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CASE REPORT
Technology

Utilizing 3D Printing for the Surgical Management of Orbital Floor Fractures

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Summary: We present a technique for treating orbital floor fractures using three-dimensional (3D) printing technology and a preoperative template based on the mirror image of the unaffected orbit. Our patient, a 56-year-old man, experienced persistent diplopia in the upward direction and left enophthalmos after previous open reduction internal fixation surgery. To address these complications, we used a simulation of the ideal orbital floor from computed tomography images and used a 3D printer to create a template. Subsequently, an absorbable plate was molded intraoperatively based on this template. Notably, the plate fit seamlessly into the fracture site without requiring any adjustment, reducing the operation time. Postoperative computed tomography scans confirmed successful reduction, improved visual function, and the absence of complications. Our method offers a precise and efficient approach to reconstructing fractured orbital floors. By leveraging 3D printing technology and preoperative templates, surgeons can enhance postoperative outcomes and minimize patient burden. Further investigations are warranted to assess the long-term effectiveness and cost-effectiveness of this technique. Our findings highlight the potential of this approach to improve treatment strategies for patients with orbital floor fractures. *(Plast Reconstr Surg Glob Open 2023; 11:e5433; doi: 10.1097/GOX.0000000000005433; Published online 21 November 2023.)*

In recent years, three-dimensional (3D) printing technology has been introduced for the treatment of orbital floor fractures. This report describes the use of a template created from preoperative 3D computed tomography (CT) images for the formation of an absorbable plate in the management of a patient with orbital floor fractures.

CASE

A 56-year-old man fell in April 2019 and sustained a left orbital floor fracture. Although the patient was followed up with conservative treatment, he was referred to our hospital for further treatment because diplopia in the superior direction persisted. In June 2019, he underwent open reduction internal fixation, but postoperative diplopia in the upward direction and left enophthalmos remained. Visual function was determined to be abnormal due to the placement of an inappropriate plate for the bone defect, and reoperation was planned. To treat the complicated fractures, the decision was made to use a 3D printer to print a physical model and create a template before surgery. Preoperative CT showed fractures in the left orbital medial wall, inferior wall, posterior wall, skull base, and ethmoid and sphenoid sinuses.

The 3D CT data of the facial bones were output in STL format, and an ideal orbital floor plate was simulated from the mirror image of the unaffected orbit on the software (Blender: Blender Foundation, Amsterdam, the Netherlands) to create a template (Fig. 1). Extensive fractures from the medial wall to the posterior wall were observed, and a simple plate would likely have fallen off backward because of a lack of bone width for stable insertion. Therefore, we decided to fold the infraorbital rim toward the cheek and secure it with a screw. The prepared template was printed using a 3D printer (Creality 3D CR-10S: Shenzhen Creality 3D Technology, Shenzhen, China), sterilized, and brought into the surgical field. Translacrymal and transconjunctival incisions were made to expose the fracture site, and the previously inserted plate was identified and removed. An absorbable plate (Super Fixsorb MX sheet plate, Teito Medical Technology Co., Ltd., Osaka, Japan) was placed on the template and molded accordingly using hot water (Fig. 2). The plate was

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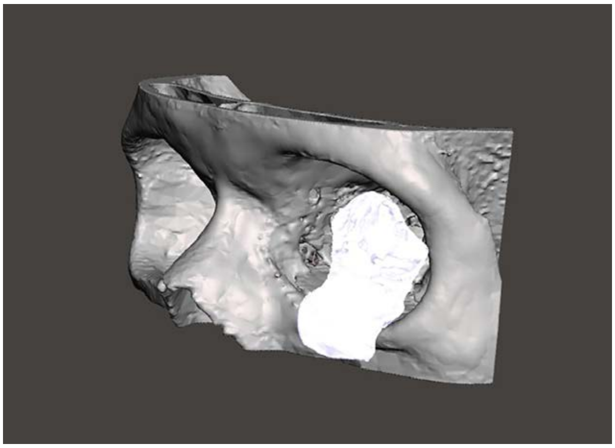

Fig. 1. Simulating an ideal orbital floor plate to cover the fracture, based on the mirror image of the unaffected orbit.

