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Going 3D to Reconstruct and Repair Post Traumatic Residual Facial Deformities - A Case Report and Literature Review

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Abstract: ***Maxillofacial trauma is one of the commonly encountered injuries in the emergency department. Failure to intervene at the right time or in the right way could result in highly disfiguring post traumatic residual facial deformities. Correction of these deformities constitutes a challenging but worthwhile endeavor. The introduction of 3D printing technology to the field of maxillofacial surgery has revolutionized treatment outcomes and can help obtain satisfactory results based on an accurate pre-operative work up. Nevertheless, tertiary corrections are sometimes unavoidable, if the patient insists on a near perfect result. The following article presents a case of a patient with a post traumatic residual facial deformity involving the frontal and the periorbital region, managed using 3D printing technology to fabricate a prosthesis of the frontal bone defect. While the frontal bone reconstruction was graded to be highly satisfactory, inability to mobilise and reposition the right zygomatico-maxillary complex resulted in a less than satisfactory outcome pertaining to globe position and malar prominence. The results of this case indicate that the time lapse after which the residual deformity is addressed is crucial, better results being obtained on intervening within 3-6 months.***

Keywords: Post-traumatic residual facial deformity, zygomatic bone, frontal bone, 3D printing, bone cement

1. Introduction

Maxillofacial trauma is one of the commonly encountered injuries in the emergency department. Proper diagnosis and prompt treatment can result in marked improvement in outcomes in terms of function and aesthetics. Failure to intervene at the right time or in the right way could result in highly disfiguring post traumatic residual facial deformities (PTRFD) which imposes a huge burden on the quality of life of the patients. Imola et al described an accurate system for classifying deformities based on the anatomic region affected as frontobasilar, naso-ethmoid, peri-orbital and maxillary- mandibular [1].

Incorrect primary reconstruction of the facial skeleton is the underlying problem of virtually every PTRFD. This may include delayed treatment, underestimation of the injury or technical errors during surgery [2]. In certain cases, absence of a required intervention also could result in PTRFD. Functional deficits due to PTRFD can be grouped into three major physiological systems for consideration and treatment planning, they being opthalmologic, sinonasal and masticatory. While often functional deficits may be a patients' chief concern for seeking re-surgery, certain patients seek PTRFD correction solely for aesthetic purposes [1].

Typical squeal of inadequately treated orbital injuries include enophthalmos, telecanthus and loss of the malar prominence. Malposition of the zygomatic complex is mainly an aesthetic problem. Especially in post-traumatic cases is this noticeable to the patient because of the asymmetry, although functional aspects must also be considered [3].

Introduction of rapid prototyping technology into the field of surgery has dramatically improved the quality of results obtainable in surgical procedures. The following case report discusses the management of a patient of PTRFD managed by the use of 3D printing technology.

2. Case Report

A 24- year old male, reported to our department of Oral and Maxillofacial Surgery with a chief complaint of a depression over the right side of the forehead and unequal level of eyes since the past 1- year secondary to a surgery done in 2014. Detailed history and patients records revealed a history of RTA in December 2014. The patient had suffered multiple comminuted fractures of the right frontal bone, orbital roof and floor and nasal bones, an en block infero-lateral displacement of the right zygomatico-maxillary complex (ZMC), and simple fractures on the left frontal bone and left lateral orbital rim region (Figure 01 - A). The patient was operated upon for the injuries. The multiple comminuted fracture fragments were reduced and stabilized with miniplates (Figure 01 - B).

At presentation 1st year post-surgery, clinical and radiological findings revealed: depression over the right side of the frontal bone measuring approximately 7*4 centimeters (cms) (Figure 01 - C), vertical orbital dystopia, right globe pseudoptosis, dilated and fixed pupils of the right eye, a soft nodular swelling in the right upper eyelid crease without discharge of blood or pus, widening of the midface owing to a lateral displacement of the ZMC and a normal occlusion. CT scans of the facial bones and a 3D reconstruction revealed complete resorption of a large segment of the frontal bone on the right side with infero-lateral displacement of the right ZMC (Figure 01 - D).

