

## Original Article

# Drilling of the marginal tubercle to enhance exposure via mini pterional approach: An anatomical study and clinical series of 25 sphenoid wing meningiomas

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## Abstract

**Background:** The marginal tubercle (MT) of zygomatic bone can be an obstacle in the standard mini pterional (MPT) craniotomy; we aim to evaluate the effect of drilling this MT in enhancing the exposure of MPT craniotomy for resection of sphenoid wing meningiomas (SWMs).

**Methods:** The authors utilized 60 dry skulls to perform the anatomical part of the study. The MT size was reflected by the *AB* distance, wherein point *A* is the most prominent part of MT and point *B* is located on the orbital rim in the same axial plane as point *A*. The authors analyzed the effect of MT size in masking the sphenozygomatic suture (SZS), which is the most anterior part of the MPT craniotomy. One silicon-injected embalmed specimen was used to demonstrate other modifications to the standard MPT approach. The results of the anatomical analysis were translated into the second part of the study, which consisted of the resection of 25 SWMs.

**Results:** The MT obscured visualization when the *AB* distance measured 13 mm or greater. In the clinical series of SWMs, drilling such prominent MT maximized exposure during MPT approach.

**Conclusion:** The MPT approach could be used for the resection of SWMs. Drilling of prominent MTs can enhance and optimize exposure to SWMs through standard MPT approaches.

**Key Words:** Anatomic study, meningioma, minimally invasive neurosurgery, minipterional approach, skull base, surgical technique

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## INTRODUCTION

The minipterional (MPT) approach was first described by Figueiredo *et al.*<sup>[10]</sup> as a less-invasive alternative to the classic pterional approach. The MPT approach optimizes the balance between surgical exposure and craniotomy size in addition to yielding better functional and cosmetic results.<sup>[5,25]</sup>

Because of its small bony exposure, the MPT approach requires maximization of craniotomy by removing all obstacles that can hinder the microscopic view.

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The marginal tubercle (MT) of the zygomatic bone (*processus marginalis*) is an elevation on the posterior border of the frontal processes of the zygomatic bone, just above the angle between the frontal and temporal processes of the zygoma.<sup>[7,18]</sup>

Sphenoid wing meningiomas (SWMs) account for approximately 20% of supratentorial meningiomas.<sup>[19,23]</sup> They were first described in detail by Drs. Cushing and Eisenhardt, who distinguished between globoid SWMs and en-plaque SWMs.<sup>[8]</sup> Globoid meningiomas were subdivided into three groups, namely, inner/medial, middle, and lateral/pterial.<sup>[19,23]</sup>

Various surgical approaches have traditionally been used for the resection of SWMs, including frontolateral,<sup>[19]</sup> pterional,<sup>[6,14,19,22]</sup> lateral trans-zygomatic,<sup>[16]</sup> supra-orbital-pterional,<sup>[2]</sup> frontotemporal-orbito-zygomatic,<sup>[9,17]</sup> and fronto-orbito-malar.<sup>[4]</sup>

The authors aim to determine if the MT could be an obstacle in the standard mini pterional MPT approach. Second, to evaluate the effect of drilling the MT for increased exposure during resection of SWMs.

## MATERIALS AND METHODS

The study is comprises two parts: The first one is anatomical; the authors analyzed the degree to which the MT obscures the surgical window in the standard MPT approach. The second part aims to translate the results of the anatomical part of the study into a series of 25 SWMs where the MPT approach was used. However, two additional technical modifications have been added to the standard MPT approach based upon the authors' experience in skull base surgery.

### Anatomical study

This anatomical study was performed in the Mayfield skull base laboratory in the University of Cincinnati, Ohio, USA. Sixty dried skulls were utilized bilaterally (120 cranial hemispheres). We identified the size of MT by the *AB* line, wherein the point *A* is the most prominent part of MT. The point *B* represents the intersection of a line drawn on axial plane from point *A* to the anterior edge of frontal processes of zygomatic bone "orbital rim" [Figure 1].

