Evaluation of Three Cases Using a Novel Titanium Mesh System—Skull-Fit[®] with Orbital Wall (Skull-Fit WOW[®])—For Cranial Base Reconstructions

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ABSTRACT

Cranial base reconstructions associated with tumor resections around the orbital wall often require that both the upper and lateral orbital walls be reconstructed during a single procedure. Previously, we used titanium mesh plates that were preoperatively fabricated based on three-dimensional models. Although these plates are precise and do not increase the probability of infection, we still had to use autologous bones to reconstruct the orbital walls. Recently, we developed a new titanium mesh plate—called Skull-Fit[®]—with orbital wall (Skull-Fit WOW[®]), enabling us to reconstruct the cranial base and orbital walls without bone grafts. Here, we report on three reconstruction cases in which the novel titanium mesh-orbital wall system was used. In all three cases, the customized titanium mesh system performed satisfactorily with little, if any, complications.

KEYWORDS: Titanium mesh plate, skull base reconstruction, Skull-Fit WOW[®], meningioma

For decades, following neurosurgical extirpations of tumors, surgeons used autologous bone grafts to reconstruct the skull and cranial base, a procedure that was very invasive and time-consuming. More recently, surgeons used titanium mesh plates manufactured according to precalvarial construction models for skull reconstructions. Although these titanium plates are very useful and precise, surgeons still had to use autologous bones for orbital rim and upper and lateral wall reconstructions. Surgical invasiveness was still excessive.

To overcome these shortcomings, we recently developed a novel titanium mesh plate system fitted with an orbital wall called Skull-Fit WOW[®].

METHODS

During a preoperation conference, we carefully discussed details about the proposed tumor resections (location and extent) with neurosurgeons. On the basis of these discussions, we demarcated the predicted skull defects

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that would result from the proposed resection operations and constructed custom-made models from three-dimensional computed tomography (3-DCT) images of each patient (Figs. 1A and 1B). Next, we constructed the actual 3-D titanium mesh plates, which comprised both a calvarium portion and an orbital wall (Skull-Fit WOW[®]) (Figs. 1C and 1D). Construction of the customized plates was done preoperatively.

Case 1

A 31-year-old woman complained about exophthalmos of the right eye. Previously, she had undergone meningioma resection twice. Later, the meningioma recurred in the right sphenoid wing. Radical resection of the tumor was not indicated; however, surgery to improve the exophthalmos was indicated. Before the operation, we constructed a custom 3-D titanium mesh plate

(Skull-Fit WOW[®]) (Figs. 1C and 1D) for covering the temporal bone and the lateral orbital wall overlying the part of the tumor to be extirpated.

The neurosurgical procedure resulted in a skull defect involving approximately two-thirds of the lateral and upper orbital walls and temporal fossa (Fig. 2A). We adjusted the preoperatively made Skull-Fit[®] plate to fit the existing defect, and fixed the temporalis muscle and fascia flap¹ onto the titanium mesh plate (Fig. 2B).

Figs. 3A and 3B present 3-DCT and X-ray images taken immediately after the operation showing the area reconstructed with a titanium mesh plate, which extended from the lateral orbital wall to the temporal area. Although the patient exhibited exotropia 6 months after the operation, exophthalmos had improved and her facial contours, from the lateral orbital wall to temporal area, appeared esthetically reconstructed.

Figure 1 (A) and (B) A custom-made model based on preoperative, three-dimensional computed tomography (3-DCT) images of a patient. The model shows the extent of the proposed defect resulting from tumor resection surgery. (C) and (D) The model in (A) and (B) is shown here fitted with a 3-D titanium mesh plate with orbital wall (Skull-Fit WOW[®]) fixed over the proposed defect.

Figure 2 (A) Intraoperative view of Case 1 showing the bone defect after tumor resection. (B) Intraoperative view showing the reconstructed area fitted with Skull-Fit WOW[®] and temporalis muscle and fascia flap.

