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Orbital Roof and Lateral Wall Reconstruction Using Split-Thickness Calvarial Bone Graft with Titanium Mesh Complex for a Spheno-Orbital Meningioma

Cathrine P. Miura, MD
Jay Pee M. Amable, MD

Department of Otorhinolaryngology
Head and Neck Surgery
University of the East – Ramon Magsaysay Memorial
Medical Center, Inc.

ABSTRACT

Objective: To describe our reconstruction of an orbital roof and lateral wall defect using a split-thickness calvarial bone graft with titanium mesh complex after resection of a meningioma of the left greater wing of the sphenoid with extension to the left frontotemporal bone and left orbital roof and lateral wall.

Methods:

Study Design: Surgical Innovation
Setting: Tertiary Private University Hospital
Patient: One

Results: A 44-year-old woman with a left frontotemporal mass associated with left eye proptosis and epiphora underwent reconstruction of the left orbital roof and lateral wall defect using split-thickness calvarial bone graft with titanium mesh and screws after a left frontotemporal craniectomy, superior and lateral orbital wall resection of a mass of the sphenoid wing with orbital and frontotemporal extension. Final histopathology was consistent with meningioma. Surveillance of the mass and orbital reconstruction showed evidence of bone growth and osteointegration of the titanium mesh into the bone grafts.

Conclusion: The initial good outcome of orbital roof and lateral wall reconstruction using split-thickness calvarial bone graft with titanium mesh is evidenced by osteointegration of the titanium mesh and revascularization leading to new bone growth. This autogenous-alloplastic complex may provide a more stable option for orbital reconstruction, but long term follow-up is needed for surveillance of recurrence and monitoring the status of orbital reconstruction.

Keywords: *orbit; sphenoid wing meningioma; calvaria; bone grafting*

Tumor resection of the orbital walls produces a defect that needs to be reconstructed. Restoration of anatomic integrity is imperative to minimize ocular and neurologic complications.[1-5] Orbital wall reconstruction can utilize different alloplastic materials and autogenous grafts.

Correspondence: Dr. Jay Pee M. Amable
Department of Otorhinolaryngology
Head and Neck Surgery
University of the East – Ramon Magsaysay Memorial
Medical Center, Inc
5th Floor, Hospital Service Bldg., 64 Aurora Blvd.
Brgy. Doña Imelda, Quezon City, 1113
Philippines
Phone: (632) 8715 0861 local 257
Fax: (632) 8716 1789
Email: jpamablemd@gmail.com

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Figure 1. Pre-operative photos of the patient demonstrating left proptosis (photos published without eye bars, with permission).

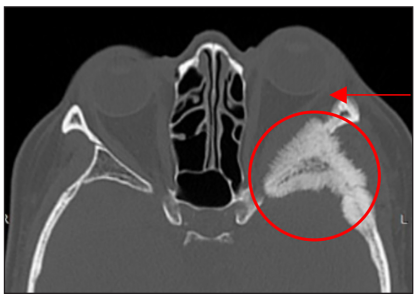

Figure 2. Representative axial cranial CT image with orbital cuts (bone window). The lesion involved the left greater wing of the sphenoid with left frontotemporal bone and left orbital roof and lateral wall extension (encircled), causing mild extrinsic compression on the lateral extraconal space with resultant proptosis of the left globe (arrow).

Polymethylmetacrylate and hydroxyapatite are alloplastic materials that are easy to manipulate, avoid donor site morbidity and graft resorption and reduce operative time but are more prone to infection.[3] Autogenous grafts (such as calvarial bone, rib, and iliac crest) have less rejection and can revascularize.[6,7] However, they entail risks of donor site morbidity, longer operative times and are prone to bone resorption. Combined alloplastic and autogenous grafts have been described[8] but their use is controversial. Both alloplastic and autogenous grafts have their advantages and disadvantages and there is no clear cut superior approach of one over another. The choice of reconstruction depends on the surgeon's propensity and the patient's condition.[2] Combined alloplastic and autogenous grafts functioning as a unit has been described but only for a large anterior skull base defect.[8] Moreover, a search of HERDIN Plus, MEDLINE (PubMed)), Clinical Key, EBSCO, CINAHL, Cochrane and Google Scholar using the keywords "orbital wall reconstruction," "spheno-orbital meningioma with reconstruction," and "calvarial bone graft for craniofacial defect" yielded no reports of orbital reconstruction using a combined calvarial bone graft with titanium mesh. This paper aims to present our experience with a split-thickness calvarial bone graft and titanium mesh complex for reconstruction of an orbital roof and lateral wall defect after excision of a spheno-orbital meningioma.