From point *A*, a line is drawn perpendicular on the extracranial surface of greater sphenoid wing; the intersection is referred to as point *C* [Figure 1]. The *AC* line represents the straight perpendicular axis of view on the anterior part of the MPT craniotomy.

Starting from the sphenozygomatic suture (SZS), which is the most anterior part of the MPT craniotomy, a perpendicular line is drawn to intersect the *AC* line at point *E*; this line is referred to as *ED*, wherein the point *D* is the starting point on the SZS [Figure 1].



Figure 1: *AB*, *AC*, and *ED* lines; Red arrow = sphenozygomatic suture

The *ED* line represents the part of bone flap masked by the MT. This area is termed the marginal recess (MR). The relationship between *AB* distance (MT Size) and *ED* distance (MR size) was analyzed in order to determine the size of MT, from which this bony projection becomes an obstacle in MPT approach.

Two other modifications to the standard MPT approach were added, these modifications are demonstrated on a silicon-injected embalmed head specimen. The dissection study was performed in the skull base laboratory in Allegheny General Hospital, Pittsburgh, USA.

### Clinical series of sphenoid wing meningiomas

Utilizing the MPT approach, 25 patients with SWMs underwent microsurgical resection between July 2006 and February 2016. Surgeries were performed in Allegheny General Hospital, Pittsburgh, Pennsylvania, USA by a single surgeon (KA). *AB* distance was measured on the preoperative computed tomography (CT). MT was drilled in some cases according to the results of the anatomical study in order to enhance the surgical exposure. The value of an additional exposure offered by MT drilling was evaluated by the surgeon's impression and comfort during the surgery.

## RESULTS

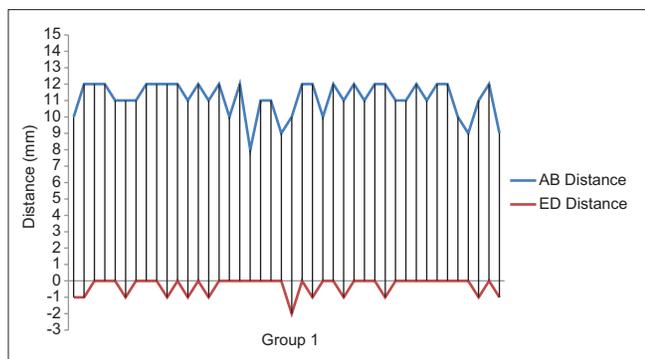
### Anatomical study

The SZS was visualized in an unobscured, straight-on perpendicular fashion when *ED* (MR) was 0 or less [Figure 1].

To demonstrate this, the authors divided the craniums into two groups; Group 1, where the *ED* distance measured 0 or less, and Group 2, where the *ED* distance measured 1 mm or greater [Table 1].

The authors noted a relationship between *AB* (MT size) and *ED* (MR size). The bigger *AB* was, the bigger *ED* was. In essence, the more prominent the MT was, the more anterior the SZS was (Chart 1 and 2), [Figure 2].

Forty-two of 120 cranial hemispheres (35%) were assigned to Group 1. In this group, the MT size ranged 8–12 mm.



**Chart 1: Measurements of AB distance and ED distance in Group 1**

**Table 1: Cranial hemispheres classification according to MR size**

	Group 1	Group 2
Cranial Hemispheres No.	42 (35%)	78 (65%)
ED Distance (mm) (MR size)	-2-0	1-12
AB Distance (mm) (MT Size)	8-12	13-20

