A Case Report on the Application of a 3D Printed Patient-specific Zygomatic Implant for a Post-traumatic Facial Deformity

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ABSTRACT

We present the case of a 47-year-old male with a post-traumatic facial deformity after electrocution injury and a fall that occurred two years prior to consultation. The patient presented with ectropion on the left, hypoglobus, and step-off deformities on the left malar area owing to the loss of a large portion of the inferior orbital rim, orbital floor, and the zygomatic bone. House-Brackmann IV facial palsy was also present on the left hemiface since the injury. A 3D-printed biocompatible zygomatic implant was fabricated using Polyetheretherketone (PEEK). This case highlights the versatility of PEEK for facial implants and the importance of virtual surgical planning and 3-D printing in the management of post-traumatic facial defects.

Keywords: polyetheretherketone, PEEK, zygomatic implant, facial trauma, facial reconstruction, case report

INTRODUCTION

The craniomaxillofacial skeleton consists of multiple bones that give structure to our face. It also protects essential organs such as the brain and eyes. Reconstruction of this intricate anatomy poses a challenge to the clinician, especially when traumatic events lead to the destruction of multiple structures.

Traditionally, defects of the maxillofacial area were reconstructed with alloplastic materials such as silicone, acrylic, metals, and alloys.[1] However, factors such as cost, biocompatibility, and infection rates have affected their overall usability. In addition to this, the complex shape of the maxillofacial area makes the traditional practice of conforming non-customized alloplastic materials to the patient's anatomy quite difficult. 3D printing overcomes this difficulty by creating implants based on the patient's anatomy.

Polyether-ether ketone (PEEK), a thermoplastic polymer, has emerged as a popular material for the reconstruction of craniofacial defects. PEEK is highly biocompatible, lightweight, and has a tensile strength that closely mimics bone. Implants fabricated from PEEK can be secured to facial bones with titanium plates and screws and may also be trimmed with cutting burrs.[2-4] Computer-aided 3D design has allowed us to fabricate patient-specific implants.

We present the case of a patient with a post-traumatic facial deformity who underwent a surgical application of a

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PEEK implant for reconstruction of his left inferior orbital margin, anterior orbital floor, and zygoma.

CASE PRESENTATION

A 47-year-old male presented to our institution in September 2024 with a complex post-traumatic facial deformity resulting from a high-voltage electrical injury and subsequent fall sustained two years prior. At the time of the incident, the patient, working at a construction site, experienced contact with a live wire, leading to a fall of approximately 5 meters and direct facial impact with a sharp metal object. This resulted in significant facial lacerations and a transient loss of consciousness.

Initial evaluation at a local hospital included suture repair of the lacerations and a computed tomography (CT) scan revealing multiple facial fractures. Surgical intervention for definitive fracture repair was recommended; however, due to significant financial constraints, the patient was unable to undergo the proposed treatment at that time. Consequently, the patient presented to our tertiary care center two years following the initial injury, highlighting a significant delay in the definitive management of the complex facial trauma.

On presentation, the sequelae of the untreated facial fractures were evident. The patient exhibited a significant left-sided facial nerve palsy, graded as House-Brackmann IV, manifesting as marked ptosis of the left hemiface. Furthermore, a 4 mm inferior displacement (hypoglobus) of the left globe and a resultant ectropion of the left lower eyelid were observed. Palpable step-off deformities along the left lateral and inferior orbital rims (Figure 1) indicated persistent bony malunion. While extraocular muscle movements remained intact and the patient reported no visual blurring, he described a substantial decrease in sensation (rated 8/10 on a visual analog scale) within the left V2 (maxillary) and V3 (mandibular) divisions of the trigeminal nerve, likely secondary to nerve impingement or damage from the unaddressed fractures. Notably, malocclusion and trismus were absent.

A subsequent high-resolution craniofacial CT scan with three-dimensional reconstruction confirmed the persistent and complex nature of the neglected injuries. Imaging revealed a significantly fractured and displaced left lateral orbital rim, along with the complete absence of the anterior portion of the zygomatic body, the lateral half of the inferior orbital rim and orbital floor, and the anterior half of the zygomatic arch (Figure 2). These findings underscored the extent of the initial trauma and the subsequent bony remodelling and soft tissue changes that occurred over the two-year period of untreated fractures.

