67 \pm 2,23^\circ$ provided by the extended open-door variant to the same targets, respectively.

The addition of the superolateral hinge-orbitotomy to the conventional endoscopic transorbital approach allowed us to gain $26,68 \pm 1,31^\circ$ in addressing the ACP ($p < 0.001$), $29,50 \pm 2,46^\circ$ in addressing the FR ($p < 0.001$), $19,86 \pm 1,98^\circ$ in addressing the FO ($p < 0.001$), and $17,44 \pm 2,21^\circ$ in addressing the lateral aspect of the TI ($p < 0.001$).

These data are showed in Figure 3 and summarized in Table 1.

Table 1. Comparison of the widening of the horizontal angle of attack in a “standard” SETOA and “extended open-door” SETOA (ODETA)

Anatomical target	Horizontal angle of attack (degrees) Standard SETOA	Horizontal angle of attack (degrees) ODETA	Gain angle (degrees)	Statistical significance (P value)
ACP	$11,05 \pm 1,81$	$37,73 \pm 2,42$	$26,68 \pm 1,31$	$p < 0.001$
FR	$10,82 \pm 1,65$	$40,32 \pm 2,89$	$29,50 \pm 2,46$	$p < 0.001$
FO	$7,14 \pm 1,43$	$27 \pm 2,12$	$19,86 \pm 1,98$	$p < 0.001$
TI	$6,23 \pm 1,32$	$23,67 \pm 2,23$	$17,44 \pm 2,21$	$p < 0.001$

ACP: Anterior Clinoid Process; FR: Foramen Rotundum; FO: Foramen Ovale; TI: Trigeminal Impression; SETOA: Superior Eyelid Transorbital Approach

- Illustrative Case

A 65-years-old female complaining six months history of diplopia on the left lateral gaze and hypoesthesia involving the sensory distribution of maxillary branch of left trigeminal nerve, was observed.

On admission, neurologic examination, including comprehensive assessment of ocular motility, visual acuity and facial sensory changes, revealed moderate deficit of the abducens nerve and mild proptosis in the left eye, while no deficit of visual acuity was detected. A Contrast-enhanced magnetic resonance imaging (MRI) of the brain (Figure 4B-C) showed a lesion, with homogeneous contrast-enhancement, arising from dura forming lateral wall of left cavernous sinus with permeative pattern of growth, characterized by lateral extension and infiltration of dura propria of mesial surface of ipsilateral temporal pole and consequent compression on cerebral parenchyma, and medial extension into cavernous sinus where displaced medially the internal carotid artery. The head CT scan (Figure 4A) detected mild hyperostosis of intracranial surface of left greater sphenoid wing and the area around foramen rotundum. The patient was observed at 6 and 12 months, during which MRI monitoring revealed a slight increase in the volume of the lesion. Because of the radiologic progression of the lesion, surgical strategy was offered to the patient, with the aim to prevent/arrest worsening of clinical symptoms.

Patient underwent Extended Open-Door SETOA to middle fossa, with the aim of debulking of extra-cavernous component of the lesion, through the intradural exposure of dura propria covering the mesial surface of temporal pole and forming the outer layer of cavernous sinus lateral wall, intentionally without entering the neurovascular compartment of CS to mitigate the risk of postoperative cranial nerves deficits. Of paramount importance, the gain angle on axial plain provided by hinge-orbitotomy allowed for the removal, with an optimal angle of attack and slight orbital

retraction, of the most anterior and medial extracavernous component of lesion, that was hidden by the posterior content of orbit. This approach enabled the achievement of the planned goal. The operative time was 2 hours and 38 minutes. Postoperative course was uneventful. The diagnosis was in favor of cavernous sinus meningioma WHO grade 1 and patient was addressed to adjuvant radiation treatment of the residual lesion.

Clinical follow-up at 1 month after surgery, revealed improvement of diplopia and unchanged V2-hypoesthesia.