CASE REPORT

A 44-year-old hypertensive, dyslipidemic midwife presented to our clinic for a gradually enlarging 3 cm firm, non-tender mass over the left frontotemporal area of 3-months duration. This was associated with epiphora and proptosis of the left eye. *(Figure 1)* A Cranial computed tomography (CT) scan with orbital cuts revealed an expansile, osteoblastic lesion with spiculated borders involving the greater wing of the sphenoid with frontotemporal bone and orbital roof and lateral wall extension. *(Figure 2)* She was advised excision of the left spheno-orbital and frontotemporal osteoblastic mass by neurosurgery and was referred to our service for reconstruction of the anticipated orbital wall defect.

Surgical Technique

The patient underwent left frontotemporal craniectomy, superior and lateral orbital wall removal, and resection of mass; orbital roof and lateral wall reconstruction using split-thickness calvarial bone graft with titanium mesh and screws; frontal sinus obliteration, and cranioplasty of frontotemporal bone defect using bone cement under general anesthesia.

For reconstruction, we utilized the same frontotemporoparietal trauma flap previously created for resection of the mass. *(Figure 3A)* The left parietal bone coronal and sagittal sutures were identified to ensure a distance of 2 centimeters from the sagittal suture to avoid bleeding from injury to the sagittal sinus.[9,10] *(Figure 3B)* Parallel troughs two centimeters apart were drilled on the parietal bone using a 2-mm matchstick burr. These troughs were connected to each other horizontally, parallel to the sagittal suture. *(Figure 3C)* The bone grafts were outlined using the burr until the diploic layer was reached. *(Figure 3D)* The split-thickness calvarial bone grafts were carefully osteotomized from the inner table of the parietal bone using a chisel and mallet. Each harvested bone graft segment measured 2cm x 4.5cm. *(Figure 3E)* Bone wax was applied for hemostasis. *(Figure 3F)* One segment of the bone graft was laid on the axial plane while the other bone graft segment was placed on the sagittal plane to cover the orbital defect, simulating