3D Planning and Implant Fabrication

An in-house design team did 3D planning and printing. Patient craniofacial computer tomography Digital Imaging and Communications in Medicine (CT DICOM) data were segmented and converted to a three-dimensional surface model using Slicer 3D (The Slicer Community, USA). Using the same software, a patient-specific implant design was generated by mirroring the zygoma, right inferior orbital floor, superior and lateral orbital rim, and zygomatic arch. Due to the planned size of the surgical incision, the implant was divided into separate components. The final design consisted of two segments linked by a dovetail joint: an inferior segment (zygomatic segment) and a superior segment (orbital rim segment). The resulting implant design was then loaded into Rhinoceros 3D software (Robert McNeel & Associates, USA) for further geometric adjustments and 3D printing optimization. The final model was exported as an STL file (Figure 3).

The implant was manufactured using a Fused Filament Fabrication (FFF) 3D printer (Funmat 410, Intamsys, China) with the following settings: 80% infill, gyroid infill design, and the same support material. The rest of the settings were left at the default. The implant was post-processed by

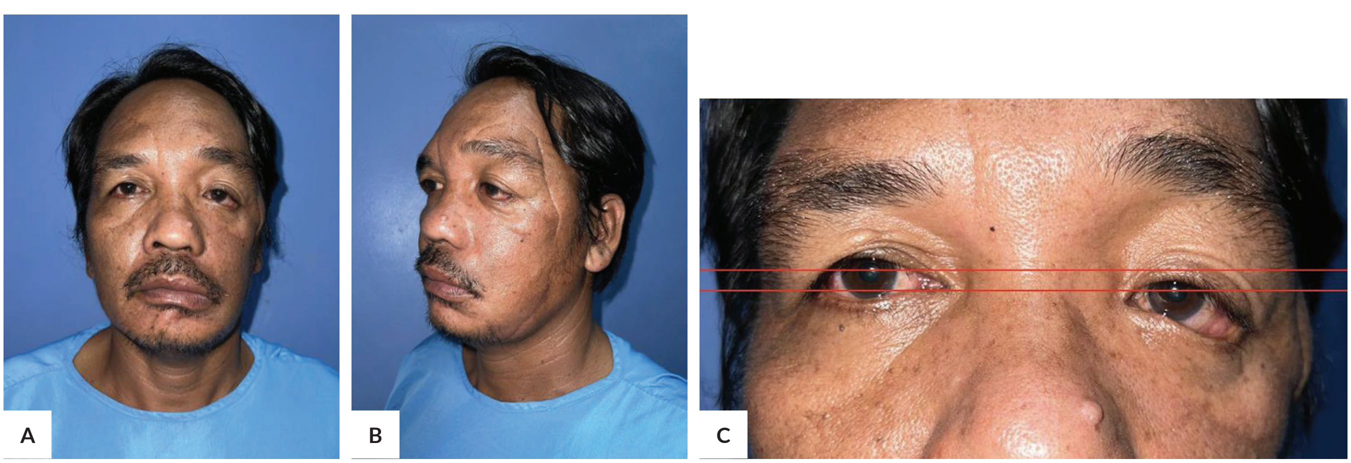

Figure 1. (A) Front-view, **(B)** Left 45-degree view, **(C)** Front-view: showing hypoglobus of the left eye and ectropion of the left lower-lid.

