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CASE REPORT

Craniofacial/Pediatric

A Three-dimensionally Printed Acrylonitrile Butadiene Styrene Model for the Reduction of Nasomaxillary Fracture

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Summary: The successful reduction of a nasomaxillary fracture was performed using a three-dimensional printed model. A 16-year-old boy was struck in the left orbit by a baseball; subsequently, he was diagnosed with the nasal bone fracture at a hospital, and was referred to the authors' department. A left nasomaxillary fracture and nasal bone fracture were diagnosed by computed tomography. Standard triangulated language data for the mirror image of the frontal process of the right maxilla were obtained from digital imaging and communications in medicine data for preparing a three-dimensional printed acrylonitrile butadiene styrene model. On postinjury day 13, the frontal process fracture was reduced via transconjunctival and intraoral approaches. After the reduction of the fracture, an absorbable plate fitting to the shape of three-dimensional printed acrylonitrile butadiene styrene model was molded, and the maxillary frontal process and infraorbital rim were reduced and fixed with an absorbable plate and screws. Postoperative computed tomography demonstrated a favorable reduction. The intraoperative use of the 3D printed acrylonitrile butadiene styrene model was helpful in the nasomaxillary fracture reduction and fixation. *(Plast Reconstr Surg Glob Open 2021;9:e3877; doi: 10.1097/GOX.0000000000003877; Published online 18 October 2021.)*

Nasomaxillary fracture was defined as a maxillary fracture with the concurrent fractures of the orbit, orbital rim, and/or nasal bone, by Morgenstein in 1971. Nasomaxillary fracture induces not only aesthetic problems (including deviated nose, enophthalmos, and facial asymmetry), but also functional problems such as lacrimation due to lacrimal duct obstruction.[1] Although three-dimensional (3D) printing technology is now widely used in craniofacial surgery,[2] intraoperative 3D printing technology is never used for treating nasomaxillary fractures. This report describes the use of a 3D printed acrylonitrile butadiene styrene (3D-ABS) model for reducing and fixing a nasomaxillary fracture.

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CASE PRESENTATION

This study was performed in accordance with the Declaration of Helsinki and its subsequent amendments. A 16-year-old boy with no previous medical history was struck on the left side of his face by a baseball. At the emergency room in a hospital, he was diagnosed with nasal bone fracture using computed tomography (CT), and was referred to the authors' hospital for surgical treatment. Physical examination revealed a deviated nose, but no other symptoms (such as double vision, ocular motility disturbance, and dysfunction of the infraorbital nerve) were observed. CT also showed a nasomaxillary fracture along with a nasal bone fracture (Fig. 1). The angles between the frontal process and the anterior wall of the maxilla at the right normal side and the left fractured side were respectively 123 degrees and 147 degrees, as measured by the axial CT image, and the left frontal process apparently fattened. For reconstructing the symmetry of the frontal processes, a 3D model of the left maxilla was created. The STL data of the left side of maxillary frontal process was produced by mirror imaged DICOM date of the right uninjured side using Mimics 21.0 software (Materialise, Leuven, Belgium) (Fig. 2). These data were

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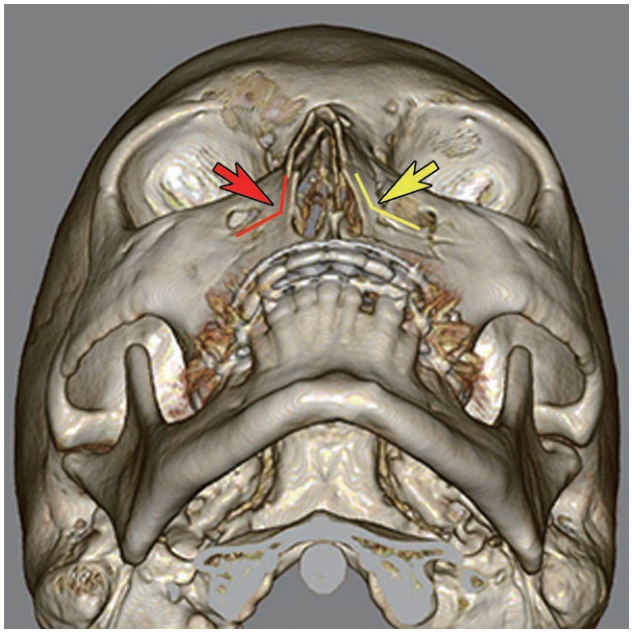