Patient expectations were primarily aesthetic and included a correction of the depression over the right side of the forehead and an improvement in the level of the right orbit. Owing to the complex nature of the defect, a plan for fabricating a customized prosthesis using 3D printing to restore the defect was decided upon. Latest CT scans of the patient were obtained and exported in DICOM format to a customized software (Osteo3d). A 3D reconstruction of the skull was obtained and the exact extent of the defect could be assessed (Figure 02 - A). The osteotomy of the ZMC along its articulations was simulated in the software and repositioning of the right ZMC was performed (Figure 02 - B). Once repositioned, the final size of the frontal bone defect was measured (Figure 02 - C). Based on the dimensions of the defect, a starch- based mould was designed to generate the prosthesis for reconstructing the defect intra operatively. To avoid any undercuts and a smooth installation of the prosthesis, a 1 cm segment of the frontal process of the ZMC was planned for removal during the surgery to allow for a better fit. The mould was fabricated and sterilized using ethylene tri-oxide (Figure 02 – D [above]).

The patient was taken up for surgery after obtaining informed consent. The defect was exposed using a bicoronal incision (Figure 03 - A). Old implant material used during the first surgery was removed. A gentamicin based polymethyl methacrylate bone cement was used to fabricate the prosthesis. The powder and the liquid were mixed to obtain a workable mass. The sterilized mould was assembled, the workable mix of the bone cement was packed into it and allowed to set. Once set, the bone cement prosthesis was delivered out (Figure 02 – D[below]). The prosthesis was checked for any irregularities or sharp edges and was stabilized using four 2 hole plates and 4 millimeter screws (Figure 03 - B).

The ZMC repositioning was undertaken next. A forced traction test was carried out on the right eye to assess the favorability to obtain an improvement in the enopthalalmos. A considerable resistance was encountered. The complete ZMC was exposed with an additional maxillary vestibular incision, the old implant materials were removed and the ZMC was re-osteotomised in the buttress region. Other sutural attachment zones of the ZMC exhibited no bony fusion. Complete stripping of the ZMC was performed to enable mobilizing it. However, sufficient resistance prevented from repositioning it in the ideal position. The frontal process of the zygomatic bone was superimposed over the prosthesis and the overlapping part was trimmed to achieve a snug fit. The repositioned ZMC and the prosthesis were then secured using a 2 hole plate (Figure 03 - C). Re-entry to the right orbital floor was obtained through the scar of the old infraorbital incision. The globe was gently raised upwards to correct the orbital dystopia and a titanium orbital floor mesh was placed along the floor and secured using 4mm screws (Figure 03 -D). Drains were placed in relation to the coronal incision and closure was done in layers. The post-operative healing of the patient was uneventful.

At the 2nd month post-operative follow up, the correction of the forehead depression was graded as highly satisfactory. There was no associated pain or step defect evident at the margins of the prosthesis. A slight improvement in the anti-mongoloid slant and the level of the globe was observed and was hence rated as poorly satisfactory (Figure 04 – A, B, C). The frontal bone contour was maintained at the 6th month post operatively as well (Figure 04 - D).

3. Discussion

Experienced surgeons recognize the challenge to restoring premorbid form and function to patients with established deformities after craniofacial trauma. PTRFD involving the periorbital region are common. In an extensive study by Imola et al, majority of the PTRFD in his studies were centered around the orbito-zygomatic region [1]. While minor deformities can be managed with camouflage treatment using augmentation or reduction procedures, more severe deformities call for surgical repositioning of the displaced bone segment using a fresh osteotomy of the segment. The patient in this case report presented with a severe infero-lateral displacement of the right ZMC. A fresh osteotomy and mobilization of the right ZMC was hence attempted. However, very minimal mobilization could be achieved in this case. Extensive scarring and the adaptation of the overlying soft tissue to the underlying skeletal framework over a period of 1 year could have been responsible for this.