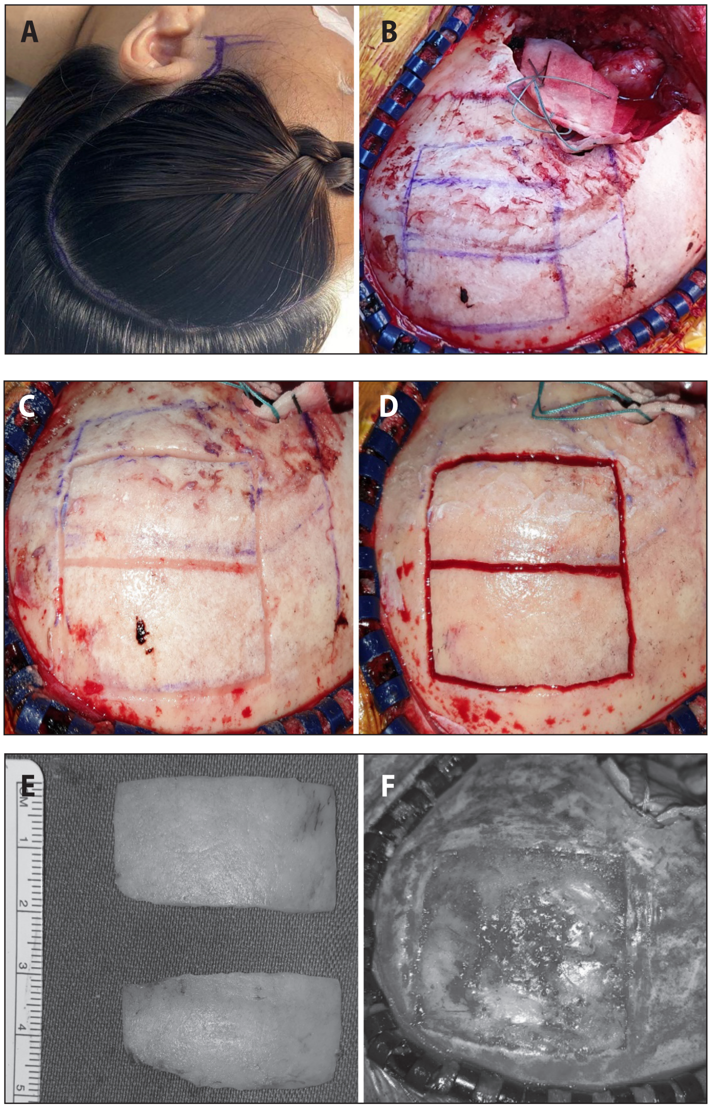

Figure 3. Surgical markings: **A.** for the frontotemporoparietal trauma flap; **B.** on the left parietal bone for harvesting the split-thickness calvarial bone graft; **C.** parallel troughs created on the parietal bone; **D.** deeper outlining of the bone grafts until the diploic layer; **E.** harvested split-thickness calvarial bone graft measuring ~2cm x 4.5cm each; and **F.** diploic layer of the parietal donor site covered with bone wax for hemostasis.

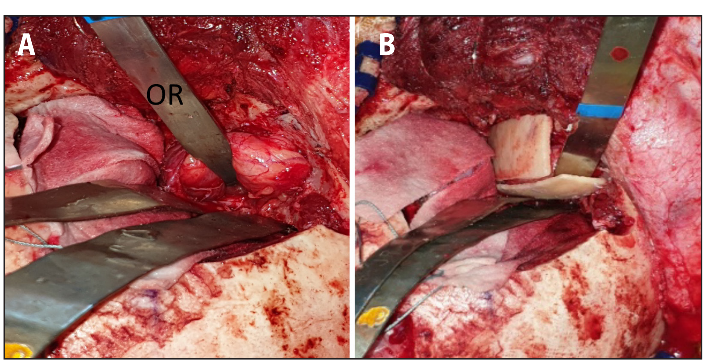

Figure 4. **A.** Left orbital defect with the left globe retracted using an orbital retractor (OR); **B.** bone graft segments temporarily placed in the orbital defect to simulate the orbital roof and lateral wall.