Figure 3 (A) Postoperative 3-DCT and (B) X-ray of Case 1 showing the area reconstructed with a titanium mesh plate with orbital wall.

Case 2

A 52-year-old woman complained about exophthalmos of the left eye. She had undergone meningioma resection three times, which was followed by the recurrence of meningioma of the left orbit. As in the previous case, radical resection of the tumor was not indicated; however, surgery to improve the exophthalmos was indicated. We constructed preoperatively a custom 3-D titanium mesh plate (Skull-Fit WOW[®]) (Figs. 4A and 4B) for covering the temporal bone and the lateral and upper left orbital walls.

Partial resection of the tumor resulted in a skull defect extending from the upper half of the lateral orbital wall to the temporal fossa (Fig. 5A). We used a pericranio-galeal flap for reconstructing a dural defect and for closing a gap between the brain and paranasal sinuses. Since little soft tissue remained in the temporal fossa following the dural repair procedure (Fig. 5B), we used phospho-calcium bone paste (Biopex[®]) to repair the temporal fossa (Fig. 5C).

Figs. 6A and 6B presents 3-DCT images taken after the procedure showing smooth lines around the area reconstructed with the titanium mesh plate and bone paste, which extended from the lateral orbital to the temporal area. Although the patient displayed ptosis of the left eye 3 months after the reconstruction, her overall facial lines appeared well reconstructed (Figs. 6C and 6D). We chose not to treat the ptosis because the treatment could have potentially caused ocular supra-duction impairment.

Case 3

A 46-year-old woman complained about headache, exophthalmos of the right eye, and double vision (Figs. 7A and 7B). She was diagnosed with a recurrence of meningioma in the right sphenoid wing. She subsequently underwent neurosurgery to remove the tumor.

As with the other two cases, we constructed preoperatively a custom titanium mesh plate to cover

Figure 4 Case 2: (A) Preoperative model showing a custom-made Skull-Fit WOW[®] from frontal and (B) lateral views.

skull defects resulting from the surgical extirpation of the tumor (Figs. 8A and 8B). The operation caused a skull defect involving half of the upper orbital wall and lateral orbital wall extending to the temporal fossa (Fig. 9A). Since the frontal sinus had to be opened during the operation, part of the temporal fascia was used to close the opening. We elevated the pericranial flap using the remaining temporal muscle, and then the flap was used

to reconstruct the dura (Figs. 9C and 9D). Postoperative 3-DCT indicated that the reconstruction was in good shape (Fig. 10A). Although a local infection developed after surgery, we were able to treat it successfully without removing the titanium mesh plate by irrigating the area. The temporal area appeared bulky; thus, we plan an operation to reduce the bulging in near future (Figs. 10B and 10C).

Figure 5 (A) Intraoperative views of Case 2 (Figs. 4 and 6) showing the bone defect after tumor resection. (B) Intraoperative views showing the reconstructed area fitted with Skull-Fit WOW[®]. (C) The temporal fossa was repaired with Biopex[®].

Figure 6 (A) Postoperative 3-DCT and (B) X-ray images of Case 2 showing the area reconstructed with a titanium mesh plate with orbital wall and bone paste. Postoperative photographs showing frontal (C) and lateral (D) views of the reconstructed area. Note that the facial line contours are good.

DISCUSSION

Extensive tumor resection (e.g., meningioma in the sphenoid wing) often requires reconstruction of both the calvarium and orbital walls. In previous orbital wall reconstructions, we used autologous bone grafts. Autologous bone grafting, however, can cause donor-site morbidity and bone resorption. Moreover, bone-grafting surgery is technically difficult, imprecise, and time-consuming. Because the shape and size of grafts often do not conform fully to the area to be reconstructed, orbital volume is quite difficult to control intraoperatively.

Recently, bone paste calvarium reconstructions have been reported.² Although bone paste is a facile and suitable tool for creating small contours, it is not suitable for repairing large calvarial defects because the material is too fragile. On the other hand, titanium mesh plates are constructed of tough material that can withstand significant external forces.