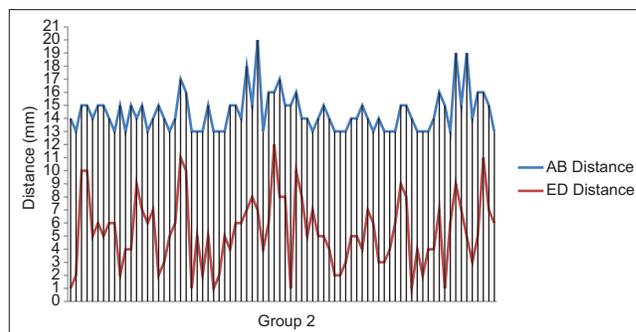
Group 2 included 78 (65%) cranial hemispheres. In this group, MR size ranged between 1 and 12 mm, which implies that the anterior perpendicular surgical view is hidden at least 1 mm by the MT. The AB distance ranged in this group between 13 and 20 mm.

Because of the direct correlation between MT and MR, and by looking at the results of Group 2, the authors concluded that the straight perpendicular surgical view on the anterior limit of MPT approach (SZS) is hidden by at least 1 mm when the AB distance measured 13 mm or more. In these cases, drilling the MT should be considered to enhance surgical exposure. These results were subsequently translated into the clinical series.

### Clinical series

Utilizing the MPT approach, 25 patients with SWMs underwent microsurgical resection. There were 16 females and 9 males, with an age range of 26 to 85 years (mean = 60.2). Eleven patients had lateral SWMs, 7 had middle SWMs, 5 were en-plaque meningiomas, and 2 were sphenocavernous meningiomas. Tumor size ranged from 2.2 cm to 6 cm in maximum diameter (mean: 3.6 cm). Simpson grade one resection was achieved in 22 (88%) patients. The 2 patients with sphenocavernous meningiomas had Simpson grade 4 resection (excision did not extend beyond the lateral wall of cavernous sinus). One patient with en plaque meningioma had Simpson grade 4 resection due to erosion of sphenoid bone and extension into the nasal cavity.

Preoperative CT scans were used to measure the AB distance. Drilling the MT was considered when the AB distance was 13 mm or more. In result, MT was drilled in 13 out of 25 patients. At the time of surgery,

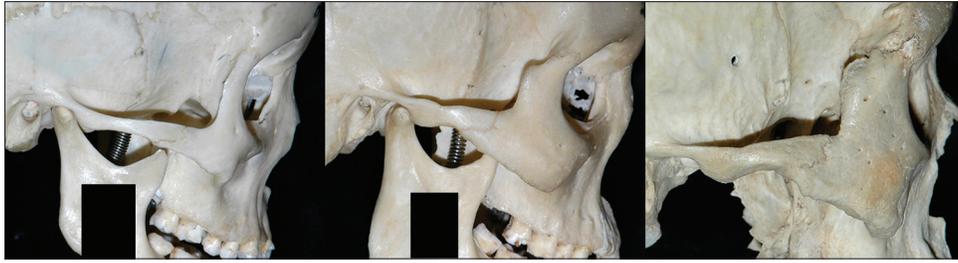


**Chart 2: Measurements of AB distance and ED distance in Group 2**

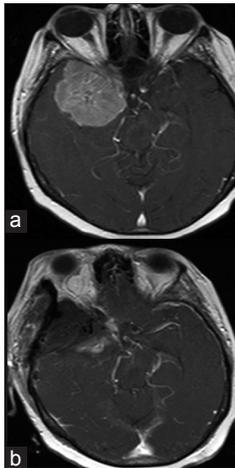
exposure enhancement was subjectively recorded by the surgeon (KA). [Figure 3].

