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Post-Ablative Orbital Reconstruction: A Case Report

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Abstract

Orbital reconstruction is a core skill in the repertoire of an oral and maxillofacial surgeon. Although reconstruction of traumatic defects is a common operation, post-ablative reconstruction is more rarely performed. Meningioma is the most common benign intracranial neoplasm. Tumours that grow in the spheno-orbital region may result in bony destruction of the orbit. The resultant defect requires custom reconstruction to prevent functional and aesthetic complications. Restoring premorbid orbital volume is the primary objective to minimise these complications. This case report highlights a post-ablative orbital reconstruction using 3-dimensional (3-D) printing and a custom-designed titanium plate for a patient requiring resection of a spheno-orbital meningioma. With the development and accessibility to 3-D anatomical models, the mechanical properties of titanium are utilised to improve the accuracy of reconstruction. Sharing these concepts and techniques allows development and adaptation of these technologies so they may be transferred to other medical and dental specialties.

Introduction

The bony orbit is a complex structure comprised of seven bones and has a number of important functions. In addition to protecting the globes, the bony orbit provides attachment points for extraocular muscles and supporting ligaments. In addition, the neurovascular supply to the region traverses these bones (Rene, 2006). The position of the globe within the orbit is essential for normal vision. Discrepancies in relative position between the two eyes can contribute to binocular diplopia (double vision). In addition to these functional roles, the orbit is also vital for facial aesthetics. Symmetry between the orbits is required for a harmonious facial appearance (Travieso, 2019). The thin bone of the medial wall and orbital floor results in a susceptibility to fracture. Although orbital reconstruction of these traumatic defects is common, reconstruction of post-ablative defects is rare and more varied. The primary aim of orbital reconstruction is to reproduce the original orbital volume.

Since its innovation by Chuck Hull in 1984, 3-D printing technology has been increasingly used in the medical and dental fields including maxillofacial surgery (Whitaker, 2014). 3-D printing, also known as additive manufacturing, works on the basis of layer-by-layer addition of material to create a stereolithographic model. It has now developed numerous utilities, including creating anatomical biomodels. The development of this technology has also changed the arena for choice of materials to reconstruct the orbit. This case report highlights an orbital reconstruction using 3-D printing and custom-made titanium plate for a patient requiring resection of a spheno-orbital meningioma.

Case Report

A 55-year-old female was referred to the maxillofacial surgery unit for reconstruction of an anticipated left posterolateral orbital wall defect as a result of resection of a recurrent spheno-orbital meningioma. The patient had suffered from multiple meningiomas throughout her life. An initial left sphenoid meningioma was resected in 1997 and had been under regular clinical and radiographic surveillance. The tumour had recurred, with slow growth resulting in erosion of the posterolateral wall of the orbit as well as compression of the optic nerve (Figures 1 and 2).

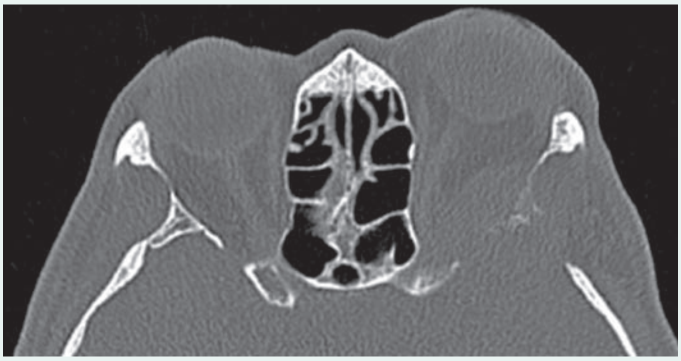


Figure 1. CT showing destruction of posterolateral orbit.