Although cases exist in which titanium mesh plates were used to reconstruct sphenoid wing,³ calvarium,⁴ and orbit⁵ defects resulting from tumor resection surgery or trauma, there are no reports of using titanium mesh plates to cover both the calvarium and orbital wall. In this study, we described a novel tool—Skull-Fit WOW[®]—for reconstructing large areas of calvarium and adjacent orbital wall unavoidably damaged by tumor resection surgery simultaneously. The new aspect of our method is the simultaneous reconstruction of the temporal bone and the lateral orbit with a single implant.

Our novel method is revolutionary and has many advantages over previous methods. First, with Skull-Fit WOW[®], bone grafting is no longer needed. Thus, the operation is simpler and completed more quickly. Since meningiomas recur at a relatively high rate,⁶ most patients with meningiomas face the prospect of undergoing several resection operations. Thus, reducing the

Figure 7 Case 3: Preoperative photographs showing frontal (A) and lateral (B) views of a 46-year-old woman complaining of headache, exophthalmos of the right eye, and double vision.

time and complexity of these operations is very important, as doing so will reduce physical stress to patients.

Second, another important advantage is that Skull-Fit WOW[®] allows surgeons to control intraoperatively the volume of the orbital cavity. We can construct the titanium mesh plate around the orbital area to fit the existing bone defect, as the mesh is easy to bend and can be cut to fit. Dividing the plate into upper and lateral orbital walls also enables us to rearrange the plate intraoperatively. This flexibility is especially useful for avoiding exo- and enophthalmos, because it is sometimes very difficult to predict orbital volume after tumor resection.

Third, another advantage of titanium mesh plates is that it is easier to position and attach ligaments to the plates than to autologous or artificial bone grafts. For

example, the re-positioning of the lateral canthal ligament following orbital reconstruction surgery proceeds with relatively little effort. As the lateral canthal ligament is the main ligament responsible for maintaining lateral eye position, its fixation should be done carefully. In our system, we use strings to fix the lateral canthal ligament to the mesh plate. The mesh plate allows us to easily adjust and fine-tune the position of the ligament during the operation, which is critical for creating a natural postoperative appearance.

Although titanium plates are very useful for skull reconstructions, surgeons need to use caution when reconstructing the temporal region to prevent excavation in this area after reconstruction. In the temporal region, although a depression in the bone exists at the temporal

Figure 8 Case 3: (A) Preoperative model showing a custom-made Skull-Fit WOW[®] from frontal and (B) lateral views.

Figure 9 (A) Intraoperative views of Case 3 (Figs. 8 and 10) showing the bone defect after tumor resection. (B) Intraoperative views showing the reconstructed area fitted with Skull-Fit WOW[®] and pericranial flap (C).

Figure 10 (A) Postoperative 3-DCT image (oblique view) of Case 3 showing the area reconstructed with a titanium mesh plate with orbital wall. Postoperative photographs showing frontal (B) and lateral (C) views of the reconstructed area.

fossa, a person's external contours appear almost flat because of the temporal muscle and fascia overlying the bone. To achieve a natural-looking contour, surgeons need to know whether the temporal muscle and fascia flap will be used to reconstruct the dura. The thickness of the titanium mesh plate will depend on how the temporal muscle and fascia flap is used. Despite detailed preoperative planning and discussions, surgeons may have to place the temporal muscle flap or fascia under the plate for intracranial reconstruction. In uncertain situations like this, using artificial bone paste as a supplemental tool to create a natural temporal contour would be an acceptable alternative (Fig. 5C).

The risk of infection associated with titanium mesh plates used for orbital reconstructions is very low.⁵ One case (Case 3) experienced a local infection after surgery, but we treated it successfully without removing the titanium mesh plate by locally irrigating the area.

CONCLUSION

We report on three cases in which a novel titanium mesh system—Skull-Fit WOW[®]—was used to reconstruct

the orbital area and adjacent calvarium. This system has enabled us to both reduce operation time and physical stress to patients and produce highly aesthetic results without using autologous bone grafts.

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