One Piece Orbitozygomatic Approach Based on the Sphenoid Ridge Keyhole: Anatomical Study

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J Neurol Surg B 2016;77:199–206.

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Abstract

The one-piece orbitozygomatic (OZ) approach is traditionally based on the McCarty keyhole. Here, we present the use of the sphenoid ridge keyhole and its possible advantages as a keyhole for the one-piece OZ approach. Using transillumination technique the osteology of the sphenoid ridge was examined on 20 anatomical dry skull specimens. The results were applied to one-piece OZ approaches performed on freshly frozen cadaver heads. We defined the center of the sphenoid ridge keyhole as a superficial projection on the lateral skull surface of the most anterior and thickest part of the sphenoid ridge. It was located 22 mm (standard deviation [SD], 0.22 mm) from the superior temporal line; 10.7 mm (SD, 0.08 mm) posterior and 7.1 mm (SD, 0.22 mm) inferior to the frontozygomatic suture. The sphenoid ridge burr hole provides exposure of frontal, temporal dura as well as periorbita, which is essential for the later bone cuts. There is direct access to removal of the thickest (sphenoidal) part of the orbital roof, after which the paper-thin (frontal) part of the orbital roof is easily fractured. The sphenoid ridge is an easily identifiable landmark on the lateral skull surface, located below the usual placement of the McCarty keyhole, with comparative exposure.

Keywords

- cranial base surgery
- orbitozygomatic approach
- osteotomy
- skull base surgery
- sphenoid ridge
- McCarty keyhole

Introduction

Orbitozygomatic approach is considered the “workhorse” of anterolateral skull base surgery. It is designed to lessen brain retraction, lower the caudal extent of the surgeon’s line of sight, and permit further superior (rostral) visualization than is possible via the standard pterional approach.^{1–20} An addition of orbitozygomatic osteotomy to the standard frontotemporal craniotomy allows greater exposure to neoplastic and vascular lesions of the anterior fossa, middle fossae, and the upper segment of the posterior fossa, infratemporal fossa, petrous apex, and tentorial incisura.^{1–6,8,9,14–18} With the removal of the sphenoid wing and lateral squamous temporal bone, the orbitozygomatic approach provides a wider opening of the Sylvian fissure by creating a lateral space in which to retract the temporal lobe.^{1–3,5,8,10,12–16,19,21,22}

As early as 1912, McArthur²³ and Frazier²⁴ recognized the advantage of resecting the supraorbital rim and orbital

roof while approaching the pituitary gland. In 1975, Yasargil et al²⁵ reported removing the superior orbital rim and the orbital roof to approach an AComA aneurysm in the presence of a pronounced upward extension of the orbital roof. In the mid-1980s, Pellerin et al and Hakuba et al introduced the two-piece frontotemporal-orbitozygomatic approach to the neurosurgeon’s armamentarium.^{26,27} In 1982 Jane et al²⁸ and Al-Mefty et al²⁹ introduced the use of the one-piece orbitozygomatic approach in what they called the “supraorbital approach.” Since then a variety of similar modified neurosurgical approaches have been reported.^{1–5,8,11,12,15–17,20,22,30,31}

Precise and accurate placement of the initial keyhole is the most important factor in the appropriate and efficient execution of these extended craniotomies. Traditionally, these approaches have been based on the McCarty keyhole.^{1,2,14,28,29,31,32} Previous studies attempted to localize the best positioning of this entry burr hole,^{1,31,32} but most

received
March 30, 2015
accepted
July 28, 2015
published online
October 8, 2015

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Stuttgart · New York

DOI <http://dx.doi.org/10.1055/s-0035-1564590>.
ISSN 2193-6331.

of them have used superficial landmarks that are not always visible or consistent on older crania (e.g., frontosphenoid, sphenozygomatic, frontozygomatic sutures, etc.).

As an alternative, the sphenoid ridge is an easily identifiable landmark on the lateral skull surface, located below the usual placement of the McCarty keyhole. The sphenoid ridge represents a natural osseous border between frontal dura, temporal dura, and periorbita, all of which must be exposed to execute the one-piece OZ approach.

The present study is conducted to examine the topography of the sphenoid ridge and the possible advantage of its usage for a burr hole for the one-piece OZ approach.