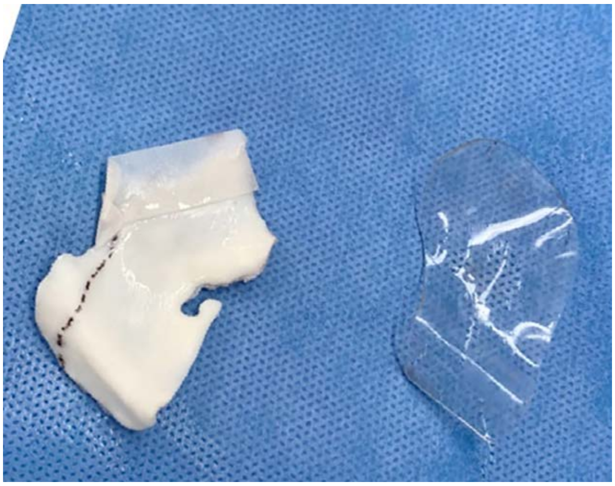

Fig. 2. The preoperative printed template and the plate based on the template.

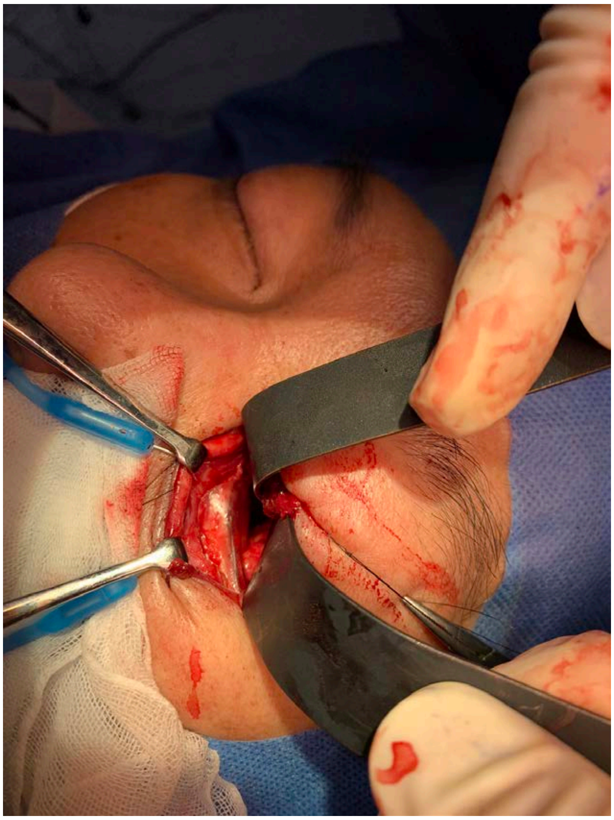

Fig. 3. A plate inserted directly into the patient's fractured orbit. The plate fit the fracture well and did not require any adjustment.

then inserted into the fractured area and secured to the upper margin of the cheekbone using two 5-mm absorbable screws (Grand Fix, Johnson & Johnson Co., Ltd., New Brunswick, N.J.).

The absorbable plate fit the fracture well and did not require any adjustment (Fig. 3). The usual tens of minutes required to prepare an absorbable plate were reduced to just minutes. No obvious postoperative complications were observed.

Postoperatively, Hertel exophthalmometry and Hess screen test were performed and showed improvement in enophthalmos and eye upward movement failure. The subjective symptoms of the patient also improved.

DISCUSSION

Orbital floor fractures can pose significant challenges in terms of accurate reduction and reconstruction due to the complex 3D anatomy of the orbit. Traditional methods often rely on intraoperative judgment and adjustments, which can lead to prolonged surgical times and potential complications. In recent years, the application of 3D printing technology has emerged as a promising solution to enhance precision and efficiency in the management of orbital floor fractures.[1]

As a concrete method for treating orbital floor fractures, preoperative CT images are used to create a physical model, which is often used as a reference for prebending plates.[2–4] Creating a physical model in advance allows surgeons to take the time to accurately adjust the plate while checking the anatomy under direct vision. Therefore, it is possible to omit the labor of forming the plate during surgery, shorten the operation time, and reduce the burden on the patient.[3,4] In addition, the position of the neural tube can be confirmed, which could reduce the risk of complications due to nerve compression.

