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How I Do It

A Targeted Problem and Its Solution

Three-Dimensional Alloplastic Orbital Reconstruction in Skull Base Surgery

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INTRODUCTION

The orbit may be directly involved by neoplasms or other destructive processes arising from the orbital contents, the osseous framework or, indirectly, as extensions of extraorbital tumors from the sinuses or cranial vault. In most osseous neoplasms of the orbit, and in tumors with extension into the orbit from surrounding areas, resection of part or all of the orbital walls will be required. If fronto-orbital osteotomies are performed as part of a craniofacial disassembly approach to a skull base tumor, the osteotomized segments are simply replaced at the completion of the procedure with no significant osseous deformity. However, precise restitution of the three-dimensional shape and position of the orbital skeleton is vital to decrease the perceived esthetic deformity that will follow significant orbital wall resection. Traditionally, significant osseous orbital defects in craniofacial surgery have been replaced most commonly with calvarial bone grafting using the principles of rigid internal fixation.[1–3] Resorption or secondary malposition is less often a concern with calvarial bone grafts as compared with other sites (iliac crest, rib, etc.).[4] Although calvarial bone graft reconstruction of significant orbital defects is straightforward in theory, achieving reliably rewarding esthetic and functional results is difficult. This is largely the result of the difficulty in reproducing the delicate three-dimensional contour of the native orbit with flat or only slightly curved bone grafts. In addition, orbital reconstruction with bone grafts may be time consuming, as well as having the potential for donor site morbidity. An ideal graft for orbital reconstruction would be biocompatible, be readily available in large quantities, have no donor site morbidity, become integrated over time by bony ingrowth, and allow for the formation of a stable three-dimensional construct.

In this article, we outline our approach to this difficult reconstructive problem using titanium mesh impregnated with hydroxyapatite cement.

METHODS AND MATERIALS

All patients undergoing titanium mesh–hydroxyapatite cement reconstruction following resection of one or more bony walls of the orbit during skull base surgery were included in this review (Table I). A total of 14 patients were treated using this alloplastic construct by the author over a period of 3 years. Minimum follow-up of 6 months was achieved in each case. There was no infection or implant exposure in any of the treated cases. A number of the implants were in contact with the ethmoid and/or maxillary sinuses. No adverse effects were noted in this subset. Epithelial or mucosal coverage of the exposed area of implant was noted in each case by 6 months as evidenced on flexible fiberoptic endoscopy. It is the author's standard practice to either cranialize or obliterate a frontal sinus that is opened in craniofacial procedures. Thus, no implants were in contact with non-obliterated/non-cranialized frontal sinuses. Six of the 14 patients underwent a full course of external beam therapy for planned adjuvant treatment of malignant neoplasms. Radiation therapy was initiated by the 8th week in each case. Doses in this group ranged from 55Gy to 70 Gy. No adverse outcomes related to the implanted hardware were noted in this subset of patients. The remaining patients were treated for a variety of osseous neoplasms and non-neoplastic destructive lesions necessitating orbit wall resection. Four patients underwent biopsy of the construct at various points in their postoperative period (range, 6 mo–3 y) when they had occasion to undergo general anesthesia for other procedures. Bone ingrowth into the complex was confirmed on histologic evaluation of each of the specimens examined.

Technique

Following surgical extirpation, the orbital reconstruction is initiated by evaluating the extent of bony loss (Fig. 1). The orbital wall defect is transferred onto an adult human skull encased in

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TABLE I.
Demographic Characteristics (minimum follow-up 6 mo).

Patient No.	Pathology	No. Orbit Walls Reconstructed	Radiation	Complications
1	Fibrous dysplasia	2 (S,M)	No	None
2	Cranio-orbital mucocele	2 (S,M)	No	None
3	Massive basal cell carcinoma	2 (S,L)	Yes	None
4	Osteoma	2 (S,L)	No	None
5	Rhabdomyosarcoma	3 (S,M,I)	Yes	None
6	Squamous cell carcinoma ethmoid	3 (S,M,I)	Yes	Dacryocystitis, synblepharon
7	Fibrous dysplasia	1 (S)	No	None
8	Fibrous dysplasia	2 (S,M)	No	Transient ptosis
9	Squamous cell carcinoma maxilla	2 (M,I)	Yes	None
10	Esthesioneuroblastoma	1 (M)	Yes	None
11	Cranio-orbital mucocele	2 (S,M)	No	None
12	Ossifying fibroma	2 (S,M)	No	None
13	Merkel cell carcinoma	2 (M,I)	Yes	Dacryocystitis
14	Meningioma	2 (S,L)	No	None