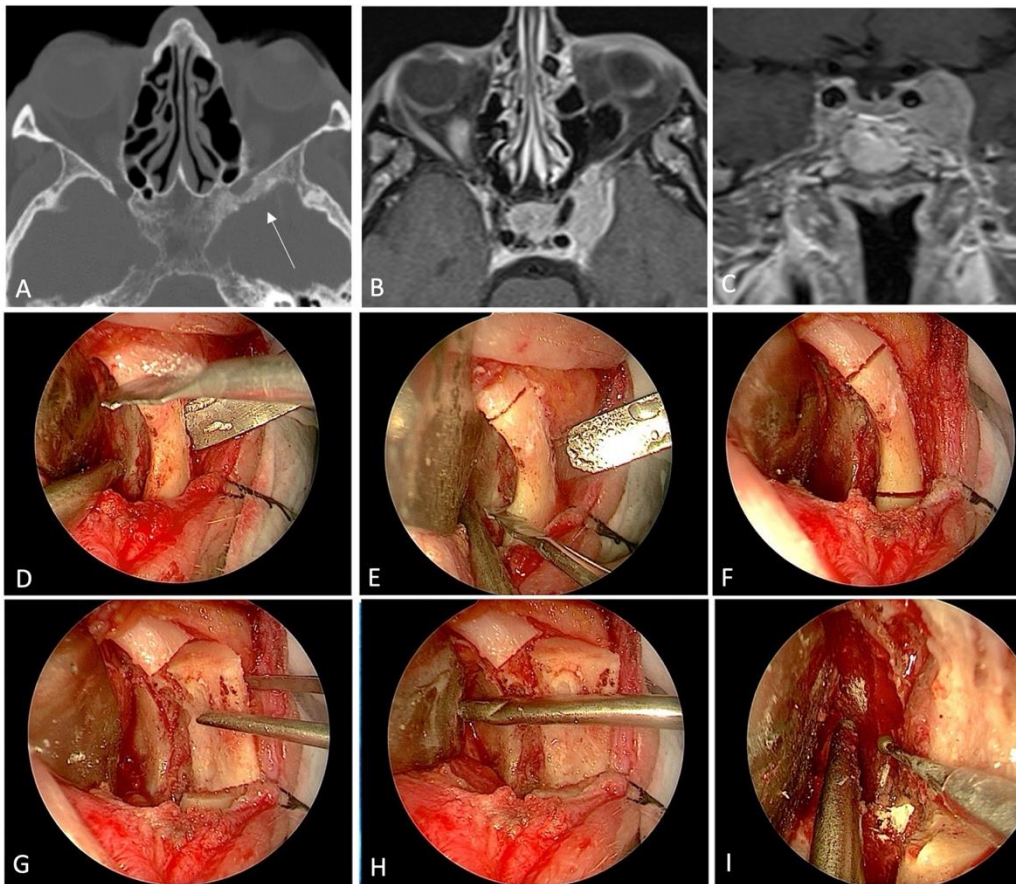


Figure 4. A) Head CT scan, axial sequence, bone window. Mild hyperostosis with remodeling of cancellous bone of intracranial surface of left greater sphenoid wing forming the lateral wall of orbit (white arrow), with involvement of foramen rotundum; **B-C) Contrast-enhanced Magnetic Resonance Imaging**

of brain, T1-weighted axial (B) and coronal (C) sequences. Lesion with homogeneous contrast-enhancement arising from dura forming lateral wall of left cavernous sinus, which exhibits permeative growth pattern, with medial extension in the cavernous sinus where displaces medially the internal carotid artery, and lateral extension into intradural space of medial surface of temporal lobe; **D-I) Intraoperative surgical steps to harvest the osteofibrosus flap of the hinge-orbitotomy of ODETA (left side):** **D)** Most anterior part of orbital lateral wall has been drilled; exposure of supero-lateral orbital rim and positioning piezoelectric device in correspondence of the first cut; **E)** First bony cut performed and positioning piezoelectric device in correspondence of the second cut; **F)** All three steps (drilling of anterior part of lateral orbital wall and two bony cuts) to perform hinge-orbitotomy have been performed; the two fixation points used to locate the holes for subsequent suturing of the bone flap are also showed; **G-H)** Osteofibrosus flap of hinge-orbitotomy is laterally displaced; **I)** Surgical procedure is completed by drilling most deep part of lateral wall and sagittal crest removal.