Material and Methods

The left and right frontotemporal regions of 20 dry skulls (40 sides) were studied by transillumination technique from a powerful light source. The boundaries of the sphenoid ridge were outlined and measured. The distances from the center of the keyhole to the following landmarks were measured: superior temporal line, pterion, frontozygomatic suture, zygomatic arch. The data was processed with a software spreadsheet (Microsoft Office Excel 2003; Microsoft Corp., Redmond, WA). The osteology of the region was examined on anatomical dry skull specimens provided by the Institute of Anatomy, the Panum Institute, and the University of Copenhagen. The results were applied to OZ approaches performed on freshly frozen cadaver heads.

Results

Osteology of the Sphenoid Ridge

The sphenoid ridge is a thick osseous border between the anterior and middle cranial fossae. On the internal side of the skull the sphenoid ridge represents a lateral extension of the posterior aspect of the lesser sphenoid wing and together with the greater sphenoid wing and frontal and zygomatic bones, the ridge forms the lateral orbital wall.³³ It comprises the thickest part of the orbital roof (sphenoidal component). Anteriorly, the lesser sphenoid wing participates in forming the superior aspect of the superior orbital fissure, part of the floor of the anterior cranial fossa, the anterior border of the middle cranial fossa and contributes medially to the formation of the anterior clinoid process. On the external skull surface (in the temporal fossa) the sphenoid ridge projects over the greater sphenoid wing. Laterally, the sphenoid ridge approximates the pterion at the sphenosquamosal suture, with this region referred as the anterior Sylvian point.^{34,35} The sphenoid ridge represents a natural osseous crossroad between frontal lobe, temporal lobe, and periorbita anteriorly (►Fig. 1).

Traditionally, the Sylvian fissure and sphenoid ridge are identified on the outer skull surface according to the following measurements—a line (Sylvian line) that extends backward from the frontozygomatic point across the lateral surface of the head to the three-quarter point (75% of the distance between the nasion and the inion on the midline).³⁴ On the outer skull surface following the main axis of the

Sylvian line (corresponding to the sphenoid ridge) there is a bony depression, which is easily defined during surgery in this area.³⁶ Following the sphenoid ridge anteriorly to posteriorly it becomes gradually thinner. Conversely, following the sphenoid ridge from posterior to anterior toward the superior orbital fissure it becomes gradually thicker, forming part of the floor of the anterior cranial fossa, anterior border of the middle cranial fossa, and the lateral wall of the orbit.

Using skull transillumination technique, we defined the superficial projection on the lateral skull surface of the most anterior and thickest part of the sphenoid ridge as the center of the sphenoid ridge keyhole (►Fig. 2).

The distance from the center of the sphenoid ridge keyhole to the following structures were measured (►Fig. 2A): (1) superior temporal line (direct distance)—22 mm (SD, 0.22 mm); (2) anterior to the pterion (which approximates the lateral end of the sphenoid ridge)—25 mm (SD, 0.44 mm); (3) the center of the keyhole is situated 10.7 mm (SD, 0.08 mm) posterior and 7.1 mm (SD, 0.22 mm) inferior to the frontozygomatic suture; (4) 5 mm posterior and 25.1 mm (SD, 0.23 mm) superior from the angle of the zygomatic arch and zygomatic bone.

The thickest part of the sphenoid ridge on the lateral skull surface, observed during the skull transillumination technique, forms a triangular area with the broad base toward the orbit. If the bone is drilled across the tip of the triangle, the frontal dura will be exposed superiorly and the temporal dura inferiorly, separated by the sphenoid ridge. If the drilling is continued anteriorly following the sphenoid ridge toward the base of the triangle, it leads to the orbit. Thus, the basic anatomical compartments which must be exposed to perform the one-piece OZ approach are revealed by drilling the boundaries of the sphenoid ridge keyhole (►Fig. 2 B).

Orbitozygomatic Approach Based on the Sphenoid Ridge Keyhole: Basic Steps

Soft Tissue Dissection

The skin incision starts just in front of the tragus, extends superiorly to the superior temporal crest, then curves anteriorly, crossing the midline. The incision is kept behind the hairline for its entire course. A longer skin incision, which may be less desirable for cosmetic reasons will allow less retraction of the flap and reduce the risk of retraction-induced injury to the frontotemporal branch of the facial nerve (FTBFN).^{37–41} The scalp is elevated in two layers—galea is separated from the pericranium in the loose areolar tissue plane above superior-temporal line preserving a frontal vascularized pericranial flap, which could be used for obliteration of frontal sinus, or potential duraplasty at the end of the procedure to prevent cerebrospinal fluid leaks. It is preferable to harvest the pericranial flap at the beginning of the operation, with the possibility to tailor the length of the flap, than to attempting to separate it from the skin flap at the end of the surgery.^{3,8} To expose the zygomatic arch and the lateral orbital rim, care must be taken to preserve the FTBFN, either by interfascial^{3,39–41} or subfascial dissections.^{20,37,38} This nerve crosses the zygomatic arch approximately 2 cm