M = medial wall; S = superior wall; I = inferior wall; L = lateral wall.

sterile plastic on the surgical field (Fig. 2). This skull will serve as a general, yet remarkably accurate initial guide to formation of the initial construct. Next, 2.0-mm Leibinger dynamic titanium mesh (Stryker-Leibinger, Kalamazoo, MI) is trimmed to size and contoured to match the defect on the skull model. At this point, it is transferred to the surgical defect and adjustments are made based on the patient's orbit. Next, hydroxyapatite cement (Bone-Source, Stryker-Leibinger, Kalamazoo, MI) is impregnated into the titanium mesh scaffold on the orbit side and tested in situ as this may affect orbital volume (especially if three walls are reconstructed) (Fig. 3). Adjustments may still be made at this point before complete impregnation and setting. Finally, the construct is impregnated completely on the contralateral side with the cement and allowed to set on a side table for 30 minutes (Fig. 4). Now, the completed titanium mesh–hydroxyapatite construct is rigidly fixated to the surrounding bone. A laterally based pericranial flap is then wrapped around as much of the construct as possible before wound closure.[5] The patients are kept on oral first-generation cefazolin and metronidazole for 10 days postoperatively (Figs. 5–13).

DISCUSSION

Reconstruction of the orbit is vital, not only for restoration of esthetic symmetry, but also for functional concerns. Anatomically correct separation of the orbital con-

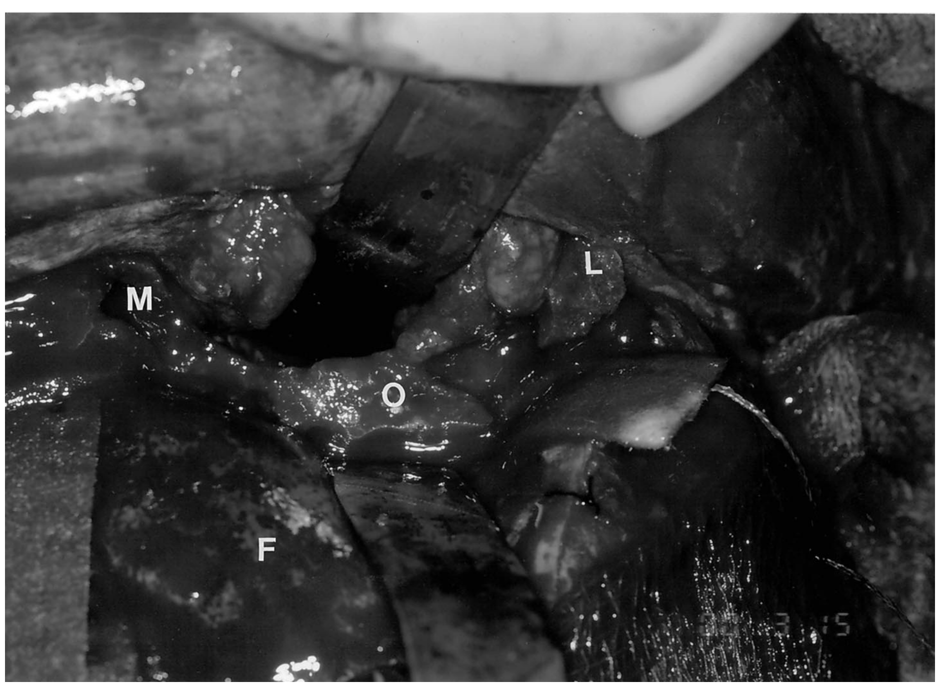

Fig. 1. Intraoperative view of orbito-cranial approach to a patient with right-sided orbital fibrous dysplasia causing compression of the optic chiasm. Orbital bar has been removed, allowing access to the markedly abnormal roof demonstrated here. M = medial; L = lateral; O = markedly thickened orbital roof; F = frontal lobe.