Further analysis of the patient at follow up also revealed the persistence of temporal hollowing bilaterally and a soft tissue bulge in the region superior to the right zygomatic arch. Vaca et al suggested that the cause for the bulging could be attributed to the bulging of the retracted fat pads superior to the zygoma. A few measures were taken to ensure minimizing the temporal hollowing at the re-intervention surgery such as minimal stripping of the temporalis muscle to attain exposure, and suture re-suspension of the stripped temporalis muscle [4]. In cases of long-standing enophthalmos, the forced traction test can be used to determine the likelihood of being able to bring the eye forward; however, inability to accomplish this maneuver should not, in and of itself, preclude a surgical attempt [5]. The forced traction test in our case had not yielded encouraging results.

Autogenous comminuted frontal bone fragments were used for cranioplasty in the first surgery in this patient. However complete resorption of the fragments resulted in the forehead deformity. Underlying parenchymal contusion, comminuted skull fracture, age $\leq$ 2.5 years, and post-traumatic hydrocephalus have been found to be significant factors affecting bone flap resorption [6]. A variety of materials for cranioplasty exist such as autograft, titanium mesh, porous polyethylene implants, methyl methacrylate, calcium phosphate bone cement, hydroxy-apatite, polymethyl methacrylate composite etc. Polymethyl methacrylate (PMMA) bone cement's ease of use, low cost and strength and durability make it a prefereable option for cranioplasty [7]. The risk of infection of PMMA is overcome by the incorporation of gentamicin powder to the bone cement. Gentamicin is active against both gram-negative and gram-positive organisms, has a low rate of allergic reaction, exhibits sustained release from PMMA, has free solubility in water, is stable at relatively high temperatures and resistance to it is rare [8]. In studies performed by Chang et al, incorporation of 1 gram of gentamicin to 40 grams of PMMA showed no reduction in the compressive strength of the resin [9].

Similar to the findings of Freihofer et al, the patient in this report sought corrective surgery mainly for improvement of aesthetics. Since there was no vision in the right eye, function was no longer a criteria for the patient [10].

To accurately obliterate the frontal bone defect for our patient, 3D printing technology was employed. Three-dimensional (3D) printing is a manufacturing method in which objects are made by fusing or depositing materials- such as plastic, metal, ceramics, powders, liquids or even living cells—in layers to produce a 3D object. This process is also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid free-form technology (SFF) [11]. Advantages of using 3-D stereolithographic models include enabling direct visualization of anatomic structures, fabrication of surgical guides/templates, performing mock surgeries, assessing bony defects for grafting, adaptation/pre-bending of reconstruction plates, fabrication of custom prostheses and as an educational tool for patients and students [12]. 3D printing technology can be classified by the techniques, the materials or aimed deposition process [13]. One of the techniques used for generating a 3D model is fused deposition modeling (FDM). An FDM printer uses a print head similar to an inkjet printer. However, instead of ink, beads of heated plastic are released from the print head as it moves, building the object in thin layers. This process is repeated over and over, allowing precise control of the amount and location of each deposit to shape each layer [11].

The starch mould obtained using fused deposition modeling was used to fabricate the prosthesis in the operation theatre. The perfect fit of the obtained prosthesis helped us achieve superior aesthetic results as well as reduced the operative time. The treatment of the displaced zygoma however was not easy. Intraoperative evaluation of the correct position is quite difficult when clear landmarks are absent and precise symmetry has to be obtained. In the study by Freihofer et al, tertiary corrections had to be performed in 33% of the patients. Secondary overcorrection was at least as common as undercorrection [10].

Correction of PTRFD constitutes a challenging but worthwhile endeavor. The basic principles of treatment include an osseous reconstructive surgery as early as possible to restore the anatomically correct architecture followed by selective ancillary procedures to address soft tissue deficits and functional deformities. PTRFD have a significant impact on the physical, functional and social aspects of a patients' life. They add to the financial burden and despite all the secondary interventions done, a few attain satisfactory results. The introduction of 3D printing technology to the field of maxillofacial surgery has revolutionized treatment outcomes and can help obtain near perfect results based on an accurate pre-operative work up. Nevertheless, tertiary corrections are sometimes unavoidable, if the patient insists on a near perfect result.