Fig. 1 Osteology of the sphenoid ridge-posterior (A) and superior view (B) of the sphenoid bone. The sphenoid ridge is a thick osseous border between anterior and middle cranial fossae. It represents a lateral extension of the posterior aspect of the lesser sphenoid wing and together with the greater sphenoid wing, frontal and zygomatic bones forms the lateral orbital wall. It composes the thickest part of the orbital roof (sphenoidal component of the orbital roof). Anteriorly the lesser sphenoid wing participates in forming the superior aspect of the superior orbital fissure, part of the floor of the anterior cranial fossa, anterior border of the middle cranial fossa, and medially participates in the formation of the anterior clinoid process. Laterally the lesser sphenoid wing approximates the pterion at the sphenosquamosal suture, with this region referred as the anterior Sylvian point. (C) Cadaveric dissection. Right temporal region representing a close up view of the sphenoid ridge and neighboring anatomical compartments. The bone above and below the sphenoid ridge is removed using a high-speed drill. Drilling is continued anteriorly following the sphenoid ridge toward the periorbital. The frontal temporal dura as well as periorbital are revealed. The sphenoid ridge represents a natural osseous cross-road between the frontal and temporal lobes as well as the periorbital anteriorly, which are key anatomical compartments needed to be exposed for the one piece orbitozygomatic approach. Superior and anterior the sphenoid ridge takes part in the formation of the orbital roof. ACP, anterior clinoid process.

anterior to the tragus and within 1 cm or less of the frontal branch of the superficial temporal artery; therefore, this artery can be used as a landmark to guide subfascial or interfascial dissections.³⁸

After exposure of the zygomatic arch and the lateral orbital rim by one of the techniques above, proper subperiosteal dissection is another important step in FTBFN preservation. The subperiosteal dissection allows anteroinferior reflection of the skin flap to facilitate zygomatic and

orbital bony cuts with minimal retraction and stretch of the FTBFN.¹

The temporalis fascia and muscle is cut in the direction of the skin incision from the root of the zygoma to the superior temporal line. A myofascial cuff is left on the superior temporal line, which is used for later closure and muscle reapproximation.^{20,38,42} A sharp periosteal elevator is used to dissect the temporalis muscle from the bone starting at the root of the zygoma to the superior temporal line in a

Fig. 2 (A) Transillumination technique used to identify the projections of the sphenoid ridge. The center of the sphenoid ridge keyhole is defined as the superficial projection on the lateral skull surface of the most anterior and thickest part of the sphenoid ridge observed during skull transillumination technique. The distance from the center of the sphenoid ridge keyhole to the following structures is measured: (a) Superior temporal line (direct distance)—22 mm (SD, 0.22 mm); (b) anterior to the pterion (which approximates the lateral end of the sphenoid ridge)—25 mm (SD, 0.44 mm); (c) the center of the keyhole is situated 10.7 mm (SD, 0.08 mm) posterior and 7.1 mm (SD, 0.22 mm) inferior to the frontozygomatic suture; (d) 5 mm posterior and 25.1 mm (SD, 0.23 mm) superior from the angle of the zygomatic arch and zygoma. The thickest part of the sphenoid ridge on the lateral skull surface, observed during skull transillumination technique, forms a triangular area with the broad base toward the orbit. If the bone is drilled across the tip this triangle superiorly the frontal dura will be exposed and inferiorly the temporal dura, respectively, separated by the sphenoid ridge. If the drilling is continued anteriorly following the sphenoid ridge toward the base of the triangle it reveals to the orbit. (B) Cadaver dissection of the sphenoid ridge keyhole. A close up view of the right temporal region. The temporalis muscle is reflected inferiorly. The sphenoid ridge keyhole is drilled revealing the frontal, temporal dura as well as the periorbital. SD, standard deviation.

retrograde fashion as described by Oikawa et al^{1,43} and continued anteriorly to the lateral orbital rim and inferiorly to the infratemporal fossa. The muscle is detached also from the zygomatic arch, fully mobilized, and retracted posteriorly, away from the skin flap.

