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Case Report
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Use of a Titanium Mesh Plate with High Three-Dimensional Flexibility to Repair an Orbital Floor Fracture: Clinical Note

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Abstract

Orbital blowout fractures are common sequelae of facial trauma. For their treatment, it is now possible to make three-dimensional (3D) implants on the basis of computed tomography (CT) images, using rapid prototyping and to bend the implants preoperatively in the desired shape. However, in orbital fracture, the unique anatomy of the orbit makes the process of fitting and aligning such implants difficult and operator-dependent. Here, we report the use of a unique and newly developed titanium mesh plate with high 3D flexibility to repair an orbital floor fracture. This mesh plate was designed basically in a hexagonal polygon shape. By creating a grating opening in the plate it is possible to alter its 3D shape. The material has high stretch ability, and its mechanical properties could be controlled to adapt to the complex geometric form of the bone. Postoperative evaluation by CT revealed that the preoperatively bent mesh plate was precisely located at the preoperatively planned site. In conclusion, use of this mesh plate system in combination with 3D models can be useful for the treatment of orbital fractures.

Keywords: Orbital fracture; High three-dimensional flexibility; Titanium mesh plate; Hexagonal shape

Introduction

Orbital blowout fractures are frequent sequelae of facial trauma [1,2]. Defects of the orbital walls cannot be reduced; instead, the injured area must be reconstructed using an implant. The aim of this reconstruction is to restore the original shape and volume of the orbit. Many studies [3-6] have evaluated the use of implant materials, such as bone, cartilage, collagen membrane, titanium, and resorbable mesh, for the reconstruction of the orbit. Titanium mesh plates are biocompatible, readily available, and offer rigid support when used to repair orbital floor defects [7]. However, even an anatomically precise implant does not support the orbital soft tissue if it is not accurately positioned. The complex geometry of the bony orbit makes its reconstruction extremely challenging, and adjusting titanium mesh plates based on complex anatomic requirements can be time consuming, difficult, and technique-dependent [8]. To address these problems, models of the skull can be made preoperatively to assist with accurate intraoperative bending. Using rapid prototyping, it is now possible to make three-dimensional (3D) models based on computed tomography (CT) images [9]. These data can then be used to fabricate stereolithographic models for reconstruction. More recently, virtual surgical planning and computer-aided design/computer-aided manufacturing (CAD/CAM) techniques, including stereolithographic modeling and cutting guide-directed resection, have been increasingly used to reconstruct orbital floor defects [10]. However, they are costly and not available at all institutions.

Here we report the use of a newly developed titanium mesh plate with high 3D flexibility that can be easily and precisely bent for the reconstruction of orbital floor defects.

Presentation of Case

In February 2014, a 49-year-old Japanese man with enophthalmos of the left eye was referred to our hospital 2 weeks after suffering facial trauma. A clinical examination determined that his facial skeleton was intact. Despite having enophthalmos of the left eye, he lacked diplopia and had normal visual acuity. These findings were confirmed by the Division of Ophthalmology. CT scanning identified a defect in the mid-left orbital floor (20 × 18 mm) with herniation of the orbital contents into the underlying maxillary sinus. The patient gave informed consent to undergo reconstruction

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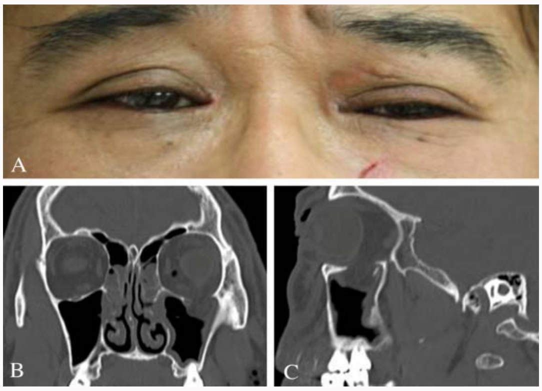

Figure 1: (A) Frontal aspect at admission, showing the intact facial skeleton with enophthalmos of the left eye. (B) Coronal and (C) Sagittal computed tomography images showing a defect in the mid-left orbital floor, with herniation of the orbital contents into the underlying maxillary sinus.