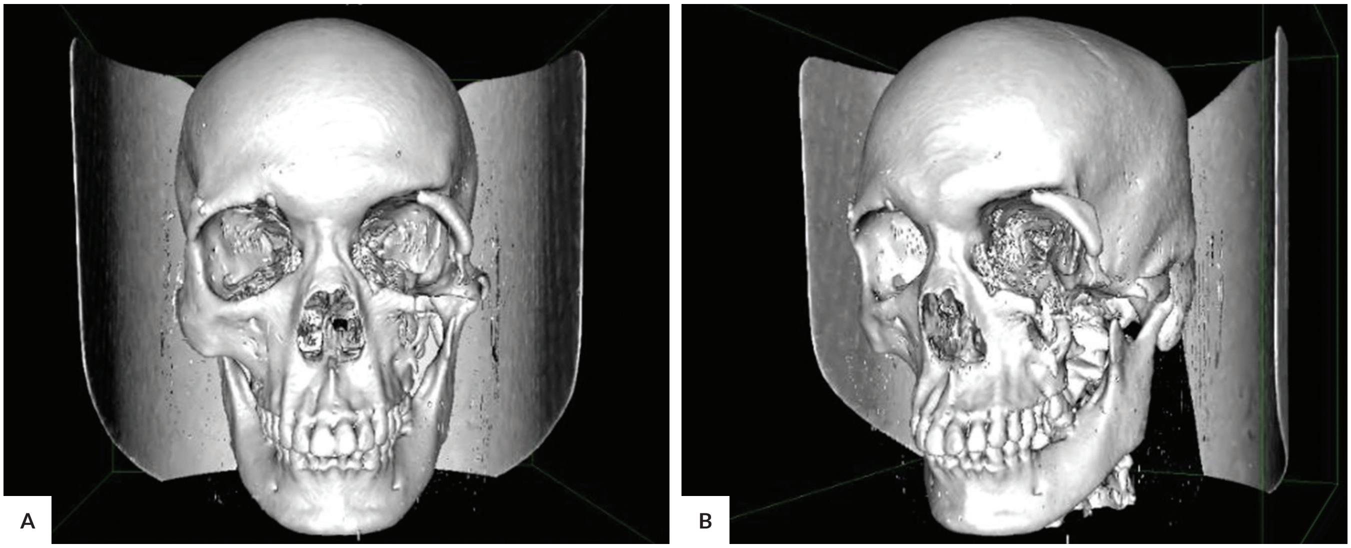

Figure 2. 3D-reconstruction of craniofacial CT scan viewed in Horos v3.3.6. **(A)** Front-view, **(B)** Left 45-degree view.

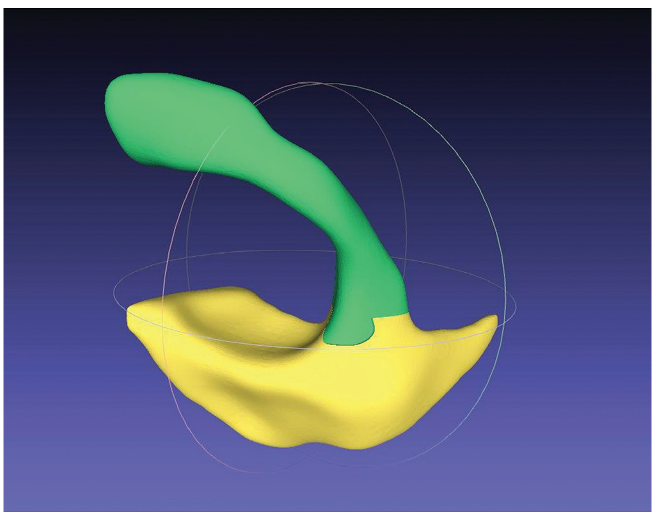

Figure 3. Final STL model of the 2-part implant. Superior and inferior portions linked by a dovetail.

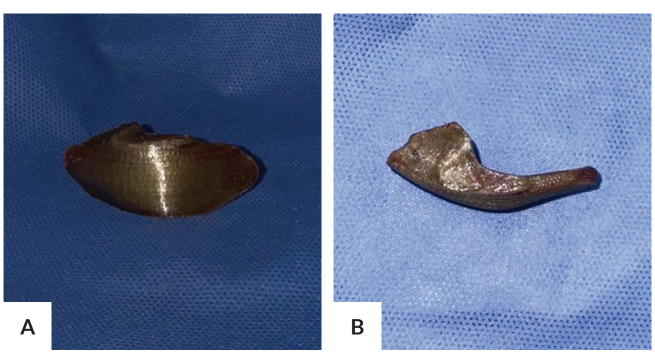

Figure 4. Zygomatic implant after contouring with a round cutting burr. Only the zygomatic segment of the two-part implant was used. **(A)** Front-view, **(B)** Top-view.

manually removing the supports and drilling down rough areas with a diamond burr. The implant was then mechanically washed and packaged for sterilization.

Surgical Procedure

Preoperative antibiotics were given, and the patient was intubated via orotracheal intubation with an armored tube. Surgical access to the left orbitozygomatic area was obtained via a hemicoronal incision, subciliary incision, and a gingivobuccal incision on the left maxillary gingivobuccal sulcus. Intraoperatively, the surgeons noted a remnant of the lateral orbital rim as well as the medial third of the orbital floor. The surgical team decided to retain the lateral orbital rim fragment; hence, only the inferior segment of the implant was used.