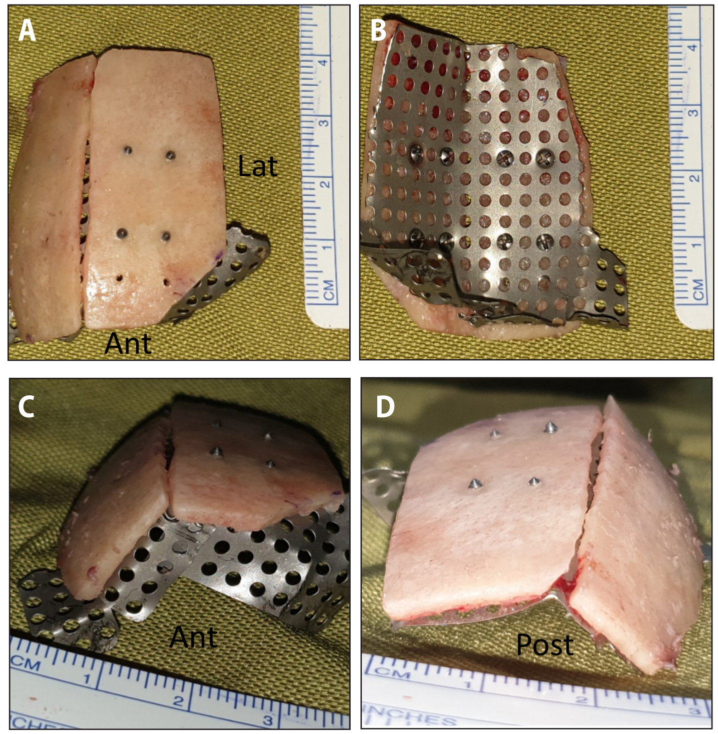

Figure 5. Split-thickness calvarial bone graft with titanium mesh complex: **A.** superior view, showing excess protruding screws were burred; **B.** inferior view; **C.** anterior view; and **D.** posterior view (Ant – *anterior*, Lat – *lateral,* Post – *posterior*).

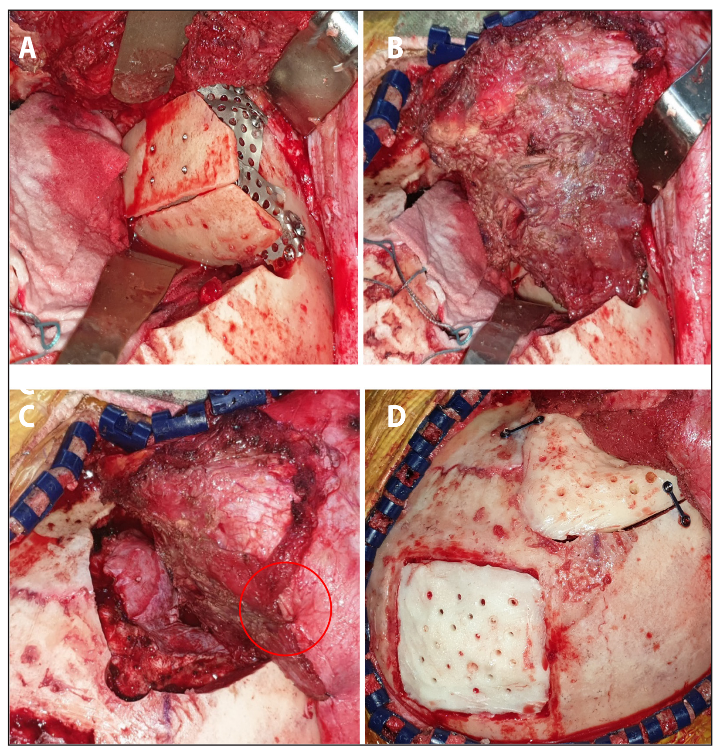

Figure 6. Intraoperative photos showing: **A.** split-thickness calvarial bone graft-titanium mesh complex placed into the orbital defect and fixed; **B.** split medial portion of the left temporalis muscle placed over the calvarial bone graft-titanium mesh complex; **C.** medial portion of the left temporalis muscle sutured to the pericranial flap (encircled; and **D.** reconstruction of the left frontotemporoparietal bone defect and left parietal calvarial bone done site using polymethylmetacrylate.

Figure 7. Photos of the patient on post-operative week 5 demonstrating resolution of proptosis seen in Figure 1 (photos published without eye bars, with permission).

Figure 8. Repeat multi-axial plain cranial CT scan on day 6 post-surgery. The calvarial bone graft-titanium mesh complex is seen. The residual osteoblastic lesion is seen in this coronal view (arrow).