DISCUSSION

The origin and development of the transorbital approach date back to 150 years ago and it has been adopted throughout the 20th century in several surgical fields²¹. Firstly it was limited to the treatment of intraorbital pathologies, with a German ophthalmologist Hermann Knapp²² who, in 1874, described the anterior orbitotomy for an optic sheath carcinoma through superior eyelid or eyebrow incision. In 1889 a Swiss neurosurgeon, Rudolf Krönlein²³, described the lateral orbitotomy for resection of orbital dermoid cysts. Neurosurgeons initially questioned the benefit of the purely transorbital approach as corridor to the intracranial space, given its narrow entry area, crudeness of instrumentation, poor visualization and magnification; however, given the anatomic relationship between the orbital cavity and the intracranial space, the incorporation of the orbit into transcranial approach, as orbito-cranial and cranio-orbital approaches, has been a natural evolution. Therefore, in 1937 Amarro Fiamberti²⁴, an Italian psychiatrist was the first to address intracranial lesion via transorbital corridor performing a prefrontal lobotomy; this procedure, was then popularized by Walter Freeman²⁵. Starting from 1970s, with the introduction and development of technology, including operating microscope and micro-instrumentation, the orbit was incorporated into different neurosurgical approaches to the skull base like the orbito-zygomatic and variations.

The last two decades witnessed a renewed and growing interest in the transorbital surgical corridor among the neurosurgical community because of its incorporation into endoscopic skull base surgery. The original concept behind endoscopic transorbital surgery was to overcome the limitations presented by endonasal skull base surgery, represented by its inability to reach the paramedian aspect of anterior and middle cranial fossae, achieving equal visibility, and in turn, decrease the overall

invasiveness and complications associated with open skull base surgery. In this scenario, since the introduction of the TONES (Trans-Orbital Neuro-Endoscopic Surgery) concept by Moe et al.¹⁶ in 2010, the neurosurgical indications of superior eyelid endoscopic transorbital approach for intracranial neurosurgical pathologies are rapidly increasing^{5,6,12} (Figure 5).

• Aneurysm clipping
• Angiofibroma (juvenile nasopharyngeal)
• Carcinoma (sebaceous gland, squamous cell, adenoid cystic)
• Cavernous sinus thrombosis
• Chondrosarcoma
• Craniopharyngioma
• CSF leak
• Dermoid
• Epidural abscess, brain abscess
• Epilepsy (mesial temporal lobe)
• Epistaxis
• Fibrous dysplasia
• Foreign body removal
• Fracture frontal bone, frontal sinus
• Gliosis, glioblastoma
• Hemangioma, cavernous
• Hematoma epidural, subdural
• Infection (orbital abscess, frontal abscess, frontal sinusitis, epidural abscess, brain abscess)
• Lymphatic malformation
• Meningocele, meningoencephalocele, meningioma
• Metastatic osteosarcoma, olfactory neuroblastoma, clear cell renal carcinoma
• Mucocele, mucopyocele (frontal lobe, orbitofrontal)
• Orbit decompression
• Orbital apex syndrome
• Olfactory neuroblastoma
• Optic nerve decompression
• Osteoma, osteosarcoma, osteoblastoma
• Paget disease
• Peripheral nerve sheath tumor (benign, malignant)
• Pituitary adenoma
• Plasmacytoma
• Pseudotumor
• Schwannoma (benign, malignant)
• Seizure (mesial temporal lobe)
• Tension pneumocephalus
• Teratoma

Figure 5. Pathology addressed through TONES.

One of the main drawbacks is its narrow surgical corridor defined by the vulnerable orbital content, medially, and the un-expandable bony tissue of the orbital rims superiorly, laterally and inferiorly, which limit the angles of attack, particularly in addressing lesions involving median and paramedian anterior and middle skull base.

To overcome this limit, bi-portal approaches have been proposed, both bilateral transorbital and unilateral transorbital combined with trans-nasal, according to the surgical target area^{13,26-28}.

Nevertheless, although there is agreement regarding the peculiar advantages resulting from SETOA^{15,16}, there is not unanimous consent about the potential benefits provided by the addition of superolateral orbital rim osteotomy^{16,27,29-33}.