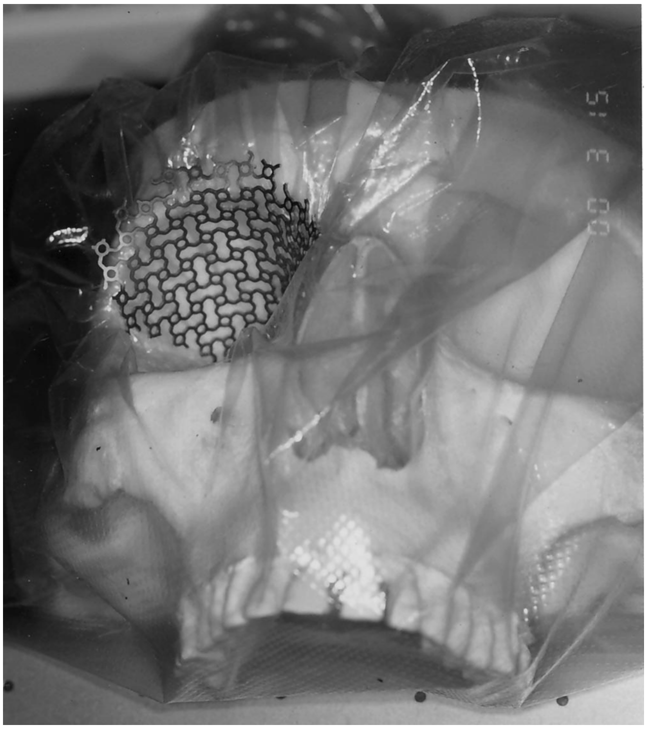

Fig. 2. Following surgical removal of orbital roof to allow for optic apex decompression, the surgical defect is analyzed and titanium mesh is then initially contoured onto a human skull model wrapped in a sterile bag on a surgical side table.

Fig. 4. Final titanium mesh scaffold completely (on orbital and brain sides) impregnated with hydroxyapatite cement on a side table.

Fig. 3. The scaffold, impregnated on the orbital side with cement is tested in situ, where final adjustments are made.

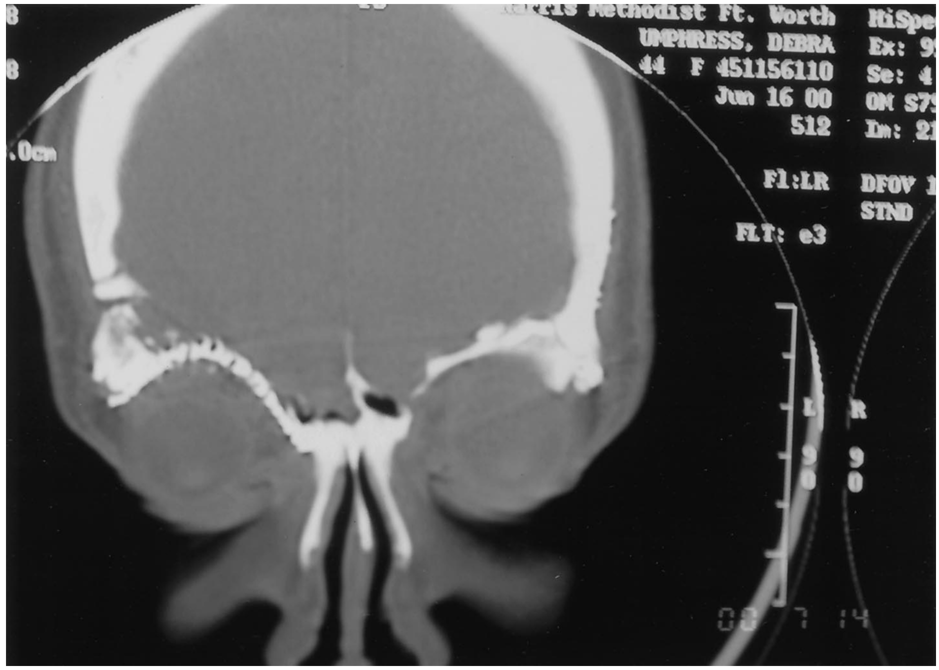

Fig. 5. Postoperative coronal CT scan demonstrating adequate reconstruction of the three-dimensional orbital contour on the patient's right side.

Fig. 6. Postoperative three-dimensional CT scan of same patient demonstrating good orbital apex decompression and adequate restoration of orbital shape as compared with the normal left side.

Fig. 7. Preoperative appearance of patient pictured in Figures 1–7.

Fig. 8. Postoperative appearance of patient in Figure 7.

tents from the temporal and frontal lobes of the brain is necessary to maintain centric globe position and decrease the risk of dystopia and diplopia. In addition, this decreases the likelihood of transmitting cerebrovascular pulsations to the orbit, which may be disturbing to affected patients.[6] We prefer the use of autologous calvarial and

Fig. 9. Preoperative coronal CT scan of patient with massive left-sided orbital osteoma causing optic nerve compression.

