Case Report

A novel individual reconstruction of a medial orbital wall blow-out fracture using a bone graft molded intraoperatively using a 3-D model: a case report

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ABSTRACT

This report describes the surgical reconstruction of a traumatic medial orbital wall blow-out fracture using an autologous calvarial bone graft modeled intraoperatively using a three-dimensional (3-D) fused deposition model of the fracture defect. Previous case reports have demonstrated the use of 3-D models in planning the surgical approach, selecting and fashioning the desired implant in the perioperative period, and even using models with sterile coverings intraoperatively to mold synthetic implants. This is an individually unique application of 3-D printing for the surgical repair of pure medical wall blow-out fracture.

1. Introduction

Orbital blow-out fractures can be the cause of both serious ophthalmic and aesthetic complications; additionally, they can pose significant technical challenges to the plastic surgeon to repair [1–3]. The vast majority of orbital blow-out fractures result from trauma or assault, with the greatest prevalence in the male population between 21 and 30 years of age [4,5]. Serious ophthalmic complications include visual disturbance, diplopia, and enophthalmus; additionally, significant aesthetic disturbance may result even with mild facial asymmetry [2]. Surgical repair and the subsequent timing of repair are somewhat controversial, but indications for surgical intervention include significant enophthalmos, hypoglobus, diplopia, and large orbital floor defects ([3,6–8]).

The use of three-dimensional (3-D) models has significantly aided the surgical planning and treatment outcome of both pathologic and traumatic maxillofacial conditions [9]. The use of 3-D models has been applied extensively in orbital fractures, as surgical guides, in teaching and educational roles, as templates for shaping and molding implants, aiding in planning surgical approaches, and in choosing incision sites [9,10]. The following case report demonstrates a novel use of a 3-D–printed model to shape a calvarial bone graft intraoperatively for a pure medial wall blow-out fracture.

2. Case report

An 18-year-old man was referred to the department of Plastic and Reconstructive Surgery at Royal Perth Hospital after an alleged assault resulting in a traumatic blow-out fracture of the medial wall of the left orbit. The computed tomography (CT) revealed a left orbital medial wall blow-out fracture without medial rectus entrapment, with moderate left periorbital soft-tissue swelling and a moderate degree of left-sided proptosis (Figure 1). The patient’s medical history was significant only for amblyopia of the right eye as a child and bilateral refractive error treated with spectacles.

On examination, there was a significant periorbital swelling and a large conjunctival hematoma, with mild enophthalmos. A small hyphema and corneal abrasion were noted, and no relative afferent pupillary defect was observed. Range of motion was limited because of pain and swelling, but visual acuity was unaffected, with both infraorbital and supraorbital nerves intact. Surgery was eventually planned 6 weeks later because of persistent nonattendance when significant enophthalmos had developed.

The case was referred to the Department of Medical Engineering and Physics at Royal Perth Hospital for operative planning and

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generation of a 3-D fused deposition model for intraoperative use (see Methods section).

The patient was scheduled for orbital bone graft under a general anesthesia. A calvarial bone graft was harvested and molded to fit the fracture defect using the 3-D reconstructed model (Figure 2). A coronal approach was used, the globe contents were delivered from the ethmoid sinus, and the molded graft was inset into the medial wall defect. The resultant calvarial bone graft donor site defect was repaired with 5 mL of HydroSet. The patient was discharged the following day after a postoperative CT was performed, demonstrating a 30% reduction in enophthalmos (Figure 3) calculated radiologically. Follow-up appointments were arranged on 3 separate occasions at 2 weeks, 3 months, and 1 year, without success. The patient has not subsequently been seen or admitted at any Western Australia public hospitals since his operation.

3. Methods

A high-resolution multi-slice CT scan (helical with 0.9 mm slice thickness, variable slice spacing) was acquired using a Philips Brilliance 64 CT scanner (Philips Healthcare, Best, Netherlands). The CT data were stored using the Digital Imaging and Communications in Medicine medical image file format. The data were processed using the medical modeling software package Mimics (Materialise NV, Leuven, Belgium). A mask was created by thresholding based on Hounsfield units corresponding to bony intensity. The mask was cropped and manually edited to isolate the left orbital bony anatomy. A virtual 3-D reconstruction of the left orbit was exported from Mimics as a 3-D triangulated surface in the STrerolithography file format (Figure 4).
The STL file was imported into Geomagic Freeform Plus (3D Systems, Rock Hill, SC, USA) where it was cropped, exposing the medial wall (Figure 2). This cropped partial orbit was also exported as a 3-D triangulated surface in the STL file format.

Fused deposition models were created for both the full and the cropped orbits using CatalystEX software (Stratasys, Eden Prairie, MN, USA). These models were 3-D-printed on a Dimension SST1200es 3-D printer in acrylonitrile-butadiene-styrene (a thermoplastic). The models were sterilized by ethylene oxide before surgery.

4. Discussion

This case describes the use of an autologous calvarial bone graft modeled intraoperatively using a 3-D–printed reconstruction of a traumatic medial orbital wall fracture to surgically reconstruct the defect. Previous case reports have demonstrated the use of 3-D models in planning the surgical approach, selecting and fashioning the desired implant in the perioperative period, and even using models covered in sterile plastic intraoperatively to mold synthetic implants.

The application of this approach allows the surgeon to repeatedly go between the defect and the model in real time to allow for minute refinements in the bone graft before fixation. This potentially eliminate one of the biggest and most debilitating problems faced with orbital fracture repair: enophthalmus secondary to orbital volume enlargement [6,11]. Any change affecting the orbital cone volume, such as use of nonanatomic implants or a misplaced implant, can cause significant enophthalmus [6,12,13].

Most significant is the low cost associated with the use of this orbital repair technique. The actual model for this case cost approximately $75 AUD in terms of the raw materials and model production, which is significantly cheaper than any other nonbiological graft or prosthesis [14,15]. Numerous previous studies have found that the use of calvarial bone grafts as opposed to the use of both prefabricated titanium and other biological implants has less associated complications. Specifically, inflammatory responses to foreign materials, infection rates, lower donor site morbidity, and reduced operative time further reinforce the financial benefits of this operative approach [14,15].

5. Conclusion

A novel technique is presented for an individual and cost-effective surgical reconstruction of a traumatic medial orbital wall blow-out fracture using an autologous calvarial bone graft modeled intraoperatively on a 3-D reconstruction of the fracture defect.

Consent

Written informed consent was obtained from the patient(s) for publication of this case report and case series and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Conflict of interest

The authors declare there are no conflicts of interest.

References