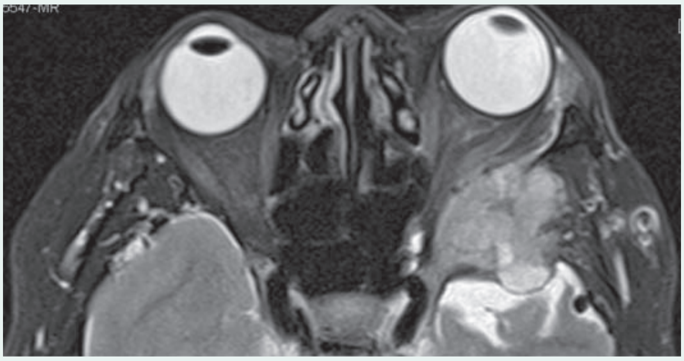
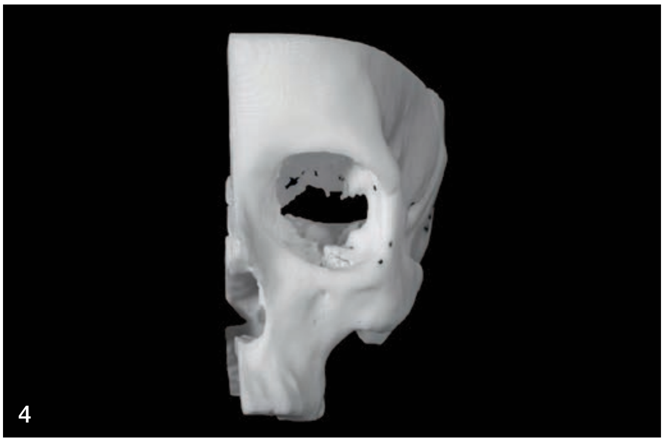


Figure 2. MRI showing location of meningioma invading the orbit.

Our maxillofacial surgical unit was tasked with planning a reconstructive option for the defect; ideally in the same surgery as the meningioma resection by neurosurgery. Pre-operatively, the patient had hypoglobus and notable proptosis of the left globe which measured 7 mm anterior to the right globe (Figure 3). The eye had full ocular motility with no restriction. Her visual acuity was slightly reduced in the left eye at 6/12, compared to 6/7.5 in the unaffected right eye.

A fine slice computed tomography (CT) scan was used to create an anatomical biomodel of the affected (left) orbit and a mirrored model of the unaffected (right) orbit (Figure 4). This 0.5 mm slice CT scan was then converted to a printer model using 3-D Slicer software, by the National Center for Image-Guided Therapy, USA. The medical physics and bioengineering department at the hospital converted this into a 3-D printed model using a Tiertime Technology Upbox 3-D printer. From these biomodels, the anticipated defect was defined and the area of the defect was measured using flexible plastic material, allowing for screws to be placed on uninvolved bone of the orbital rim (Figure 5). The design incorporated a lip that encompassed the orbital rim to assist intra-operatively in guiding the position. The plastic stencil was then cut in titanium (Figure 6). This flat titanium plate was then bent to the shape of the remaining orbit, using the contralateral orbital biomodel as a guide. The plate was bent to sit freely in the orbital biomodel, covering the majority of the defect, while allowing space for the passage of posterior neurovascular structures (Figure 7).



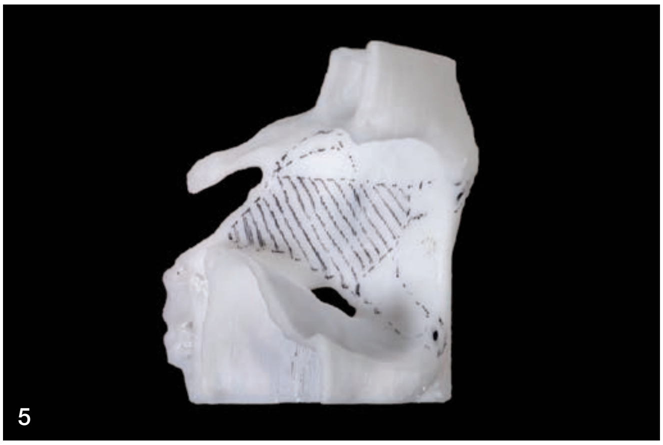


Figure 3. Clinical photo of proptosis.
Figure 4. CT reconstruction of orbital defect.
Figure 5. Design of plate for defect.