Conflict of Interest:
Nil

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Figure Legends:

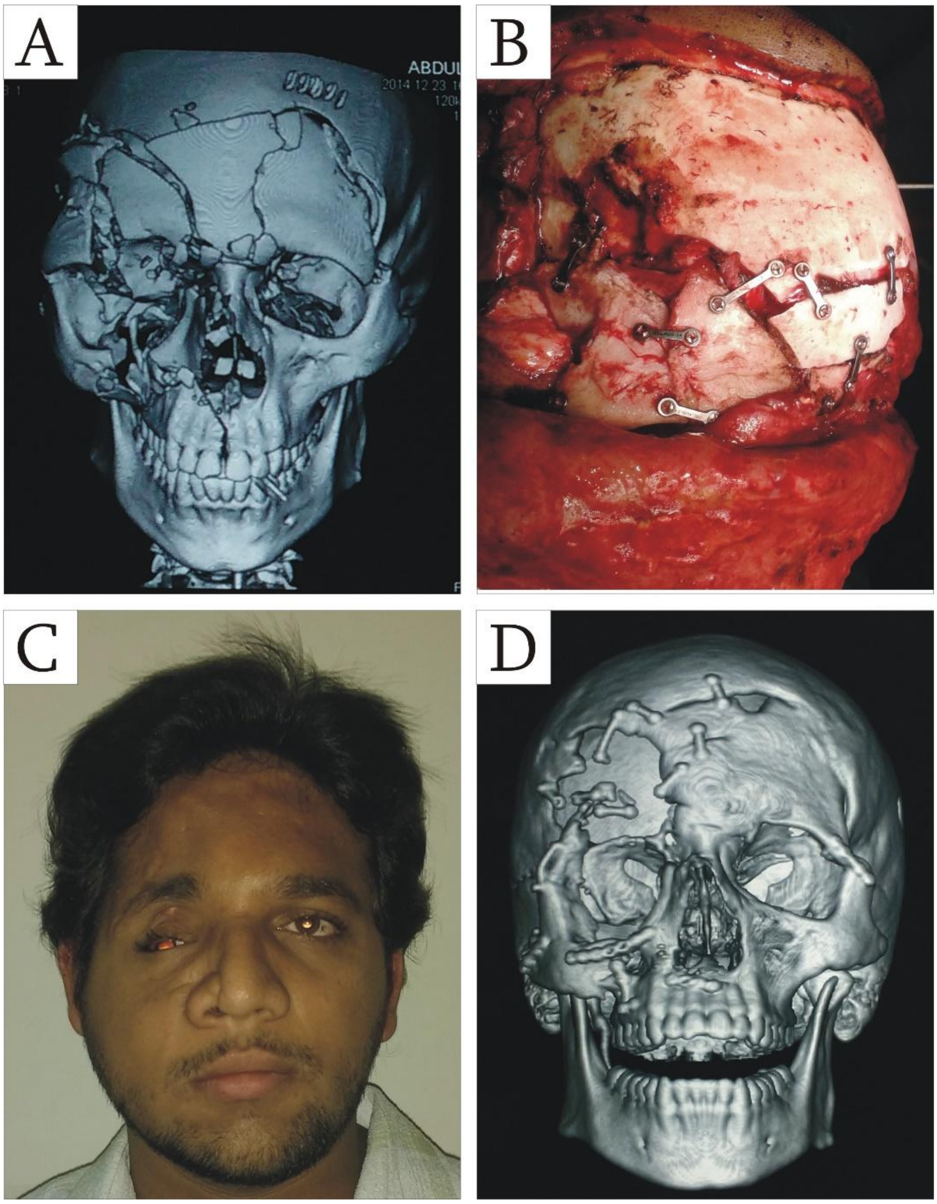

Figure 1: A – Post trauma 3D reconstruction. B – Cranioplasty using autologous comminuted frontal bone fragments secured using miniplates during the 1st surgery. C – 1 year post-operative clinical photograph after the 1st surgery. D – 1year post-operative CT scan 3 D reconstruction showing total resorption of the frontal bone fragments.