### Operative technique

- 1) Position: Same as traditional pterional approach<sup>[15]</sup>  
All patients were electrophysiologically monitored utilizing somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP)
- 2) Skin incision and soft tissue dissection stage: Same as traditional MPT approach.<sup>[10]</sup> The pterion is exposed [Figure 4a]
- 3) A sphenoid keyhole is placed at the sphenoidal component of the pterion. The authors enlarged the keyhole by drilling the whole extracranial surface of the greater wing of sphenoid. Drilling continues until the temporal dura, frontal dura, and periorbita are exposed [Figure 4b]
- 4) The large keyhole allows for sphenoid ridge drilling before elevation of the bone flap [Figure 4c]. Thereafter, the dura can be safely dissected in all directions. This technique is believed to help prevent dural tears and cortical injury during the subsequent elevation of bone flap. The anterior limit of the craniotomy is the sphenozygomatic suture. The bone flap does not surpass the level of the stephanion (junction of coronal suture with superior temporal line). This will always keep the bone flap less than 4 cm [Figure 4d]
- 5) The marginal tubercle is drilled when the AB distance is 13 mm or more, according to preoperative CT scan measurements
- 6) The authors perform an extradural flattening to orbital roof without orbital osteotomy to minimize the brain retraction
- 7) Centering it over the meningioma and Sylvian fissure, the dura is opened in a semi-lunar fashion and reflected anteriorly
- 8) Following the intracranial part of the surgery, the bone defect is repaired using titanium mesh and/or bone cement. Temporalis muscle and fascia are reattached along a muscle cuff using absorbable running sutures. Subgaleal/submuscular drains are left behind to prevent fluid collections.



**Figure 2: Different types of marginal tubercle. Notice the relationship of the marginal tubercle to the sphenozygomatic suture**

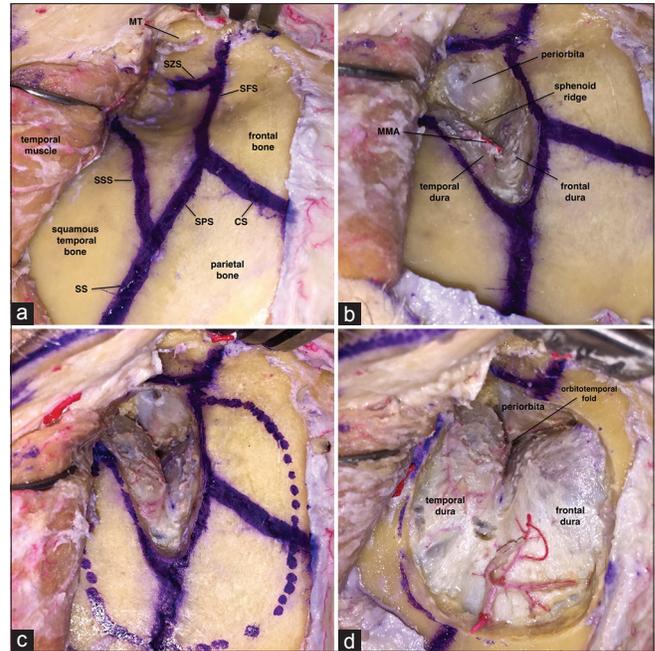


**Figure 3: Preoperative (a) and postoperative (b) magnetic resonance imaging (MRI) for a sphenoid wing meningioma with an extension into the cavernous sinus**

### Complications

One patient had postoperative epidural hematoma requiring surgical evacuation and was discharged home 1 week later without any clinical sequelae. One patient developed a pseudomeningocele, which resolved after placement of a lumbar drain for 3 days, draining at 10 cc/h. This patient was discharged home 6 days postoperatively without neurological sequelae. One patient with radiation-induced multiple meningiomas (left sphenoid wing, right parasagittal and right cerebellopontine angle) and ventriculomegaly underwent MPT approach for resection of lateral SWM, and a Simpson grade 1 resection was achieved. Three days later, the patient developed pseudomeningocele and cerebrospinal fluid (CSF) leak. Lumbar drain was placed and CSF was diverted at 10 cc/h for 6 days. Owing to inability to wean the drain, the decision was made to place a ventriculoperitoneal shunt as a more permanent solution to the CSF leak. Prior to discharge, the patient developed a pulmonary embolus (PE) requiring mechanical ventilation, from which he later fully recovered and were discharged home without any neurologic sequelae (total hospital stay was 23 day).

