Spheno-orbital Reconstruction after Meningioma Resection

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ABSTRACT

This report details a technique for spheno-orbital reconstruction after meningioma resection. The approach uses a life-size skull model generated from a thin-slice craniomaxillofacial computed tomogram. On this skull model, the planned area of bone removal of the involved orbit and sphenoid is outlined on the normal side opposite the lesion. A three-dimensional implant is then generated by reversing the anticipated area of bone resection on the normal side to create a mirror-image implant. This technique resulted in minimal intraoperative implant contouring, decreased surgical time, and satisfactory functional and cosmetic outcome.

KEYWORDS: Computer model, custom cranial implant, “reversed implant”, spheno-orbital reconstruction

Spheno-orbital reconstruction after tumor resection can prove challenging from a technical and aesthetic standpoint. While spheno-orbital reconstruction after tumor resection has been considered as unnecessary by some,^{1,2} reconstruction has been suggested for several reasons: structural, cosmetic, and to provide landmarks for postoperative imaging.³ Furthermore, if spheno-orbital reconstruction is not performed after lesion resection, several potential problems might occur: meningocele formation, diplopia from extraocular muscle fibrosis, orbital pain, pulsating enophthalmos, and restrictive ptosis.^{3–7} Reconstruction of this area has

employed several materials—split calvaria,^{3,5,7} rib grafts,^{4,8} iliac crest,⁹ titanium mesh^{3,7,10–12} and other synthetic materials^{3,4,10,11,13}—and used a variety of techniques including a number of computer-generated models.^{11–14}

Our technique uses a “reverse” or mirror-image implant from a computer-generated model to reconstruct the spheno-orbital area. This approach was employed in two patients after meningioma resection. The usefulness of this method of reconstruction and some lessons learned from this technique are the subject of this report.

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Received: May 9, 2008. Accepted: July 9, 2008. Published online: October 30, 2008.

DOI 10.1055/s-0028-1096199. ISSN 1531-5010.

Figure 1 Model generation computed tomography (CT) scan and reformat. (A) Thin-cut CT scan slices on reference view of the craniomaxillofacial area of patient 1 are shown. (B) These data are used for coronal, surface, and three-dimensional reformats and for generation of the computer model.

TECHNIQUE

A helical computed tomogram (CT) of the craniomaxillofacial bones is performed with the occlusal plane parallel to the gantry. Scans use a slice thickness of 1.0 to 1.2 mm and spacing of 1.0 to 1.25 mm (Fig. 1A). Coronal, surface, and three-dimensional reformats (Fig. 1B) are available locally. A computer disc of the original CT is sent for processing (Medical Modeling LLC, Golden, CO). A three-dimensional skull model is returned for surgical planning. The model is marked in two places. One is the area of bone resection ipsilateral to the lesion, from which a cranioplasty is made. The other is the corresponding portion of the orbit, sphenoid, and zygoma contralateral to the tumor. These latter outlined areas are then “reversed” to make an implant for reconstruction of affected bone after planned tumor resection. A prototype model is returned for further approval or additional editing. If satisfactory, two implants (Biomet Microfixation, Jacksonville, FL) are made and shipped to the hospital.¹⁵

The cost of the CT is the same as that of a conventional maxillofacial CT (\$832, exclusive of the radiologist fee). The time for the entire process

is ~25 working days. The cost for the skull model with prototypes and two sterile implants ranges from \$6000 to \$7000 depending on the complexity of the reconstruction.

The implants are made of polymethylmethacrylate spherical macrobeads that are coated and fused together with polyhydroxyethylmethacrylate. The implant is rendered radio-opaque by coating it with barium sulfate and is grafted with calcium hydroxide to promote bone growth.¹⁶

The implants have several features. First, the hardness is similar to bone and is compatible with drill and screw fixation. Second, the implant is nonresorbable. Third, the implant is porous which allows for blood product penetration and vascular ingrowth. Fourth, the implant is radio-opaque.¹⁶

CASE REPORTS

Case 1

A 52-year-old woman was evaluated for left orbital swelling. Ophthalmologic evaluation revealed the

Figure 2 Computed tomography (CT) scan of patient 1. (A–D) Preoperative axial and (E–H) coronal CT scans with bone window settings illustrate hyperostotic bone due to an intraosseous meningioma.

following left-sided abnormalities: exophthalmos; 1 + edema of the upper and lower lids; medial rectus limitation of ~ 40 degrees; applanation pressure of 17 mm Hg (14 mm Hg on the right); and normal visual acuity and visual field. A CT scan of the orbit was interpreted as fibrous dysplasia. She was treated conservatively. She did not keep subsequent appointments and was lost to follow-up. When she returned nearly 8 years later, she had marked progression of her left orbital abnormalities. Examination revealed the following: 3- to 4-mm inferior globe displacement with 10 mm of proptosis; visual

acuity of 20/200; moderate relative afferent pupillary defect; dense superior and inferior arcuate scotoma with approximately 15 degrees of central island on Goldmann visual field; severe punctate corneal staining with fluorescein; marked scleral injection and hyperemia; lagophthalmos; diplopia on lateral gaze; and equivocal hypoesthesia over V1. While standard CT with bone windows showed the progression of her disease (Fig. 2), a thin-cut CT of the craniomaxillofacial bones was performed with coronal, surface, and three-dimensional reformat for generation of a computer model (Fig. 3).