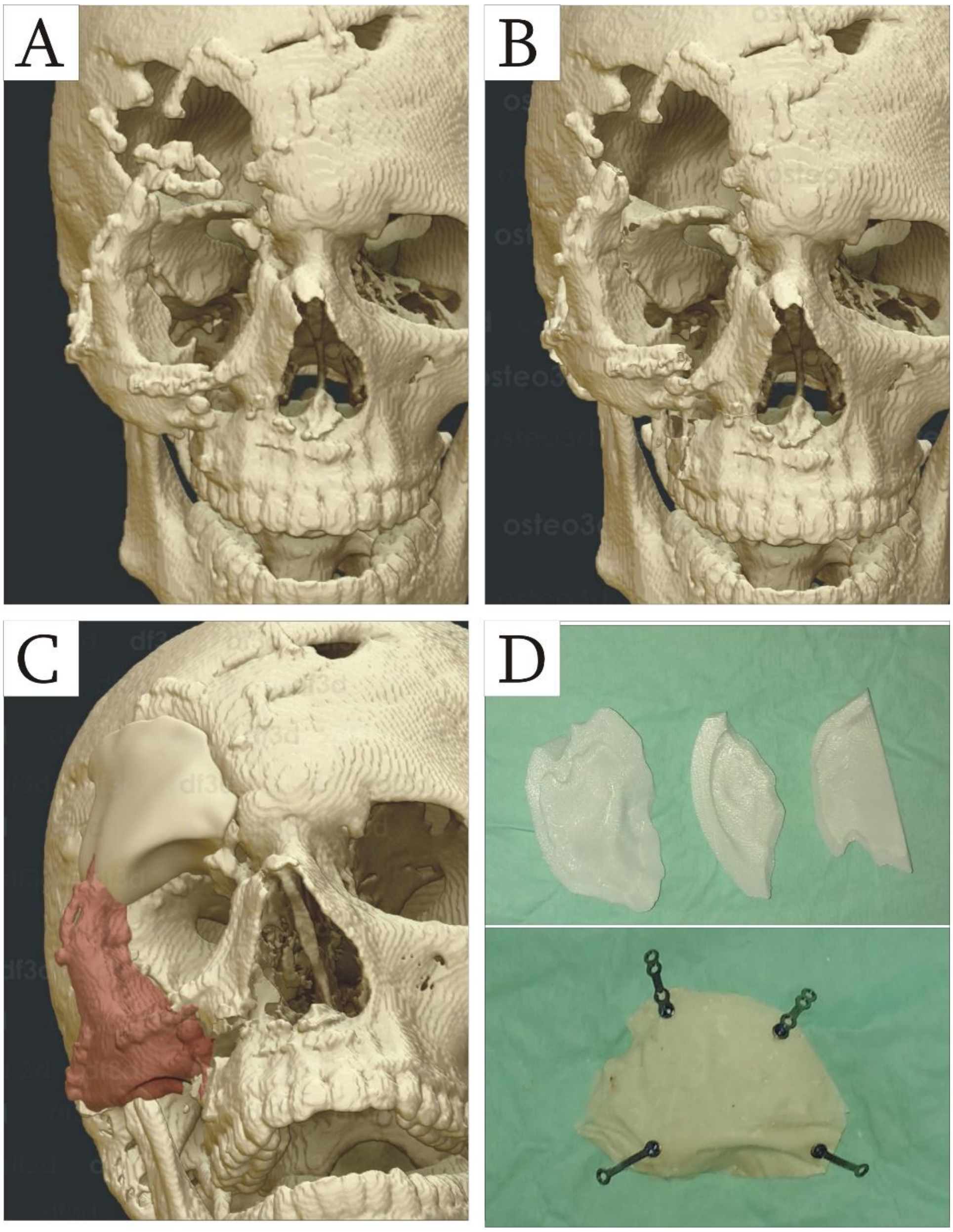

Figure 2: A – Computer software generated 3D reconstruction. B – Simulation of repositioining of the right ZMC. C – Simulation of a prosthesis to fit the frontal bone defect and to approximate well to the repositioned ZMC fragment. D (Top) – The starch mould obtained via software designing. D (Bottom): The final prosthesis obtained intra operatively and fixed with with miniplates for securing to surrounding stable structures.