Fig. 1. Three-dimensionally reconstructed CT facial image showing a nasomaxillary fracture in a 16-year-old boy. The reconstructed CT image shows a severely displaced nasomaxillary fracture in addition to a nasal bone fracture. The fracture extended as far as the orbital rim. The angles between the frontal process and the anterior wall of the maxilla at the normal unfractured side (the red line and arrow) and the fractured side (the yellow line and arrow) were 123 degrees and 147 degrees, respectively. The angles were measured on axial CT images, and the left frontal process apparently fattened.

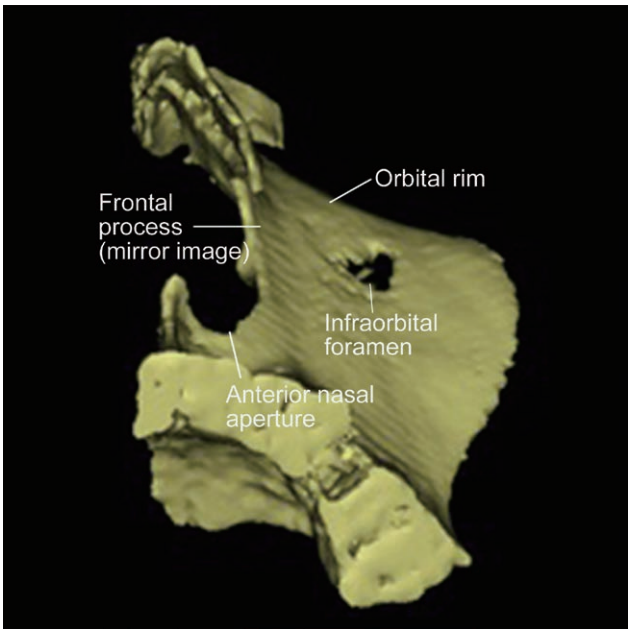

Fig. 2. The three-dimensional model of the left maxillary frontal process obtained from the mirror image of the right healthy maxillary frontal process. Surgical planning software was used for producing STL data to reconstruct the mirror image of the maxillary frontal process and nose of the right uninjured side, based on the digital imaging and communications in medicine data from preoperative facial 3D CT scan. The 3D printed acrylonitrile butadiene styrene (3D-ABS) model excluding the nasal bone was madefrom the STL image using a 3D printer.

used to create a 3D-ABS model with a 3D printer (MOJO) (Stratasys, Eden Prairie, Minn.). The model was sterilized by ethylene oxide gas before use. On postinjury day 13, the patient underwent surgery for treating the maxillary frontal process fracture via transconjunctival and intraoral approaches. Reduction was performed with a bioabsorbable plate (LactoSorb) (Lorenz/Biomet, Ind.) molded for fitting to the 3D-ABS model (Fig. 3). The anterior wall of the maxilla and maxillary frontal process was fixed to match the shape of the plate, and the nasomaxillary buttress and maxillary frontal process were reduced for allowing their angles to be bilaterally symmetrical. Fixation screws were carefully inserted without piercing the lacrimal canal (Fig. 4). Thereafter, the orbital rim was fixed with an absorbable plate, and the nasal bone fracture was reduced and fixed. (**See figure 1, supplemental digital content 1,** which displays the schematic illustration of the fixation of nasomaxillary fracture and orbital rim with absorbable plates. **http://links.lww.com/PRSGO/B807**.)

RESULTS

At 6 months after surgery, a postoperative CT revealed a favorable reduction of the frontal process fracture, as shown in Supplemental Digital Content 2, where the normally shaped maxillary frontal process and nasal bone were observed. (**See figure 2, supplemental digital content 2**, which displays a three-dimensionally reconstructed CT facial image in a 16-year-old boy. **http://links.lww.com/PRSGO/B808**.)