Previously, Noiphithak et al²⁹. have already addressed this issue, concluding that the orbitotomy resulted in wider exposure area at entry site and surgical freedom, more favorable horizontal angles of attack, whereas no difference there was in terms of widening of exposure area of the surgical target and vertical angles of attack. Conversely from our study, these authors positioned the skin incision on the lateral canthus, they dissected the insertion of the temporalis muscle from the superolateral orbital rim and the greater sphenoid wing, they limited the osteotomy between the frontozygomatic suture and the zygoma, and finally, they removed the bone flap.

More recently, Lim et al³⁴. demonstrated a significant improvement of horizontal and vertical angles of attack and of the surgical freedom, resulting from the addition of superior-lateral orbital rim osteotomy to the transorbital endoscopic approach. Also this study considerably differs from our “open-door technique”, indeed, in that case the authors placed a different skin incision “below-the-eyebrow” and then created a large free one-piece bone flap including part of the orbital roof.

In our study, through several key technical nuances, we obtained comparable surgical advantages but with potentially lesser risk of postoperative comorbidities while creating an enhanced visualization and working corridor. First, by placing the skin incision in a superior eyelid crease, we avoided the potential risk of injury of the frontalis branch of the facial nerve and we hid the scar in a natural wrinkle. Next, by leveraging the skin elasticity (in a real patient better than in the cadaveric specimen) the eyelid incision allowed to expose the superior orbital rim up to the supraorbital notch and the lateral orbital rim inferiorly up to the origin of the root of zygoma, so to allow us to extend the orbitotomy and accordingly also gaining instruments' maneuverability in the vertical plane. In this plane, considering the "clock model" provided by Paluzzi et al³⁵, the orbital area accessed through the open-door of hinge-orbitotomy is from 8 to 10 o' clock, which becomes comparable to the same area resulting from the lateral micro-orbitotomy³⁵. Additional advantages to traditional skull base approaches, include: i) we preserved the temporalis muscle attachment to the bone, avoiding the risk of atrophy and bleeding; ii) we preserved the periosteum attached to the orbital rims, so to preserve the vascularization of the flap, theoretically decreasing the rate of bone infection and facilitating its secure to the skull at the end of the procedure. The blood supply for the outer surface of the upper rim of the orbit and the calvaria is mainly represented by tiny perforators from the overlying periosteum. The vascular interconnections within the periosteum are poorly developed. For this reason, the galea and overlying vascular network should be left broadly attached to the bone when transferring a vascularized calvaria bone flap or a lateral part of the orbit. We consider that all these maneuvers are positive prognostic factors for better functional and aesthetic outcomes (Table 2).

Table 2. Main surgical, functional and aesthetic advantages and limits of open-door “extended” SETOA (ODETA) compared to the “standard” SETOA and Lateral Orbitotomy.

ODETA						
Approach	Surgical Procedure		Functional Outcome		Aesthetic Outcome	
	Pro	Cons	Pro	Cons	Pro	Cons
Vs Standard SETOA	Increased horizontal angles of attack.	Need for bone reconstruction	Decreased orbital content retraction.	---	---	---
Vs Lateral Orbitotomy	---	- Slightly minor horizontal angles of attack (thickness of bone or orbital rim)	- No risk of temporalis muscle atrophy. - No risk of facial nerve frontalis branch injury	---	- Scar hidden in a natural eyelid wrinkle. - Decreased risk of bone flap infection. - Easier reconstruction	---

SETOA: Superior Eyelid Transorbital Approach; ODETA: Open Door Extended Transorbital Approach

In term of surgical advantages provided, the hinge-orbitotomy allowed us to considerably expand laterally the surgical entry site, in dynamic or static way, depending if the harvested osteofibrosus flap was left free to reflect on the horizontal plane based on the pericranial hinge, according to the instruments' movement, or if it was fixed under a retractor, respectively (Figure 6).