Along the supraorbital rim, the periorbita is contiguous with the pericranium. It is firmly attached at the supraorbital foramen/notch and the frontozygomatic suture, but can be easily lifted between these two locations. The periorbita is bluntly dissected from the bone, starting at the lateral orbital rim and continuing along the superior orbital rim medially to the supraorbital notch. The supraorbital nerve is freed from the supraorbital notch or foramen and is reflected with the periorbita. In the case of a true supraorbital foramen, the foramen is opened using a small chisel and the nerve is freed and reflected with the periorbita.^{1,16,29}

The periorbita is separated for a distance of 2 to 3 cm posteriorly from the orbital rim. Care should be taken not to violate the periorbita.

The dissection is continued on the inner surface along the lateral wall of the orbit inferiorly toward the inferior orbital fissure (IOF). The dissector can be passed safely through the IOF because it contains only fibrous and adipose tissue.¹

Bone Work

After all soft tissue dissection is completed it should provide adequate exposures of the orbitozygomatic bar, frontal and temporal bones. A sphenoid ridge burr hole is performed with a high-speed drill and round cutting burr according to the technique described above (►Fig. 3). The sphenoid ridge burr hole provides early exposure of frontal dura, temporal dura as well as the periorbita. Additional burr holes are optional and can be made on temporal squama just above the root of the zygoma and on the superior temporal line where it crosses the coronal suture. The following bone cuts are made (►Fig. 3):

1. From the temporal exposure of the sphenoid keyhole to the temporal squama burr hole
2. From temporal squama burr hole to the superior temporal line burr hole
3. From superior-temporal line to the orbital rim. Staying lateral to the supraorbital notch decreases the risk of frontal sinus entry
4. Orbital rim cut can be performed either by oscillating saw or by B8 straight attachment (Midas Rex Legend EHS, Medtronic, Fort Worth, TX)
5. Bone cut from IOF to the level of sphenoid ridge burr hole using the B1 foot attachment, while the periorbita is being protected by a brain spatula

Fig. 3 Steps in the bone work for the one-piece OZ approach. (A) After exposure of the frontal and temporal dura as well as the periorbita provided by the sphenoid ridge burr hole, additionally, two other burr holes are made: on temporal squama just above the root of the zygoma and on the superior temporal line where it is crossed by the coronal suture. The craniotomy is as follows: From the temporal exposure of the sphenoid keyhole to the temporal squama burr hole (1). From temporal squama burr hole to the superior temporal line burr hole; (2) from superior temporal line to the orbital rim. Staying lateral to the supraorbital notch decreases the risk of frontal sinus entry; (3) orbital rim cut can be performed either by oscillating saw or by B8 straight attachment (Midas Rex Legend EHS, Medtronic, Fort Worth, TX); (B) (4) bone cut from IOF to the level of sphenoid ridge using the B1 foot attachment, while the periorbita is being protected by a brain spatula; (C) (5) the root of zygoma cut is cut oblique and as posteriorly as possible; (D) (6) zygomatic bone cut (blue line) at the level of zygomaticofacial foramen parallel to the IOF. IOF, inferior orbital fissure; OZ, orbitozygomatic.

6. The root of zygoma cut is cut obliquely and as posteriorly as possible. Care is taken not to damage the temporomandibular joint capsule
7. Zygomatic bone cut at the level of zygomaticofacial foramen parallel to the IOF

The last part of the bone work is the orbital roof cut (►Fig. 4). The orbital roof has two components—a thick sphenoidal part and a paper-thin frontal part. Using the sphenoid ridge keyhole it provides early and direct access to removal of the thickest (sphenoidal) part of the orbital roof—the bone removal is started from the base of the sphenoid

ridge triangle (described above in the article) and is continued obliquely and anteriorly toward the thinner frontal component. After removal the sphenoidal part, the paper-thin (frontal) part of the orbital roof can easily be removed either by chisel, or fractured.

Finally, the bone flap is separated from the dura and lifted safely (►Fig. 5).