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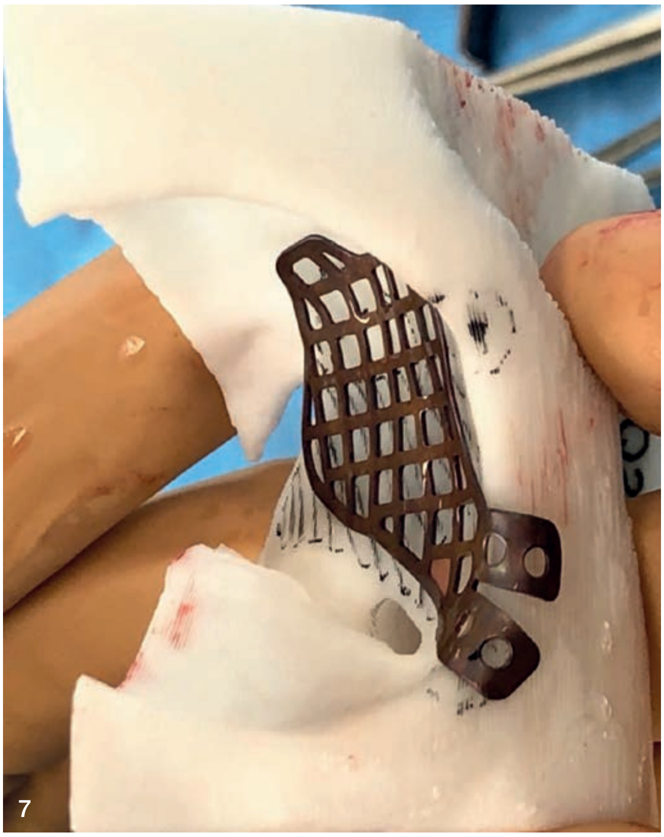
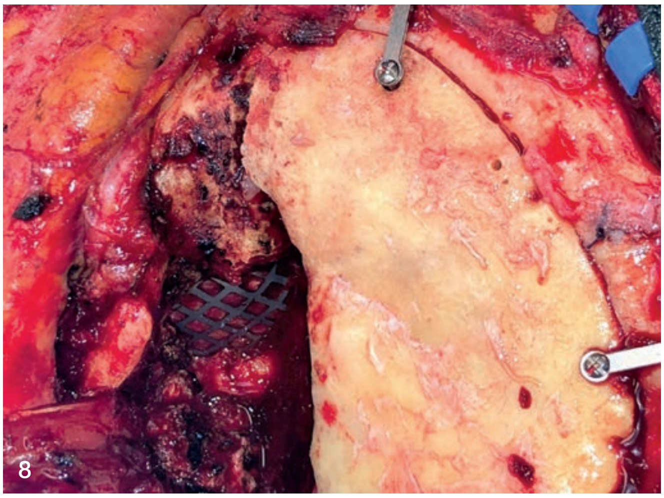


Figure 6. Titanium plate prior to bending.
Figure 7. Pre-bent plate in biomodel.



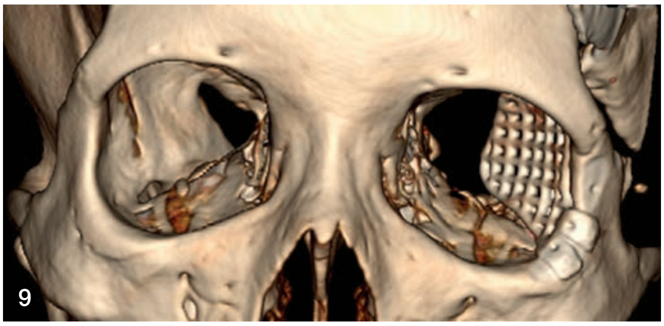


Figure 8. Plate in situ in orbit from frontotemporal approach.
Figure 9. Post-operative CT reconstruction of orbit with plate.

In a combined operation with neurosurgeons, the meningioma was resected and dural substitute placed over the exposed brain. The frontotemporal approach was used to access the posterior orbit. In addition, a lateral canthotomy and transconjunctival incision was performed to access the anterior aspect of the entire lateral orbital wall. The titanium plate seated passively and did not require any adjustment once in the correct position (Figure 8). The plate was anchored with two Synthes 6 mm titanium screws.

Post-operatively, a CT scan revealed the orbital plate accurately following the bony contour of the lateral orbital wall, symmetrical to the contralateral side (Figure 9). Clinically, the patient displayed abducens (cranial nerve VI) palsy related to the meningioma excision. She had improvement in her proptosis and was happy with her aesthetic result.

Discussion

Orbital reconstructions of traumatic defects form a key part of the workload of New Zealand oral and maxillofacial surgeons (Love and Ponnambalam, 2008; Moore et al., 2015; Anand and Sealey, 2017). These defects more predictably involve the orbital floor and/or medial wall. Reconstructions from pathology such as in the present case, are rare and have a more varied defect pattern (Markiewicz et al., 2012). Most reported cases of post-ablative orbital reconstruction are related to maxillectomy requiring reconstruction of the orbital floor (Zhang et al., 2015). As a result, post-ablative posterolateral wall reconstruction is much less frequently reported (Pritz and Burgett, 2009; Jung et al., 2011).