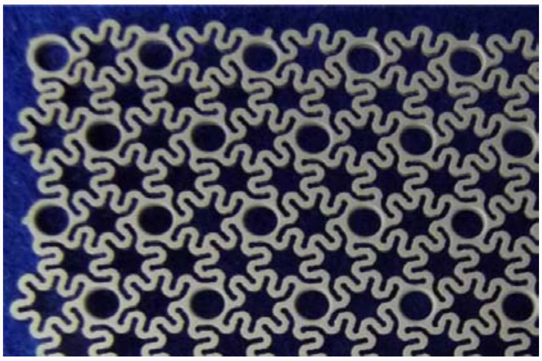

Figure 2: A titanium mesh plate with high three-dimensional flexibility was designed to create a basic hexagonal polygon shape.

of the orbital floor (Figure 1).

Preoperatively, a 3D volumetric model of the patient's skull was constructed using 3D software. The shape of the implant was designed by mirroring the shape of the intact opposite orbit. Three intact anatomic locations were chosen to design specific ledges to steer the implant into place using surface contacts.

A 3D implant model was created based on CT data. Then, 0.6 mm-thick titanium mesh plate was used to prepare reconstructive plates for reconstruction of the lower orbital wall. The titanium mesh plate was given a basic hexagonal polygonal shape designed to have very high 3D flexibility (Figure 2). The plate was cut to size and formed into the shape of the implant based on clinical symptoms, data from CT scans and the shape of the lower orbital wall in the 3D model. The aim was to precisely cover the bony defect and produce support for the orbital globe. Careful attention was paid to omit anatomic structures such as the lacrimal sac (Figure 3).

During surgery under general anesthesia, the orbital floor was explored via a transconjunctival incision. Herniated orbital tissue was reduced to restore the intraorbital structures, and fractured bone fragments were reduced. The preshaped titanium mesh plate was positioned to support the orbital globe. Because the shape of the implant perfectly conformed to that of the intact bone around the defect, the positioning of the plate was easy. Passive movement of the globe was evaluated at the end of the surgical procedure (Figure 4).

Postoperative evaluation by CT revealed that the mesh plate

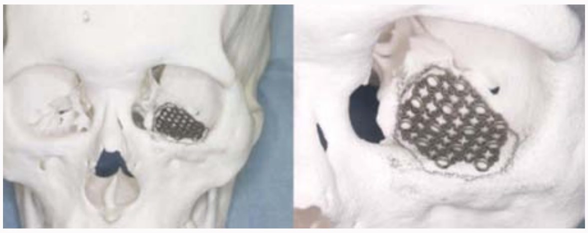

Figure 3: The implant was designed using a rapid prototype three-dimensional model that mirrored the shape of the intact opposite orbit. It was designed to precisely cover the bony defect and support the orbital globe.

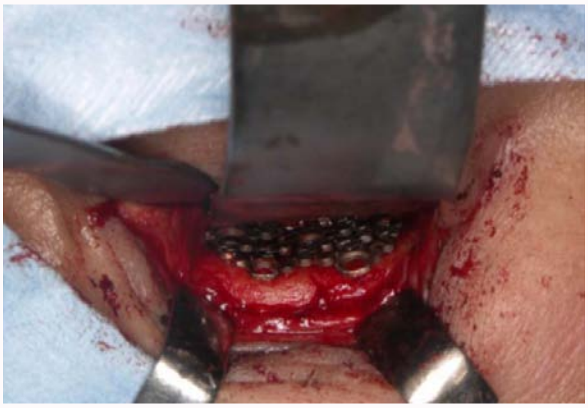

Figure 4: The preshaped titanium mesh plate was positioned to support the orbital globe in the left orbital floor. Because the implant conformed perfectly to the shape of the intact bone around the defect, positioning of the plate was easy.