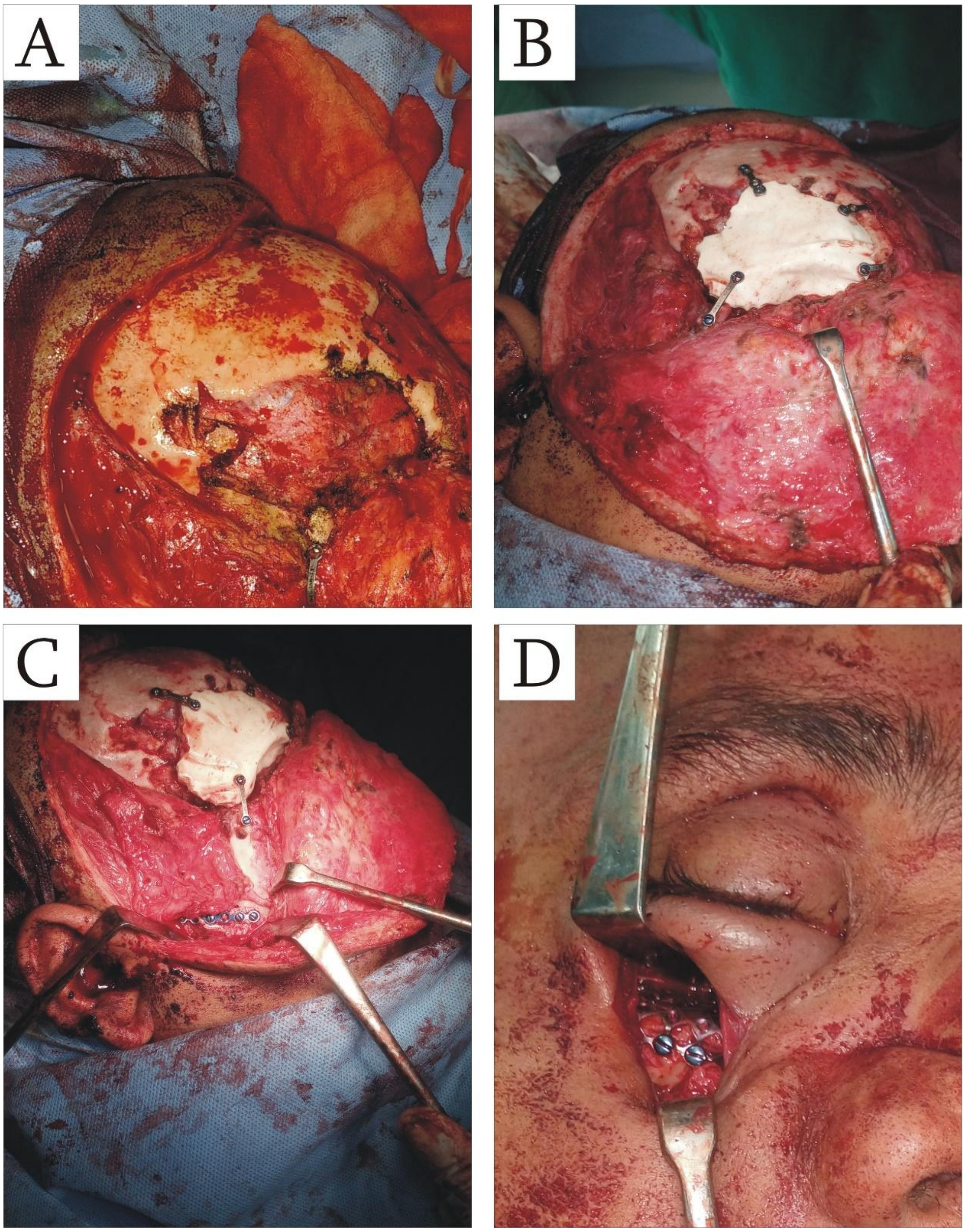

Figure 3: A – Intraoperative exposure of the frontal bone defect. B – PMMA prosthesis fixed in place. C – Repositioning of the osteotomised right ZMC and plating at the arch and the lateral orbital rim region. D – Right infraorbital floor reconstruction using a titanium orbital mesh.