Discussion

McCarty first described the keyhole burr hole in 1960s for frontal craniotomies to excise orbital meningiomas.^{44,45} After elevation of the free frontal bone flap, he used the lower (orbital portion) of the burr hole as a window through which he further removed the orbital roof and lateral orbital wall without needing to create a separate burr hole.¹ Later the McCarty keyhole was incorporated into the concept of one-piece OZ approach.^{1,2,14,28,29,31,32} However, the exact placement of McCarty keyhole is not consistent through the different studies, being just behind the arch of the zygomatic process,²⁸ just behind the frontal process of the zygomatic bone,⁴⁶ at the frontosphenoidal junction just behind the zygomatic process of the frontal bone.²⁹

In their detailed description of the technique of one-piece OZ approach Aziz et al¹ use the McCarty keyhole and the IOF as main key points in their technique. They define the localization of the McCarty keyhole as follows: “over the frontosphenoidal suture 1 cm behind the frontozygomatic junction (between the frontal process of the zygomatic bone and the zygomatic process of the frontal bone).” They stress the need to distinguish between the frontozygomatic suture and the frontosphenoidal suture because burr hole drilling at the frontozygomatic suture will expose only periorbital.¹

In another detailed anatomical study for the location of the McCarty keyhole, drill holes are placed along, above, and below the frontosphenoid suture, beginning anteriorly at an area referred to as the three-suture junction, located at the junction of the frontozygomatic, sphenozygomatic, and frontosphenoid sutures. The authors concluded that placing the McCarty keyhole on the frontosphenoid suture 5 to 6 mm behind the three-suture junction results in greater preservation of the lateral wall and roof of the orbit.

However, as other have pointed out in their publications, relying on sutures of the temporal fossa that are often unperceivable in older crania is not reliable. In their study Tubbs et al⁴⁷ use an alternative method for localization of the McCarty keyhole, by placing initial 1-mm holes from inside the cranium to outside. Based on their measurements they define the location of the McCarty keyhole as approximately 7 mm superior and 5 mm posterior the frontozygomatic suture, which is a reliable external landmark on the cranium.

On the other hand the sphenoid ridge, which corresponds to a bony depression in the temporal fossa, on the lateral skull surface following the main axis of the Sylvian fissure, is an easily identifiable landmark during surgery. Moreover, it can be identified by classical craniometrical measurements for the localization of the Sylvian fissure by the Sylvian line.³⁵ Traditionally, the sphenoid ridge is removed during standard

Fig. 4 (A) Close up view of ►Fig 3a, right temporal region presenting the orbital roof cut through the sphenoid ridge keyhole. The direction of this cut is illustrated with blue arrowhead. (B) Osteology of the orbital roof. The orbital roof consists of two parts—sphenoidal part which is could sometimes be very thick (~3 mm) and a paper-thin frontal.¹² The sphenoid ridge burr-hole provides early and direct access to the thickest part of the orbital roof. After removal of the thick sphenoidal component of the orbital roof, its paper-thin (frontal) part could be easy and safely fractured.

Fig. 5 (A) Exposure after the bone flap removal. The frontal, temporal dura as well as the periorbital are exposed. In this specimen, the frontal sinus is very well developed and opened. (B). One-piece OZ bone flap. The sphenoid ridge burr hole is situated slightly below the location of the traditional McCarty keyhole burr hole (white circle). Using the McCarty keyhole the sphenoid ridge has to be drilled also as a part of the exposure to lift the one-piece OZ bone flap and increase the exposure (C). The one-piece OZ flap inner side—the projections of the sphenoid ridge drilling are visualized with its relevant exposures as stated above. The sphenoidal part (thicker) of the orbital roof is drilled and the frontal (thinner) part is fractured. In this particular specimen the frontal sinus is very well developed and comprises part of the orbital roof. OZ, orbitozygomatic.

pterional craniotomies to decrease the brain retraction and to gain maximum exposure of the basal compartments of the brain.⁴⁸ The aggressive removal of the sphenoid ridge is even more valid when OZ approach is used—therefore, either using the Dandy keyhole for the standard pterional craniotomy or the McCarty keyhole for the OZ approach, the sphenoid ridge must be removed as an essential part of the operation.

Nathal et al first incorporated the use of the sphenoid ridge as a keyhole for the treatment of cerebral aneurysms.³⁶ This is designed as a minimally invasive approach with a small incision in the temporal region just behind the hairline. For the bone work they place their burr hole posteriorly—at the most caudal aspect of the surgical exposure and centered over the bony depression representing the sphenoid ridge (according to the illustrations in the article the initial burr hole is placed approximately at the pterion). Then they tailor a bone flap and use a chisel to complete the cut line over the anterior thicker portion of the sphenoid ridge. The rest of the sphenoid ridge is removed by use of high-speed drill.