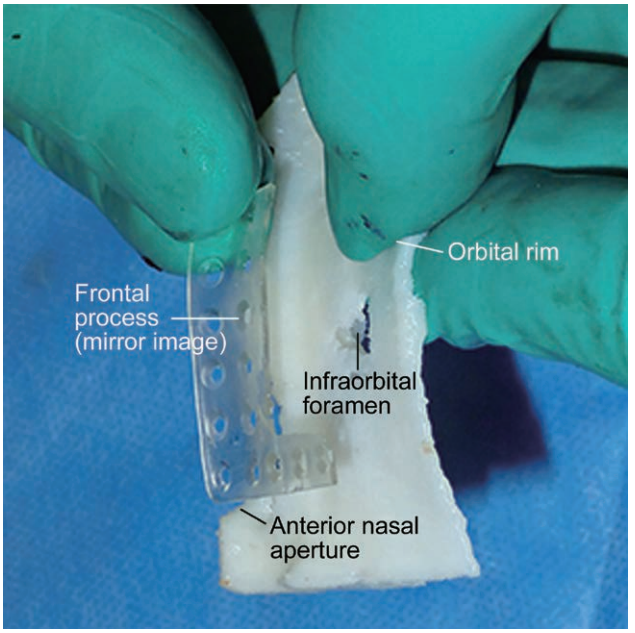

Fig. 3. A transparent absorbable plate fitting to the fracture site and a white model mimicking the anatomical configuration of the fracture site. The transparent absorbable plate was molded for fitting to the shape of the white 3D printed acrylonitrile butadiene styrene model.

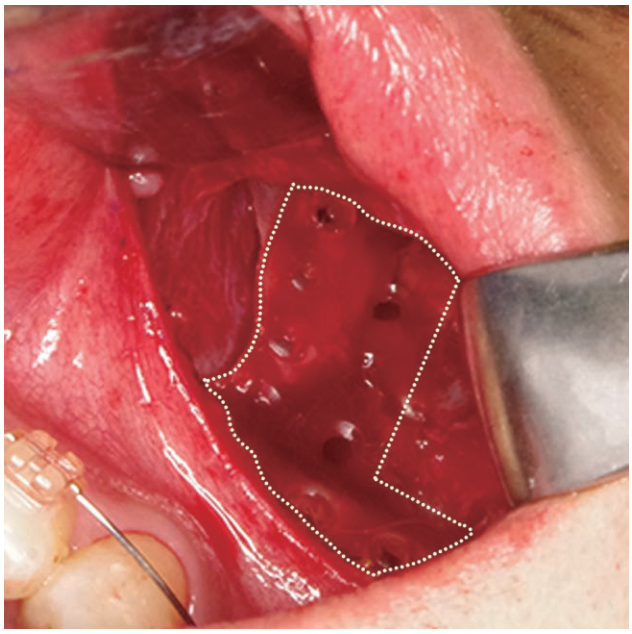

Fig. 4. Intraoperative finding through an intraoral approach. Nasomaxillary buttress was fixed with absorbable plates, and a favorable reduction of the frontal process was found. In the photograph, the plate with several holes that are surrounded by a white-dotted line is the absorbable plate.

In the coronal section, the angles between the frontal process and the maxillary anterior wall at the right normal side and the left treated side were 134 degrees and 135 degrees, respectively, and the bilateral symmetry was confirmed to be restored. Although the minimal displacement of nasal fracture is noted after closed nasal fracture reduction and a nasal splint at 2 weeks after surgery, no deviated nose was found at 6 months after surgery.