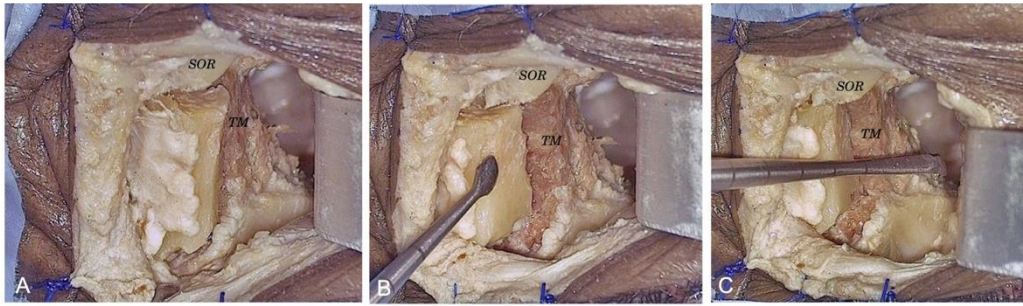


Figure 6. A) Osteofibrosus flap has been harvested in a hinge-orbitotomy; B) Lateral displacement of the osteofibrosus flap; C) demonstration of the increased lateral-to-medial trajectory of the surgical instrument after dynamic lateral displacement of the harvested osteoplastic flap (TM: Temporalis Muscle; SOR: Superior Orbital Rim).

This area is wider in comparison to that one resulting from standard endoscopic transorbital approach, while is narrower compared to that one resulting from lateral orbitotomy with removal of the bone flap just for the osteofibrosus flap thickness left in situ. The expansion of the access door resulted in wider angles of attack (Figure 7).

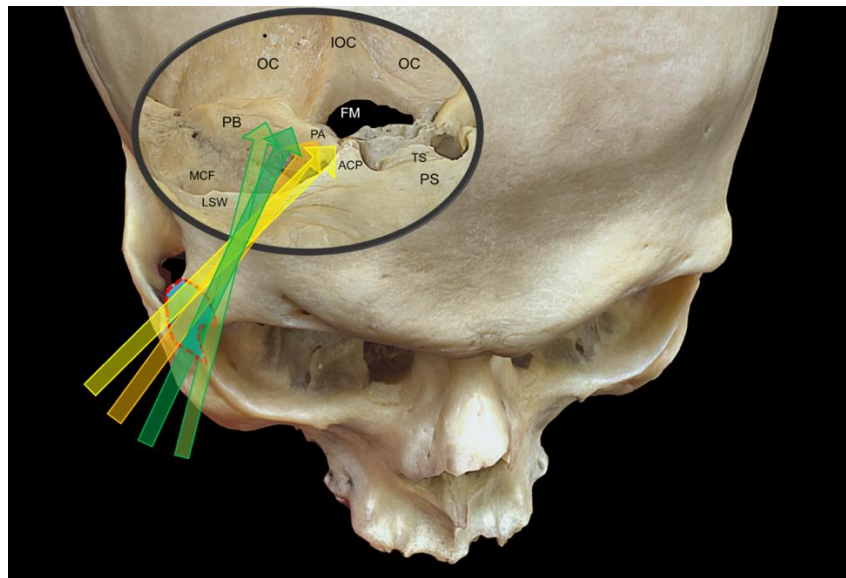


Figure 7. 3D skull reconstruction. Multiple vectors (colored arrows) representing the multiple surgical trajectories gained in the axial plane

addressing the paramedian anterior and middle skull base after performing the hinge-orbitotomy of extended open-door technique (OC: Occipital Condyle; IOC: Internal Occipital Crest; PB: Petrous Bone; MCF: Middle Cranial Fossa; LSW: Lesser Sphenoid Wing, PA: Petrous Apex; ACP: Anterior Clinoid Process; TS: Tuberculum Sellae; PS: Planum Sphenoidale; FM: Foramen Magnum).

Furthermore, the open-door technique should not be viewed solely as a definitive method to enhance the angle of attack. In cases where it is necessary, the bone can be perfectly dissected from the temporal muscle, converting the technique into a standard lateral orbitotomy. Our recommendation is to approach the lateral orbitotomy in a graded manner, considering the open-door method as the initial step. This adaptability allows for the customization of the surgical approach based on the specific needs presented by the pathology and the individual patient's anatomy.