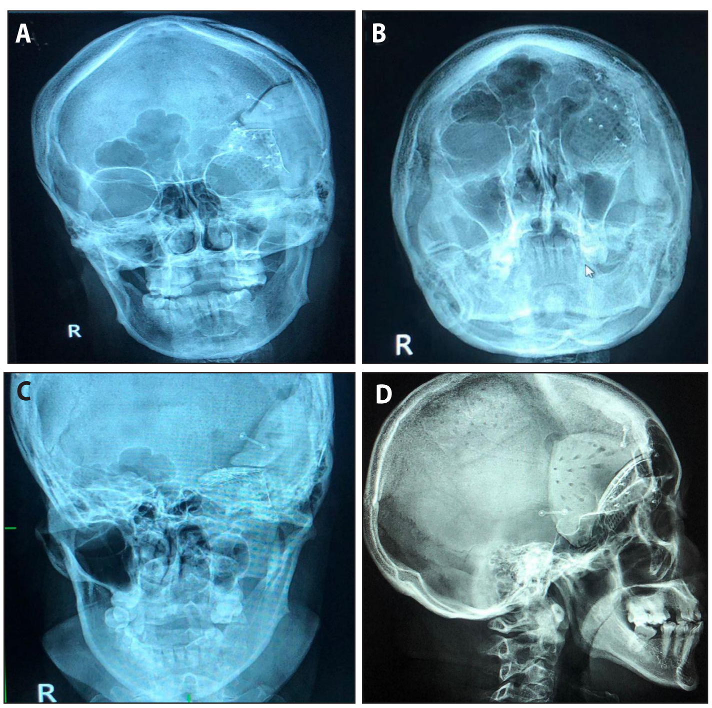

Figure 9. Paranasal sinus x-rays obtained 5 weeks post-operatively: **A.** posteroanterior view; **B.** Water's view; **C.** Townes view; **D.** sagittal view showing calvarial bone graft-titanium mesh complex in place.

the orbital roof and lateral orbital wall, respectively. *(Figure 4)* The bone grafts were removed while the titanium mesh was measured, molded, and trimmed, then fixed to the underside of the harvested bone segments with 4-mm titanium screws. *(Figure 5)* The resulting split-thickness calvarial bone graft with titanium mesh complex was placed into the orbital defect. *(Figure 6A)* After frontal sinus obliteration with a pericranial flap, the temporalis muscle was dissected and split sagittally into a medial and lateral portion. The split medial portion of temporalis muscle was placed over the calvarial bone graft-titanium mesh complex *(Figure 6B)* and sutured to the pericranial flap. *(Figure 6C)* The lateral temporalis muscle was replaced to maintain the bulk of the cranium and lessen the defect. The left frontotemporal bone defect and the left parietal calvarial bone donor sites were reconstructed using polymethylmetacrylate or bone cement molded to the normal contour of the skull. Perforations were created in the bone cement using a cutting burr to facilitate osteointegration. *(Figure 6D)* The molded frontotemporal bone cement was fixed with NS kit titanium microplates and screws. Layered closure was performed after hemostasis, over a Jackson-Pratt suction drain.

Surgical Outcome

In the immediate post-operative period, the epiphora resolved. She developed left periorbital swelling that eventually resolved after a few weeks. There were no changes in visual acuity and she had full extraocular movements. The patient complained of a transient minimal diplopia with tolerable pain on leftward gaze, both of which resolved 4 months post-operatively. *(Figure 7)* A repeat cranial CT scan on post-operative day 6 denoted the area of surgical resection but revealed a 1.7 x 1.1 x 1.3 cm residual tumor. *(Figure 8)* The rest of her course in the wards was unremarkable. Final histopathology result was meningioma with hyperostosis (WHO Grade I). A paranasal sinus x-ray 5 weeks post-operatively showed the calvarial bone graft-titanium mesh complex in place. *(Figure 9)* Cranial MRI with contrast 6 weeks post-operatively showed abnormal enhancement in the left orbital apical region which could represent a small amount of residual meningioma admixed with some amount of post-operative granulation changes; with resolution

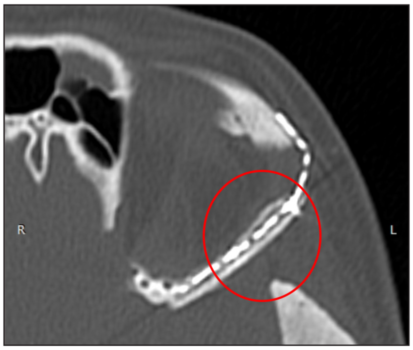

Figure 10. Osteointegration of the titanium mesh within the bone graft seen on cranial CT scan with orbital cuts at 9 months post-surgery (encircled).

of proptosis and a grossly normal looking optic nerve. Repeat plain CT scan with orbital cuts 9 months post-operatively showed no significant interval change in the size of the previously reported residual tumor at the greater wing of the sphenoid measuring 1.9 x 1.2 x 1.4 cm although cranial MRI with contrast demonstrated no evidence of residual or recurrent meningioma. Osteointegration of the titanium mesh with the calvarial bone graft was seen on the CT scan *(Figure 10)* and bone growth was observed connecting the graft with the rest of the orbit.