Fig. 10. Preoperative basal view of same patient demonstrating severe left-sided exorbitism.

rib grafts in the reconstruction of the developing pediatric orbit following resection. The ability of these grafts to become integrated over time, with subsequent growth in keeping with the overall growth of the pediatric maxillofacial skeleton, makes this the material of choice in this age group.[1] In addition, calvarial bone grafts in this age group are fairly malleable, allowing reconstructive surgeons to reproduce the curvature of the orbit with relative ease. This is not the case in the adult requiring orbital wall reconstruction, in which subsequent growth and the necessity of the reconstruction to remodel over time and the poor compliance of adult calvarial bone grafts make this a more difficult surgical option to accomplish with reliably rewarding outcomes. Thus, a number of osseous alternatives have been proposed over time, including microvascular free tissue transfer and pedicled calvarium-bearing flaps.[7,8] Both of these approaches are associated with some difficulty in reproducing the orbital contour while maintaining intraorbital volume, especially when more than one wall of the orbit is involved. Thus, a variety of alloplasts have been used for this purpose.[9–11] The potential for long-term implant infection and extrusion and the ability of the construct to withstand radiation make these options less desirable.

Titanium is a corrosive-resistant, non-magnetic metal with a favorable modulus of elasticity, closely resembling that of bone.[12] It represents the most biocompatible metal that is widely available. Hydroxyapatite consisting of interlinked chains of calcium phosphate has been shown to be osteoconductive at a number of sites.[13–15] In addition, hydroxyapatite appears to be well tolerated even when placed in direct contact with dura.[16] The titanium mesh serves as a stable scaffold for the subsequent ingrowth of bone into the hydroxyapatite cement. This was confirmed on histologic evaluation of the specimens in this series. In fact, there was early evidence of osseous ingrowth at sites within the complex that were more than 3 cm removed from the closest native bone. This may be related to pluripotential cells at the recipient being stimulated in part by the localized increase in fibro-

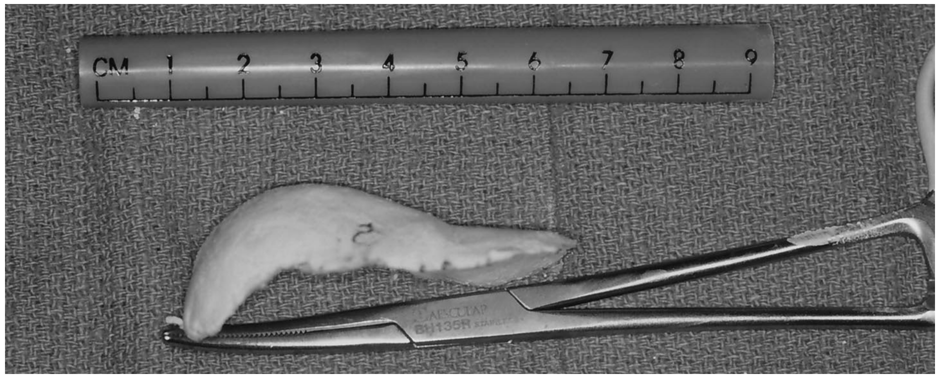

Fig. 11. Completed orbital roof and lateral orbital wall construct following tumor extirpation.

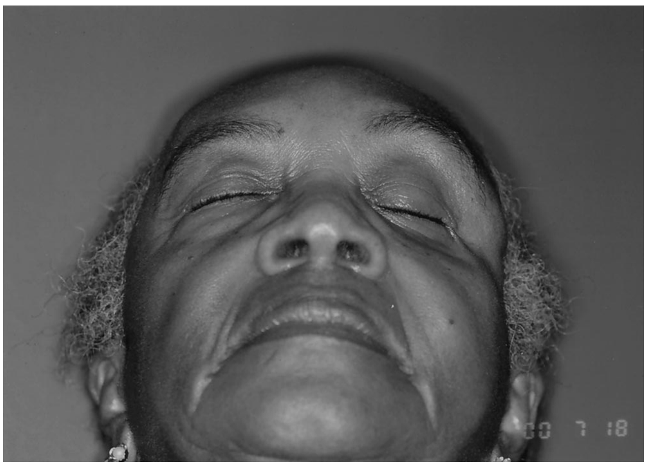

Fig. 12. Postoperative basal view of patient in Figures 10–12 demonstrating reasonable restoration of orbital shape and relief of exorbitism.