Sigron et al[5,6] prebent a titanium plate using a mirror image of the unaffected side as a guide, and compared the operation time and orbital volume difference between the unaffected side treated with the conventional method. They found a statistically significant difference in volume with the conventional method, but no significant difference was observed in the prebending group. Furthermore, the operation time in the prebending group was significantly shortened. This result suggests that the use of a stereoscopic model using a mirror image of the unaffected side also leads to more accurate reconstruction and shortens the operation time.

In the present case, we simulated an accurate orbital floor plate from the mirror image of the unaffected side, created a template, brought it into the surgical field, and formed an absorbable plate during the surgery. Molding the plate took very little time, and the inserted plate fit snugly into the recess without the need for any adjustment. In addition, there were no obvious postoperative complications. It was thought that prebending the plate before surgery would lead to a further shortening of the operation time, but the absorbable plate deforms when heated, so it was difficult to sterilize preoperatively. Therefore, in the present case, we first sterilized the printed template, then brought it into the surgical field, and finally molded the plate during surgery.

The selection of materials suitable for orbital floor reconstruction is still being debated, and titanium mesh is often used for complex fractures that are complicated by large defects or medial wall fractures. However, titanium mesh can cause fibrosis of the surrounding tissue, and postoperative complications such as adhesion, infection, and oculomotor disorder can also occur.[7] In addition, a study comparing the treatment results of an absorbable plate and a titanium mesh plate in 1954 patients showed successful treatment with absorbable plates even for defects larger than the currently recommended 200 mm^2, and postoperative complications were significantly reduced.[8] However, for large and unstable fractures, including multiple orbital wall fractures, the use of a titanium mesh plate is recommended. The bone defect in the present case was relatively large, but good results were obtained using an absorbable plate. Although there are few reports of molding an absorbable plate using a 3D printer, it was thought to be useful in the present patient with orbital floor fractures.

CONCLUSION

Use of a 3D printer may be advantageous in the treatment of orbital floor fractures that require use of absorbable plates.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Kang S, Kwon J, Ahn CJ, et al. Generation of customized orbital implant templates using 3-dimensional printing for orbital wall reconstruction. *Eye (Lond)*. 2018;32:1864–1870.
2. Kozakiewicz M, Elgalal M, Loba P, et al. Clinical application of 3D pre-bent titanium implants for orbital floor fractures. *J Craniomaxillofac Surg*. 2009;37:229–234.
3. Mustafa SF, Evans PL, Bocca A, et al. Customized titanium reconstruction of post-traumatic orbital wall defects: a review of 22 cases. *Int J Oral Maxillofac Surg*. 2011;40:1357–1362.
4. Lim CG, Campbell DI, Cook N, et al. A case series of rapid prototyping and intraoperative imaging in orbital reconstruction. *Craniomaxillofac Trauma Reconstr*. 2015;8:105–110.
5. Sigron GR, Rüedi N, Chammartin F, et al. Three-dimensional analysis of isolated orbital floor fractures pre- and post-reconstruction with standard titanium meshes and "hybrid" patient-specific implants. *J Clin Med*. 2020;9:1579.
6. Sigron GR, Barba M, Chammartin F, et al. Functional and cosmetic outcome after reconstruction of isolated, unilateral orbital floor fractures (blow-out fractures) with and without the support of 3D-printed orbital anatomical models. *J Clin Med*. 2021;10:3509.
7. Kersey TL, Ng SG, Rosser P, et al. Orbital adherence with titanium mesh floor implants: a review of 10 cases. *Orbit*. 2013;32:8–11.
8. Seifert LB, Mainka T, Herrera-Vizcaino C, et al. Orbital floor fractures: epidemiology and outcomes of 1594 reconstructions. *Eur J Trauma Emerg Surg*. 2022;48:1427–1436.