DISCUSSION

We successfully reconstructed an orbital roof and lateral wall defect after resection of a meningioma of the left greater wing of the sphenoid with extension to the left frontotemporal bone and left orbital roof and lateral wall using an autogenous split-thickness calvarial bone graft with an alloplastic titanium mesh complex.

Orbital reconstruction is invaluable especially in cases of large orbital defects to avoid complications. Although some authors considered reconstruction of small orbital defects unnecessary because no complications were reported, Jung postulated that radical resection of involved bones for tumors without proper reconstruction may lead to postoperative aesthetic and functional complications.[11] Such complications include exophthalmos, proptosis, diplopia, changes in visual acuity, pain, transmission of cerebral pulse to the globe, bulbar dystopia and ophthalmoplegia.[2-4] Other life-threatening sequalae include CSF leaks, meningitis and traumatic encephalocele.[5]

The calvarial bone was our selected autogenous graft due to its proximity and good long-term outcomes in orbital and skull base reconstruction. Other advantages of the split-thickness calvarial bone graft are scar hidden in the hair-bearing area, minimal to no post-operative pain and no obvious deformity of the donor site.[9] Calvarial bone grafts (which are membranous bone grafts) have also been reported to have greater volume survival and early revascularization.[9] In addition, endochondral bone grafts (such as iliac crest and rib) are reported to have a resorption rate as high as 60-80% volume loss versus membranous bone grafts (such as calvarial bone) at 17-20%.[6]

Available materials for orbital reconstruction may be divided into autogenous grafts and alloplastic materials. Autogenous grafts may have donor-site morbidity but this is minimal when using a split-thickness calvarial bone graft and its optional donor-site reconstruction. The difficulty in molding autogenous grafts due to low malleability increases operative time.[2,3,7] Graft resorption has also been reported but this is usually noted when using iliac crest or rib grafts.[6] Autogenous grafts are still better indicated for reconstruction in the growing orbit as these have the ability to revascularize and have lower rejection rates**.**[9]

In contrast, alloplastic materials are convenient to use due to malleability and adaptability to the shape of the orbit. However, they have higher infection rates because they are still foreign bodies.[2] Use of alloplastics may also be more expensive and they may be difficult to remove when needed in case of infection or plate extrusion.[11] The use of titanium mesh for orbital reconstruction has been well established especially in trauma cases. It has the advantage of good malleability and has the ability for osteointegration with surrounding bones. It may however injure adjacent soft tissues due to its sharp edges and may cause inflammatory response and infection.[2]