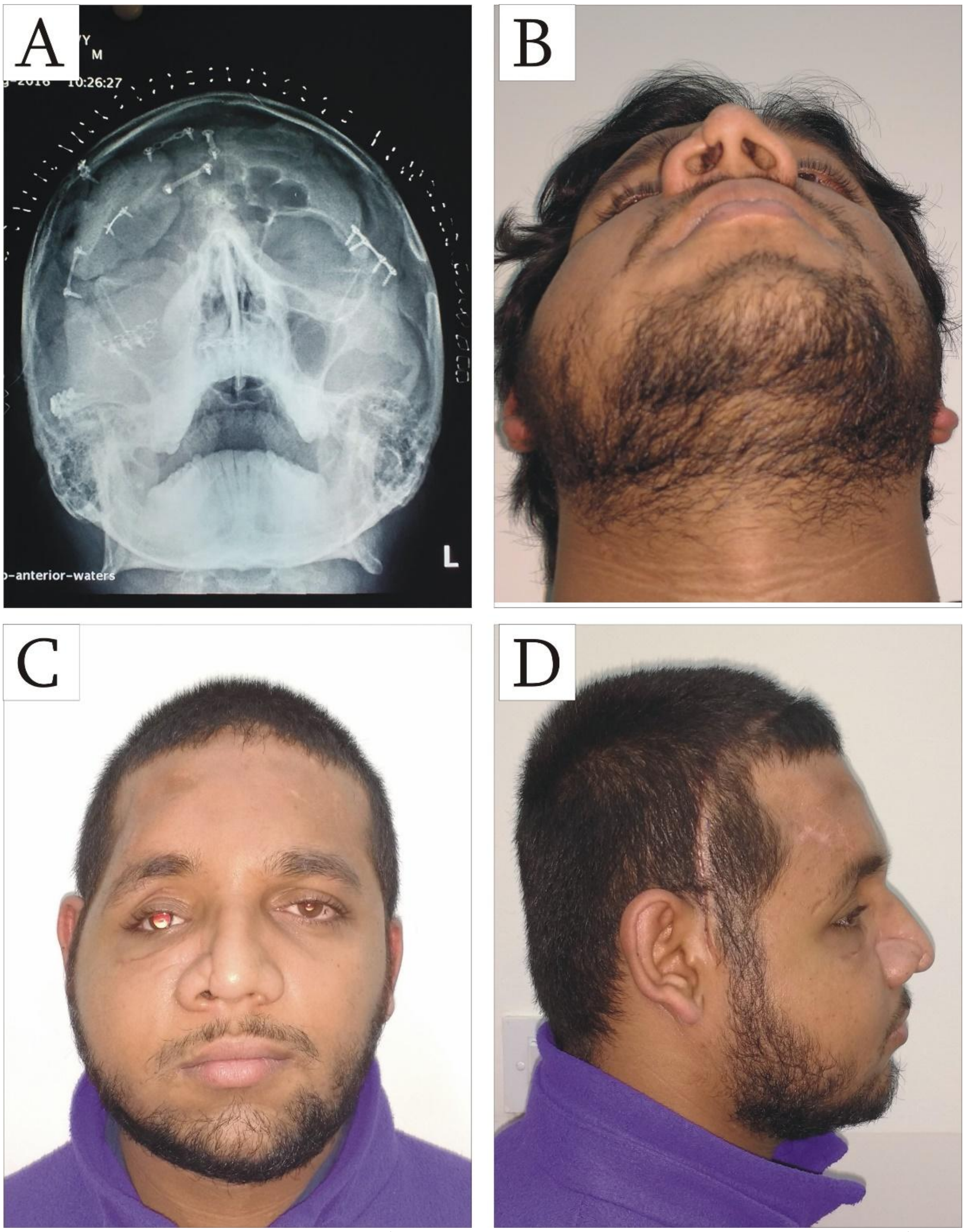

Figure 4: A – Post-operative PNS view after the 2nd surgery. B – Worms eye view of the patient at the 6th month follow up after the 2nd procedure showing restored contour of the frontal bone. C – 1st month frontal clinical photograph after the 2nd surgical procedure. D – 1st month post-operative right profile view after the 2nd surgical procedure.