DISCUSSION

This case report showed that the nasomaxillary fracture of a 16-year-old boy was treated with the use of a 3D-ABS model for reducing the fracture. Nasomaxillary fractures, including medial maxillary fracture and fracture of the medial infraorbital rim, were found at the nasomaxillary buttress without the fracture of the zygomatic complex.[1,4,5] In 2014, Yoshioka et al defined that this kind of fracture could not be extended to the frontomaxillary suture and should be distinguished from the naso-orbito-ethmoid fracture type 1 reported by Markowitz et al in 1991.[6,7]

Nasomaxillary fracture reduction without deviated nose and lacrimal duct obstruction is a challenging surgery. For investigating surgical supportive technologies, Yu et al used a navigation guide in the reduction of zygomatic-orbital-maxillary complex fractures during fracture treatment. Briefly, a mirror image of the uninjured side is made from preoperative CT scans and is used as a navigation guide for manipulating the fracture site and fixing the plates.[8] In this study, a 3D-ABS model based on the mirror image of the right uninjured side was created. Unlike the bone fractures in other facial bones, the reduction of nasomaxillary fracture is difficult to confirm directly through the incision made in a conventional manner, resulting in uncertainty about the reduction of the fracture. The superiority of the model used in this study is that instead of conventionally fixing a plate fitting to the reduced bone-fracture site, the model was prepared for fitting the shape of the bone fracture, and applied and fixed to the fracture simultaneously. In other words, the model was able to play the role of a reduction guide for the bone fractures for which reductions are difficult to observe. The 3D-ABS model offers five-fold advantages: the model (1) allows surgeons to ensure that the bended plates fit to the fractured bones unlike a navigation guide, (2) accurately reproduces the angle of the projection of the maxillary frontal process, (3) gives bilateral symmetry easily (because the model expresses a mirror image of the uninjured site), (4) could probably reduce surgical time because of no trial-and-error process, and (5) could probably allow the fixation to be performed safely and easily without lacrimal duct injury (because the 3D-ABS model is able to show the wall of lacrimal duct). Although 3D-ABS seems to be useful, further investigations are needed for evaluating the reductions of surgical time and the rate of complication upon the use of 3D-ABS model.

The nasomaxillary fracture (including the frontal process) is known to cause secondary nasal deformities such as deviated nose and depressed deformity of the mid face. The technique in this report reduced the nasomaxillary fracture perfectly while minimizing the emergence of these deformities. Although 3D-ABS seems to be effective, further studies would be needed for investigating how much surgical time could be shortened and how much the rate of complications would be decreased by the 3D-ABS model.

Facial fracture sites have been reported to be accessed through a circular incision, which is found in coronal, intraoral, eyebrow, and subcilial incisions, and transconjunctival approaches.[5,6,9] In the authors' case, because the orbital rim needed to be fixed, transconjunctival and intraoral approaches were selected. A transconjunctival incision allows surgeons not only to access the fracture site but also to minimize scarring. Unlike subciliary incision made on the surface of skin below the eyelid, the transconjunctival approach used in this study reached the bone-fracture site through an incision inside the lower eyelid, and after healing, the incisional scar is automatically and completely covered by the lower eyelid, resulting in the perfect aesthetic outcome. However, the transconjunctival approach could not provide a sufficient visual field, the surgical maneuver was expected to be difficult, and this study also used an intraoral approach for performing the reduction of nasomaxillary fractures.[9]

In fixing the facial bones, Yoshioka reported that the infraorbital and piriform rims of the fracture are fixed with absorbable plates.[6] In the present case, absorbable plates were used because the patient was young, and absorbable plates have no risk of developing long-term complications due to foreign matters, requiring no further surgery for removing the pins. However, Mahmoud et al reported that there are no significant differences between absorbable and titanium plates in terms of the intraoperative fixation

performance, postopertive complications, and postoperative course.[10] Further studies would be required for comparing the relapse rates of complications after using absorbable and titanium plates.

The limitation of this study is that only one case was reported. The authors will accumulate cases and evaluate the successful reduction rates of facial-bone reductions with and without using a 3D-ABS model.

CONCLUSIONS

A 3D-ABS model was successfully used for the reduction of nasomaxillary fracture. In managing nasomaxillary fracture, a 3D-ABS model was considered for easily and safely obtaining reduction with outcomes.

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