There are reports of different techniques used for anterior skull base and orbital wall reconstruction. A purely alloplastic reconstruction of an orbital roof and lateral wall defect was performed by Jung *et al.* using titanium mesh previously molded on a skull model after resection of a spheno-orbital meningioma.[11] The defect in their case also involved removal of the supraorbital rim which was reconstructed with a calvarial bone graft but this was not fixed to the titanium mesh they used for the orbital roof and lateral wall reconstruction. Kim *et al.* used a commercially available porous polyethelene sheet with embedded titanium mesh developed for inferomedial orbital wall reconstruction for their orbital roof reconstruction with selected use of calvarial bone graft for reconstruction of the supraorbital rim defect.[2] The porous polyethelene sheet has micropore structures enabling fibrovascular ingrowth which act like a bone graft.[2] However, this entailed additional expenses for the patient and may not be practical and readily available in our setting. Sinha and colleagues used a three-layered reconstruction for large anterior skull base defects mostly involving the cribriform plate, fovea ethmoidalis and medial portion of the orbital roof.[8] A pericranial flap was used as the base with one segment of split-thickness calvarial graft in the middle which was fixed to a superiorly placed contoured titanium mesh to reconstruct the large anterior skull base defect. Their addition of a segment of calvarial bone graft in the anterior skill base was done as added rigid support for they had plate extrusion in their previous cases when they used the two-layer technique of pericranial flap and titanium mesh only. Leake *et al.* performed orbital reconstructions after resection of sphenoid wing meningiomas using calvarial bone grafts which were rigidly fixed with X-titanium plates and 1.2 mm screws to recreate the superior and lateral orbital walls.[1] This complex was plated to the remaining superior orbital rim and zygoma. Half of their patients had abdominal fat grafts placed in the temporal space and around the bone graft complex, while the other half only had pure calvarial bone grafts. One of their patients had reconstruction with titanium mesh and abdominal fat graft but no calvarial bone was utilized due to hyperostosis in the sagittal sinus. Their cases showed good results with minimal or no significant post-operative complications on long term follow-up. The autogenous-alloplastic complex of Leake and colleagues differed from our technique in the sense that their X-titanium plate served to rigidly fix the bone graft segments and would not act as a stand-alone orbital reconstruction in the event of bone resorption compared with using the titanium mesh.

In comparison with other studies, the use of a combined split-thickness calvarial bone graft with titanium mesh in our study may provide a more stable reconstruction of the orbital roof and lateral wall. Aside from the technical difficulties of bone graft harvest an unseasoned surgeon would encounter, bone grafts alone are prone to resorption. Titanium mesh alone may be easier to handle but it still has chances of migration and extrusion if only a small portion of the titanium mesh is in contact with bone. By combining these two materials, their properties can complement each other and provide a more secure reconstruction. The titanium mesh fixed the calvarial bone graft segments to each other with screws and to the surrounding bones. Bone revascularization could be facilitated by the contact of bone grafts to normal bones. In addition, the ability of titanium mesh to osteointegrate into the bone and bone graft could lessen the possibility of implant migration and extrusion. Both materials can also be monitored through imaging. The most recent CT scans obtained 9 months post-operatively already showed evidence of bone growth. This may be due to the contact of the calvarial bone grafts to the rest of the cranium, which would not have occurred if we used titanium mesh alone. The titanium mesh here allowed better contour for the reconstruction and served as a 'lifeboat' in the event that bone resorption occurred. The titanium mesh has in fact been osteointegrated into the bone grafts as seen on CT images obtained 9 months post-surgery. Thus, our calvarial bone graft-titanium mesh complex serves as a scaffold for bone growth, favoring this reconstruction over other options.

Our experience with the split-thickness calvarial bone graft-titanium mesh complex is based on only one patient. Replicating this technique in more patients with orbital roof and lateral wall defects may yield more robust observations particularly if performed by several surgeons in multiple centers. As of this writing, the patient is on her 10th post-operative month, and surveillance is still in the early phase with long-term follow-up needed. As recommended by Heufelder and colleagues, it is advisable to follow-up patients with spheno-orbital meningiomas for 20 years or longer due to their high recurrence rates.[12] A reliable indicator for recurrence is globe protrusion which can be assessed on serial imaging. Although initial globe protrusion resolved in this patient 6 weeks post-operatively, long-term follow up is necessary (especially considering the residual tumor). A follow-up period between 2 and 8 years by Hendus showed that the calvarial bone grafts remained stable in size and shape, with no complications of graft rejection, osteomyelitis or bone resorption noted.[13]

In summary, orbital roof and lateral wall reconstruction using a split-thickness calvarial bone graft with titanium mesh has shown an initial good outcome evidenced by osteointegration of the titanium mesh and revascularization leading to new bone growth. This autogenous-alloplastic complex may provide a more stable option for orbital reconstruction as the materials complement each other and combining them may be more practical and beneficial in the long run. Especially because this case involved a spheno-orbital meningioma, long term follow-up must be done for surveillance of recurrence and monitoring the status of the orbital reconstruction.

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