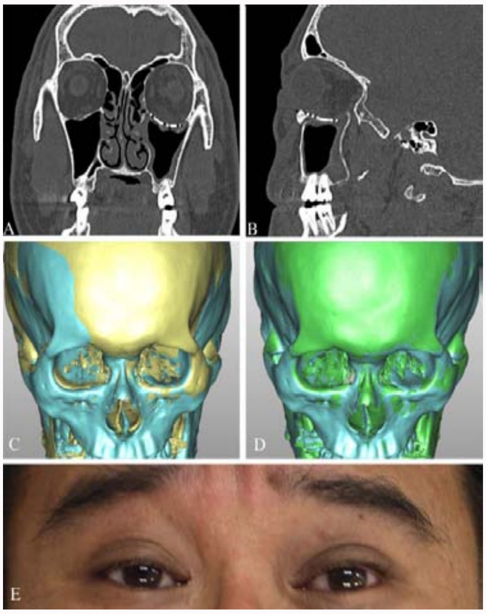

Figure 5: (A) Coronal and (B) Sagittal computed tomography (CT) images showinggoodreduction of the left orbital floor without herniation of the orbital contents. We evaluated the postoperative CT data using Sim Plant 11.04 (Materialise Dental Inc., Leuven, Belgium). Key: green skull, original preoperative image; yellow skull, mirror image created using the original preoperative image; bull skull, postoperative image. (C) The original preoperative three-dimensional (3D)-model image was evaluated overlapping the mirrored 3D-model image. (D) The mirrored 3D-model image was evaluated overlapping the postoperative 3D-model image. The preoperative bending of the implant was exactly similar to the preoperative plan. (E) Frontal aspect at 6-month follow-up, showing the improvment with enophthalmos of the left eye.

was located precisely at the preoperatively planned site (Figure 5). At a 6-month follow-up, the patient reported the improvement of the enophthalmos, and had not experienced complications such as changes in visual acuity or diplopia.

Discussion

Regarding the bending of titanium plates for orbital floor reconstruction, when not an emergency, mesh plates are often bent preoperatively to resemble as closely as possible stereolithographic models created by 3D mirroring [11]. However, because bending plates to match the complex forms of the infraorbital rim and orbital floor subjects them to strain, reproduction of the fine details of the bone can be challenging. Conventional mesh plate is used in maxillofacial reconstruction, because it is substantially rectangular in form and inelastic vertically and horizontally. Therefore, conventional mesh plate possesses poor stretching and bending capabilities [12]. As the plate form for maxillofacial reconstruction and was intended to not be exert a sufficient effect. Conversely, our mesh plate has a basic hexagonal polygonal shape. Creation of a grating in the plate confers high stretch ability, permitting alteration of its 3D shape and allowing complex bending. Reportedly, titanium mesh plates of hexagonal shape offer better 3D flexibility than triangular- and square-shaped mesh plates [12]. The hexagonal polygonal mesh plates used in this study allowed easy bending without distortion. Additionally, the margins of conventional mesh possess a sharp edge after cutting, which could become problematic in the intraorbital region. In contrast, the hexagonal polygonal mesh plate does not have sharp edges, because plate cutting is unnecessary.

This plate system, in combination with 3D models, is suitable for the reconstruction of orbital fractures. Furthermore, including the orbital floor, this system may also allow the complex bending necessary for periorbital reconstruction, such as for orbital rim, orbital medial and zygomatic fractures. Also, in contrast to CAD/CAM, this plate system does not require a large-scale preparation line, so the technique can be introduced and used in more institutions.

Conclusions

In this article, we reported the use of a newly developed titanium mesh with high 3D flexibility that can be easily and precisely bent for the reconstruction of orbital floor defects. The mesh plates used in this study allow advanced 3D bending, yielding a hexagonal polygonal structure. These titanium mesh plates have high flexibility, and their mechanical properties allow their adaptation to complex geometric bone forms, such as the orbital floor and rim.

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