Others have used similar techniques as minimally invasive “pterional keyhole approach,” which is analogous one described by Nathal et al.^{4,49,50} However, compared with the technique described in our study we place our burr hole more anteriorly corresponding the superficial projection of the most anterior and thickest part of the sphenoid ridge which would give advantage of early and more complete removal of the thickest bone between the temporal and frontal dura, simultaneous exposure of these two anatomical compartments as well as possibly easier bone flap elevation.

One of the largest case series using the sphenoid ridge keyhole concept for the simultaneous exposure frontal, temporal as well as the periorbital is the series of Abdel Aziz et al using the eyelid approach.⁵¹ Although this series is again a minimally invasive surgical technique the sphenoid ridge keyhole exposure is similar to the one described in our study. In their article, Abdel Aziz et al recommend to start the drilling of the sphenoid bone at frontosphenoidal and sphen-

nosquamosal sutures, posterior to the zygomaticosphenoidal suture, and 10 mm behind the frontozygomatic junction. However, others point out that it might be difficult to distinguish the individual suture lines for guidance of burr hole placement and the use of more reliable anatomical landmarks is preferred.⁴⁷

Based on the results of our study we recommend centering the keyhole 10 mm posterior and 7 mm (SD, 0.22mm) inferior to the frontozygomatic suture in the natural groove on the lateral skull, corresponding to the sphenoid ridge in this location. The drilling should be across the sphenoid ridge until the frontal and temporal dura separated by sphenoid ridge are revealed. Then the drilling can be continued anteriorly following the sphenoid ridge toward the orbit.

An important aspect of the one-piece OZ approach is the orbital roof cut. One possibility is to use a small chisel and gentle hammering from inside the orbit and by carefully protecting the dura with a cottonoids or Gelfoam (Pfizer Inc., New York, NY) to cut the orbital roof in a desired direction (► Fig. 4 A).

Another possibility is to fracture the orbital roof, when elevating the bone flap. The roof of the orbit is triangular in shape and formed by the frontal bone and lesser sphenoid wing (► Figs. 4 B and 5). Fracturing forward the orbital roof is possible because the anterior region is markedly thin.⁷ Using the sphenoidal keyhole provides early and direct access to removal of the thickest (sphenoidal) part of the orbital roof—the bone removal is started from the base of the sphenoid ridge triangle (described above in the article) and is continued obliquely and anteriorly toward the thinner frontal component. The thicker sphenoidal component of the orbital roof prevents the surgeon from injuring the contents of the optic foramen and superior orbital fissure when performing the supraorbital craniotomy because it is difficult to fracture and can be as thick as 3 mm.⁷ Since the anterior part of the orbital roof is thin and fragile, the orbital fracture is most easily made anterior to the thick

lesser sphenoid wing component and the whole bone flap is easily removed.

One of the possible drawbacks of our study is the transillumination method used to assess the localization of the sphenoid ridge keyhole. As others have pointed out in their studies the most accurate technique is to drill holes in the skull with the aid of small burr and a high-speed drill and after that to measure the distance from the relevant anatomical landmarks.^{32,47} However, this would eventually damage the skulls, which was not possible in our study.

One probable advantage of the sphenoid ridge burr hole over the McCarty keyhole is a possible less bone loss, because the sphenoid ridge must be removed as an essential part of the operation even if the McCarty keyhole is chosen (► Fig. 5).

Another possible advantage is that drilling of the thickest portion of the sphenoid ridge might facilitate an easier bone flap elevation, which is noticed by other authors although described the use of the sphenoid keyhole in minimally invasive approaches.¹

Although our report is only anatomical description of a technique it might present an important technical nuance of the standard OZ approach.

Conclusion

The sphenoid ridge is a natural osseous border between the frontal dura, the temporal dura, and the periorbital. It provides easy identifiable pathway to all these three distinct anatomical compartments required to perform the one-piece OZ approach. Early removal of the sphenoidal part of the orbital roof may provide safer bone flap elevation.

Conflict of Interest

None.

Presentation at a Conference

We presented this work as an e-poster at the World Federation of Neurosurgical Societies (WFNS) meeting; September 8–13, 2013; Seoul, South Korea.

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