The more lateral-to-medial trajectories in the axial plane provided by hinge-orbitotomy, along operative corridors almost parallel to the primary anterior-posterior conical vector of the orbit, are mainly favorable for management of lesions affecting the parasellar region, including the anterior clinoidal region (i.e. spheno-orbital or clinoidal meningiomas), cavernous sinus (infectious or neoplastic diseases), Meckel's cave (i.e. trigeminal schwannomas), and petrous apex, in addition to the lateral extraconal ones^{6,34}. As witnessed by results of the present study, the main benefits are obtained in addressing lesions involving the anterior clinoid process, the most anterior compartment of cavernous sinus and/or foramen rotundum – like for the patient described – where the lateral orbital rim left in situ limits the angle of attack and orbital content obscures the retroorbital area.

At last, but not least, the extended open-door technique allowed avoiding the excessive medial retraction of the orbit content, thereby decreasing

occurrence risk of ophthalmic complications^{15,36} related to intraocular and/or intraorbital pressure increase during surgery and which can lead in extreme hypothesis to the irreversible vision loss due to hypoperfusion of critical neural structures³⁶. This aspect becomes particularly important when you deal with patients with already high intraorbital pressure, like Grave's orbitopathy or glaucoma, where its further increase might be very dangerous. In a cadaveric study³⁶ it was registered an abrupt rise of the intraocular pressure for orbit content retraction higher than 1.5 cm; that is why we used 1 cm as limit of orbit content retraction.

In contrast to the benefits, the main drawback of an excessive lateral orbital wall removal and orbitotomy is represented by the enophthalmos occurrence risk¹⁵. To prevent it, the reconstruction of the bony defect follows the same principles adopted for the conventional SETOA¹⁵. In addition, when the laterally retracted osteo-fibrosus flap is released, the potential venous oozing will be identified from the temporalis muscle and the inner table as well as from the diploic veins of the flap edges and meticulous hemostasis will be performed to avoid postoperative hematomas.

The bone flap can be easily secured to the calvaria using low-profile titanium miniplates and screws to achieve anatomical re-approximation of the orbital rim. However, in some cases, patients may be sensitive to the presence of miniplates in such a subtle and delicate skin region. Our technique offers a unique advantage in this regard. Since the bone flap remains attached to the temporalis muscle, it requires only minimal fixation, which can be adeptly achieved using just two non-absorbable sutures, whose fixation points are showed in Figure 4F. This method contrasts with a standard lateral orbitotomy, where the bone is completely disconnected from the temporalis muscle, necessitating the use of miniplates for secure reattachment in most cases. The suturing method in our approach not only minimizes the palpability and discomfort for the

patient but also leverages the inherent stability provided by the temporalis muscle attachment, resulting in a robust reconstruction with enhanced patient comfort.

Finally, to note that we performed the hinge-orbitotomy with exoscope-assistance to increase illumination and visualization of surgical field, nevertheless, since the maneuvers to harvest the osteofibrosus flap involve superficial anatomical structures, this technique can be also performed under macroscopic or microscopic visualization.

Extended Open-Door Superior Eyelid Endoscopic Trans-Orbital approach represents, in our opinion, a practical compromise between the microsurgical orbito-cranial approaches and the conventional transorbital endoscopic approach, for selected lesions affecting the paramedian anterior and middle skull base, providing the peculiar benefits resulting from both surgical routes: the intrinsic advantages of minimally invasive endoscopic surgery – “eyes of the surgeon close to the surgical field”, augmented magnification and illumination, lesser aesthetic disfigurement and bone removal, short and direct route, avoiding manipulation of neurovascular structures – and the major surgical freedom and multiple angles of attack allowing better control on the lesion as for transcranial approaches.

CONCLUSIONS

The Hinge-Orbitotomy technique provides an expansion of the transorbital corridor, with considerable increase of axial angles of attack, whilst reducing the orbital content retraction, retaining the bone flap in situ, in a “floating” or “hinged” fashion.

This technique preserves the vascularization of the bone flap while decreasing the potential risk of bone infection and improves bone union with the calvaria. The osteoplastic modified SETOA craniotomy is straightforward to perform and enhances the exposure of the skull base. Moreover, the vascularized osteofibrosus flap can be easily secured to the calvaria allowing anatomical re-approximation of the orbital rims and offer excellent long-term functional and cosmetic results.

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