Figure 3 Computer-generated skull model for patient 1. (A,B) Area of the orbit and zygoma to be resected on the involved left side is marked on the model's right side. (C) Lateral view of the tumor side shows cranial osseous area to be resected. (D) Planned resected areas of bone are shown on the model. The marked area on the right is then reversed to generate the implant to be used after tumor resection. (E) Frontal and (F) lateral views of the reversed replacement orbitozygomatic implant are shown. A cranioplasty is generated to replace this anticipated area of bone removal shown in (C). Model replacement for all parts of involved bone are seen from (G) oblique frontal and (H) lateral perspectives.

Figure 4 Photographs of patient 1 show inferior orbital displacement and exophthalmos (A) preoperatively and (B) results after surgery.

The patient underwent the following procedure: a left frontotemporal craniotomy and orbitozygomatic osteotomy; removal of dysplastic bone from the orbit, middle fossa, and zygoma; unroofing of the optic canal and superior orbital fissure; and sphenoorbital reconstruction using the computer-generated implant. Her 4-day hospitalization was uneventful. The final pathology was intraosseous meningioma.¹⁷ On postoperative ophthalmological testing, the following improvements were noted: corneal exposure; globe position; proptosis (3.5 mm); conjunctival appearance; eyelid closure; ocular motility (full); and visual acuity (20/60). Her relative afferent pupillary defect resolved and her intraocular pressure was normal. Significant but incomplete tumor resection was documented on a CT scan done 5 weeks postoperatively. Her appearance was significantly improved (Fig. 4).

Case 2

A 33-year-old woman noted left eye swelling 7 months before being evaluated. However,

these changes had most likely been present for several years based on a review of available old photographs. A brain magnetic resonance and CT scan (Fig. 5A–D) were obtained. The following left orbital problems were noted: 4 mm of proptosis; upper lid fullness; and an asymmetric large pupil that responded directly to light. Visual fields, acuity, and funduscopic exam were normal. A special CT scan was performed to generate a computer model to plan for tumor resection and reconstruction (Fig. 6). The patient then underwent a left frontotemporal craniotomy and orbitozygomatic osteotomy with resection of bone and tumor, followed by reconstruction. Surgery and her 3-day hospitalization were uneventful. The pathological diagnosis was meningioma. The results of surgical resection and reconstruction were documented by a CT scan (Fig. 5E–H) done 5 weeks postoperatively. After surgery, her left orbital findings were decreased exophthalmos of 2 mm, unchanged asymmetric pupil size, and trace adduction deficit. Her acuity and visual fields remained normal.

Figure 5 Computed tomography (CT) scans of patient 2. Axial CT scan with bone window settings show (A–D) bone involvement by tumor preoperatively and (E–H) results after resection and reconstruction. Bone replacement in the left lateral orbit is overcorrected (white arrow), as shown in Part E.

DISCUSSION

Reconstruction of the spheno-orbital area has used a variety of techniques.^{3–5,7–14} The advantages of our approach are two. First, the preoperative model allows the surgeon to plan the resection and reconstruction before surgery because the model shows the pathology in three dimensions. Second, the implant accurately restores the complex three-dimensional structure of the resected bone in a manner unachievable by bone grafts from the calvarium, rib, or iliac crest. Use of this implant results in superior reconstruction of an anatomically complex area with good functional globe position,

satisfactory extraocular muscle function, and excellent postoperative cosmetic appearance.

Based on our experience, slight overcorrection of the implant is preferred. The implant is easily revised intraoperatively using standard instruments to contour bone. Even though the implant is custom-generated to match the planned defect, careful intraoperative assessment is required to ensure that the anticipated and true defects correlate and that the implant correctly fits into the defect. Despite intraoperative evaluation and editing of the implant to fit the defect, overcorrection may still occur (Fig. 5E). To circumvent this potential mismatch between the anticipated defect and implant,

Figure 6 Computer-generated skull model for patient 2. (A) Temporal area of skull resection and (B) contralateral area of orbital region that is to serve as a "reverse" implant are shown. (C) Planned areas of bone resection are shown. (D) Appearance after placement of "reverse" orbital implant is illustrated.

an intraoperative CT with bone windows may prove helpful.

ACKNOWLEDGMENTS

The authors thank J. Corbitt for manuscript preparation, J. Murphy for help with the figures, and Drs. A. Fontanilla and S. Kuric for patient referral.

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