Meningiomas represent the most common benign intracranial neoplasm (Wiemels et al., 2010). Of all intracranial meningiomas, those located in the spheno-orbital region represent 14-18% (Sandicagoglu et al., 2005). In addition to the structural and cosmetic benefits of orbital reconstruction, there are a number of risks if reconstruction is not undertaken after meningioma resection. Those recognised complications include pulsating enophthalmos, restrictive ptosis and meningocoele formation (Pritz and Burgett, 2009). For these reasons, the maxillofacial surgical team performed the reconstruction following the neurosurgical resection.

The two major factors determining globe position are orbital volume and intra-orbital soft tissue contents (Ramieri et al., 2000). Reproducing the original orbital volume is the primary aim of reconstruction (Essig et al., 2013). Prior evaluations of orbital reconstruction highlight that despite reproducing original orbital volume, patients may still develop enophthalmos (Ramieri et al., 2000). On average, orbital volume is approximately 30 mL, however there is significant variability with age, gender and ethnicity (Nagasao et al., 2007; Lefebre and Yoon, 2015; Kumaran et al., 2019). Although there are subtle asymmetries between left and right orbits, the biomodel of the contralateral orbit forms a useful indicator of the orbital architecture.

The clinical results of inadequately replicating the original volume are hypoglobus and enophthalmos (Clauser et al., 2008). With respect to clinical outcomes, function and aesthetics need to be considered. As a result of the tumour resection, the patient developed abducens (cranial nerve VI) palsy, with inability to abduct the eye. Aesthetically the patient had significant improvement in her proptosis and hypoglobus.

There are a number of material options for reconstruction of the orbit. These may be classified as biological (such as autologous bone); biological ceramics (such as porous hydroxyapatite); metals (such as titanium); or polymers (such as polydioxanone) (Dubois et al., 2016). More recently, polyetheretherketone (PEEK) has been utilised for custom craniofacial implants (Jalbert et al., 2014). Each material has advantages and disadvantages rendering them useful for different clinical situations.

The first published use of titanium mesh for orbital reconstruction was in 1992 (Sugar et al., 1992). Titanium was used in our patient to provide a rigid, non-resorbable reconstruction of the orbital wall. Benefits of titanium include its biocompatibility, ease of contouring, and intra-operative adjustment if required. Furthermore, as it is not autologous, there is no donor-site morbidity (Jung et al., 2011). The mechanical properties of titanium complement its use for bending on an anatomical model while retaining its shape.

No studies have investigated the potential for distortion of titanium orbital mesh with sterilisation, however titanium miniplates have been shown not to undergo significant distortion with repeated sterilisation (Colella et al., 2008). Prior to therapeutic use, titanium implants require approval by the relevant therapeutic goods administration (Louvrier et al., 2017). In our unit, titanium for orbital reconstruction has been previously approved, as it is frequently used for theFreconstruction of traumatic orbital fractures.

3-D printing is becoming increasingly utilised in dental practice and maxillofacial surgery. Current uses of this technology in surgery include creating patient specific implants, designing cutting and drilling guides as well as creating anatomical models (Louvrier et al., 2017). A notable barrier to increased use of 3-D printing is regulatory limitations. Implantable devices that are 3-D printed require approval from MEDSAFE, the New Zealand Medicines and Medical Devices Authority.

Pre-operative shaping of titanium mesh in reconstruction cases has been shown to have a number of advantages, including reduced cost, shorter operative time and reduced number of attempts to accurately position the plate. The recognised disadvantages are limited to pre-operative planning and preparation time (Kozakiewicz et al., 2009). The accuracy of the plate is understandably related to the accuracy of the anatomical biomodel. The accuracy in maxillofacial anatomical biomodels has previously been investigated to be <1 mm different in two thirds of cases (Safira et al., 2013).

Conclusion

This case details a post-ablative reconstruction of the bony orbit using 3-D printing. The variability in each case of pathology, such as in this case report, necessitates custom design and planning for complex reconstruction. Pre-planning and bending offers a number of benefits to patients including shorter operative time and reduced risk for further operation. Although a number of materials exist for orbital reconstruction, titanium was most suitable for reconstruction in this case. Sharing these concepts and techniques allows development and adaptation of these technologies so they may be transferred to other medical and dental specialties.

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