Trimming of the implant with a round cutting burr was required prior to placement due to the presence of bony interferences (Figure 4). The implant was fitted prior to fixation. We noted a significant decrease in hypoglobus from 4 mm to 1 mm. Forced duction testing revealed no limitation in extraocular muscle movement. The implant was then secured with titanium microplates and screws at 3 points: The lateral orbital rim, the inferior orbital rim, and the zygomatic arch prior to layered closure (Figure 5).

Postoperative Course

Postoperatively, significant improvement in hypoglobus was noted. There was no diplopia and blurring of vision; however, weakness of the frontalis muscle was noted. The patient was sent home on the 2nd postoperative day, and suture removal was done on the 7th postoperative day (Figure 6). Currently, the patient is satisfied with the aesthetic improvement. Resolution of frontalis muscle weakness was noted at 2-months postoperatively.

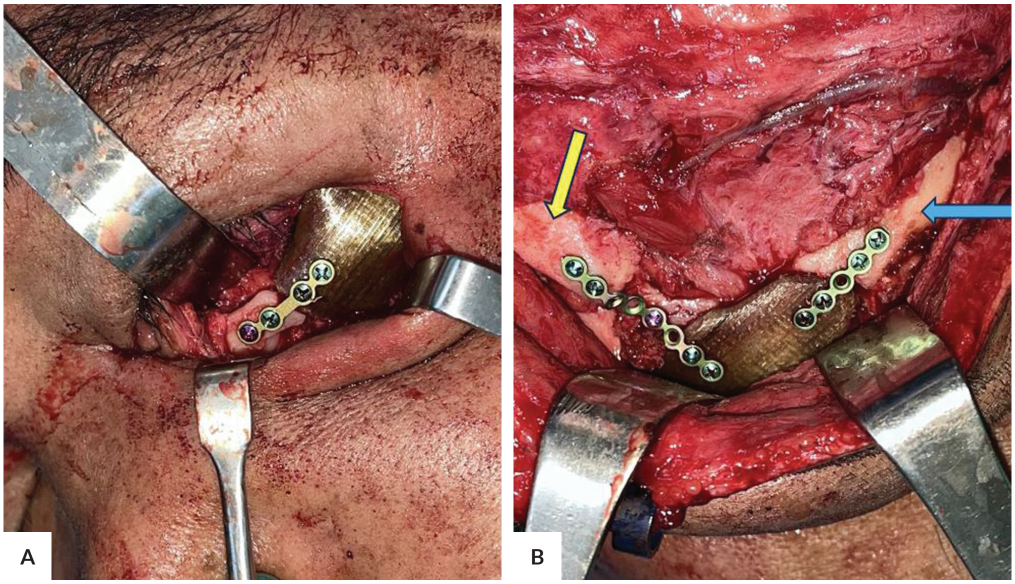

Figure 5. **(A)** Implant secured to the medial inferior orbital rim remnant with a 4-hole microplate. **(B)** Lateral view of the implant showing fixation to the zygomatic arch *(blue arrow)* and the lateral orbital rim remnant *(yellow arrow)*.

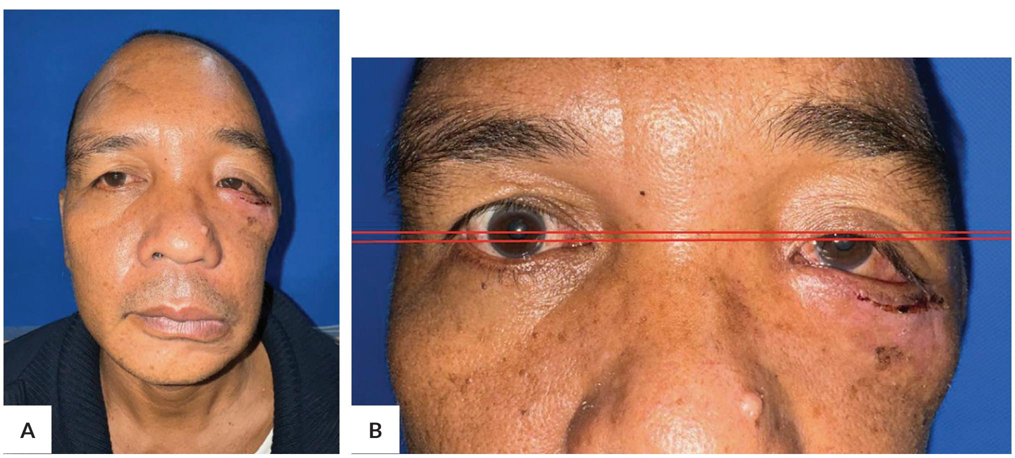

Figure 6. Day 7 post-op. Noted a decrease in hypoglobus from 4 mm preoperatively to 1 mm post-operatively. **(A)** Front view, **(B)** Close-up view. Postoperative ptosis on the left was noted.