Hospital stay ranged from 3 to 23 days, with an average of 4.28 days. Twenty of 25 patients (80%) were hospitalized



**Figure 4: Cadaver photos illustrating the authors' technique keyhole. (a) Bone exposure for a left-side standard MPT approach; (b) keyhole enlargement by drilling the extracranial surface of sphenoid wing; (c) drilling sphenoid ridge before performing the craniotomy; (d) craniotomy. CS = coronal suture; SS = squamous suture; SFS = sphenofrontal suture; SPS = sphenoparietal suture; SSS = sphenosquamosal suture; SZS = sphenozygomatic suture; MT = marginal tubercle, MMA = middle meningeal artery**

for 3 days postoperatively. One patient stayed for 4 and another for 6 days due to social reasons. Three patients had postoperative complication and stayed for 8, 6, and 23 days as mentioned above.

No approach-related complication was noted in any of the patients. Both patient and surgeon were satisfied with cosmetic results during the follow-up visit in all cases.

### DISCUSSION

The standard pterional approach is among the most popular approaches in contemporary neurosurgery. Because of the extent of dissection involved with the standard pterional approach, adverse outcomes have been described and include injury of the frontal branch of the facial

nerve, temporalis muscle dysfunction, temporomandibular joint pain, frontal sinus violation, and poor cosmetic results.<sup>[3,12,20]</sup> Because of this, modifications have been proposed to improve cosmetic outcome.<sup>[3,12]</sup> In addition, less invasive approaches have been described as alternatives to classic pterional approach such as the mini-supraorbital approach, supraorbital keyhole approach, lateral supraorbital approach, sphenoid ridge keyhole approach, minipterional approach, transiliary “eyebrow” approach, and transpalpebral “eyelid” approach.<sup>[1,10,11,13,20,21,24]</sup>

Figueiredo *et al.*<sup>[10]</sup> introduced the concept of MPT approach as an alternative to the classic pterional one. The optimum balance between craniotomy size, temporalis muscle dissection, and microsurgical exposure are the key concepts behind the MPT approach. Thus, the maximum advantage from the surgical exposure should be obtained.

Based upon the author’s experience in skull base surgery, two modifications to the standard MPT approach were added. First, after placing a burr hole on the sphenoid component of pterion, the cranial surface of greater wing of sphenoid is drilled up to the frontosphenoidal, the sphenosquamosal, and the sphenoparietal sutures. Thereafter, drilling on the sphenoid ridge is continued to obtain a large keyhole, permitting a safe dissection of the dura in all directions.

The second modification consists of an extradural flattening to orbital roof without need of orbital osteotomy. This maneuver enhances the surgical field and provides less brain traction.

In addition to these modifications, the authors noted that the MT could be an obstacle to reach the maximum anterior exposure. Because of this, the authors performed the anatomical study aiming to better understand the effect of this anatomical projection in mimicking the view in the MPT approach. The result of the anatomical study concluded that the MT should be drilled when the AB distance measures 13 mm or more.

To translate these results into operating room, AB distance was measured on preoperative CT scan. The surgeon stated that the maximum anterior exposure while resecting a SWM was better after performing a drilling of prominent MT where the AB distance is 13 mm or more.

Simpson grade 1 resection was not achieved in 3 cases, however, it is felt this is not related to lack of surgical exposure. In 2 cases, where the meningioma extended into the cavernous sinus, the partial resection was anticipated preoperatively. The other case was an en plaque meningioma extending into the nasal cavity by erosion of the sphenoid bone; the total surgical removal was not possible by a single transcranial approach, and

needed a combination with endonasal route.

## CONCLUSION

The MPT approach, when supported by several modifications, could be used for the resection of SWMs. Drilling of the MT should be considered in some cases to enhance and optimize exposure; thus, to achieve the principle of the MPT approach by creating an optimum balance between the craniotomy size and surgical exposure.

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## Conflicts of interest

There are no conflicts of interest.

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