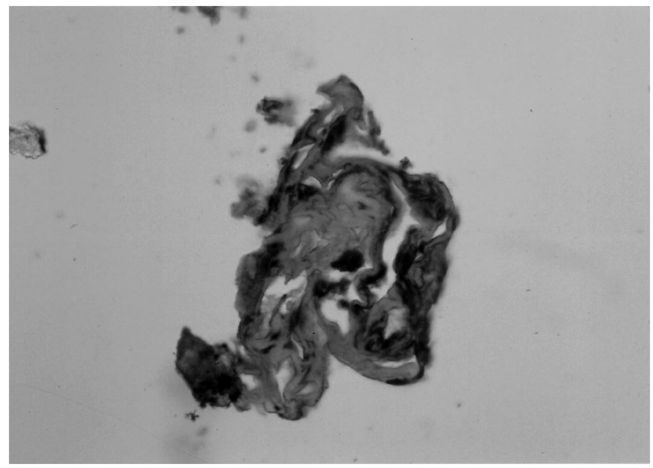

Fig. 13. Specimen taken from complex demonstrating evidence of osseous trabecular ingrowth into the hydroxyapatite cement.

blast growth factors leading to an increase in bony ingrowth into the hydroxyapatite.[12,17] Bone morphogenic protein may accelerate this process, but this was not studied in this patient population.[18]

In summary, the use of hydroxyapatite cement-impregnated titanium mesh appears to be a safe, reliable, and simple technique leading to reliably rewarding results in orbital reconstruction following skull base surgery.

BIBLIOGRAPHY

1. Derome P. Les tumeurs spheno-ethmoidales (possibilites d'exerese et de reparation chirurgicales). *Neurchirurgie* 1972;18:160–164.
2. Ilankovan V, Jackson IT. Experience in the use of calvarial bone grafts in orbital reconstruction. *Br J Oral Maxillofac Surg* 1992;30:92–96.
3. Martinez-Lage JL. Bony reconstruction in the orbital region. *Ann Plast Surg* 1981;7:464–479.
4. Ducic Y, Hamlar DD. Fractures of the midface. *Facial Plastic Surgery Clinics of North America* 1998;6:467–485.
5. Ducic Y, Stone TL. Frontal sinus obliteration utilizing a laterally based pedicled pericranial flap. *Laryngoscope* 1999; 109:541–545.
6. Gaillard S, Pellerin P, Dhellemmes P, Pertuzon B, Lejeune JP, Chritians JL. Strategy of craniofacial reconstruction after resection of spheno-orbital en plaque meningiomas. *Plast Reconstr Surg* 1997;100:1113–1120.
7. Bite U, Jackson IT, Wahner HW, Marsh RW. Vascularized skull bone graft in craniofacial surgery. *Ann Plast Surg* 1987;19:3–15.
8. Kobayashi S, Kakibuchi M, Masuda T, Ohmori K. Use of vascularized corticoperiosteal flap from the femur for reconstruction of the orbit. *Ann Plast Surg* 1994;33:351–357.
9. Mayer R, Brihaye J, Brihaye-van Geertruyden M, Noterman J, Schrooyen A. Reconstruction of the orbital roof by acrylic prosthesis. *Modern Problems in Ophthalmology* 1975;14: 506–509.
10. Piotrowsky W, Beck-Mannagetta J. Surgical techniques in orbital roof fractures: early treatment and results. *J Craniomaxillofac Surg* 1995;23:6–11.
11. Allard RH. Orbital roof reconstruction with hydroxyapatite implant. *J Oral Maxillofac Surg* 1982;40:237–239.
12. Ducic Y. Midface reconstruction with titanium mesh and hydroxyapatite cement: case report. *Journal of Craniomaxillofacial Trauma* 1997;3:35–39.
13. Sires BS, Benda PM. Osteogenesis in a human hydroxyapatite orbital implant 5.5 years after implantation. *Am J Ophthalmol* 2000;130:368–369.
14. Boyne JP, Fremming BD, Walsh R, Jarcho M. Evaluation of ceramic hydroxyapatite in femoral defects. *J Dent Res* 1978;57A:108–110.
15. Constantino PD, Friedman CD, Jones K, Chow LC, Pelzer

HJ, Sisson GA Sr. Hydroxyapatite cement. *Arch Otolaryngol Head Neck Surg* 1991;117:379–382.
16. Zide MF, Kent JN, Machado L. Hydroxyapatite cranioplasty directly over dura. *J Oral Maxillofac Surg* 1987;45: 481–486.
17. Wang JS, Aspenberg P. Basic fibroblast growth factor promotes ingrowth in porous hydroxyapatite. *Clin Orthop* 1996;333:252–256.
18. Ono I, Gunji H, Kaneko F, Saito T, Kuboki Y. Efficacy of hydroxyapatite ceramic as a carrier for recombinant human bone morphogenetic protein. *J Craniomaxillofac Surg* 1995;6:238–244.