DISCUSSION

The intricacy of the anatomy of the maxillofacial bones leads to difficulties in the design and fabrication of facial implants. Favourable implant characteristics include biocompatibility, chemical inertness, and ease of manipulation and molding.[5] Numerous materials have been used, both autologous and alloplastic. The use of autologous materials, however, requires surgical manipulation of the donor site and can lead to donor site morbidity. Alloplastic materials such as silicone have been utilized, however, with varying rates of postoperative infection and displacement.[6,7] Titanium alloys boast exceptional load-bearing capability as well as osseointegration.[8] However, 3D printing or milling of titanium implants is costly, and the technology may not be readily available. In addition to this, the use of metallic implants leaves little room for error, and intraoperative trimming and molding of the implant may not be possible.

PEEK has long been used in the fabrication of implants used in the human body. Globally, PEEK has been approved for use in the fabrication of biocompatible implants by several regulatory bodies including the U.S. FDA. However, despite the popularity of PEEK, it has not been widely used in the local setting. Currently, there are no published reports of the use of PEEK for facial implants locally.

Virtual surgical planning has aided surgeons in the fabrication of anatomically accurate implants. In the presented case, the surgical team decided to use a 2-part interlocking implant consisting of a superior segment, which would replace the superior and lateral orbital rims, and an inferior segment replacing the inferior orbital rim, orbital floor, and zygoma. Intraoperatively, the superior segment was deemed unnecessary due to the presence of a remnant of bone on the lateral orbital rim, which the surgeons decided to retain.

The ease of manipulation of PEEK was also displayed, wherein the surgeon had to manually trim the implant to avoid bony interferences, improving the overall fit. The ability to directly drill on PEEK and fixate the implant with conventional titanium plates and screws further highlights the versatility of PEEK as a material for facial implants. In hindsight, the amount of intraoperative trimming of the implant could have been lessened if the surgeons had attempted to fit the implant on the 3D printed skull of the patient. Preoperative modification of the implant could have been done to potentially decrease the operative time.

PEEK implants were noted to be safe for long-term maxillofacial reconstruction. Garg examined PEEK implant longevity and complications over 11 years at their institution and noted a single case of postoperative infection, which was adequately managed by antibiotic therapy.[9] Sanchez reviewed long-term follow-up in patients with cranioplasty implants and noted that the implants still provided protection to the brain after a mean follow-up time of 7 years.[10] In the orthopedic setting, PEEK titanium cages showed superior outcomes to titanium after a 7-year follow-up.[11]

This report also shows the advantage of having an in-house planning and design team. Delays in treatment were minimized since there was ease of coordination and avoidance of delays due to factors such as shipping time and cost.

CONCLUSION

The case reported highlights the utility as well as the versatility of 3D-printed PEEK implants in the reconstruction of complex bony defects of the maxillofacial area. The ability to perform intraoperative modifications by cutting or drilling is useful when bony interferences undetected in the CT scan are present. PEEK implants are a viable option for reconstructing maxillofacial defects and should be considered, especially in the local setting, wherein these implants are still not widely used.

Ethical Considerations

The patient is a consenting adult and has signed a consent form. Plans for writing a case report and possible publication were explained to the patient. The patient does not belong to a vulnerable group. Risks were explained to the patient, including the usual surgical risks like bleeding, hematoma formation, and possible facial nerve weakness. Risks relating to the implant were also explained, which include postoperative infection and the possibility of an allergic reaction to the implant. Benefits were explained, which include correction of his post-traumatic facial defect at no cost and implant provision at no cost. Patient data is stored in the Electronic Medical Records of the Philippine General Hospital. Patient photos are stored in a password-protected folder in the laptop of the primary investigator.

Statement of Authorship

All authors certified fulfilment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

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