Stereophotogrammetric Method for Fabrication of Cranioplast Using Digital Facial Scan Technology - A Case Report

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Abstract

Rationale: Traumatic brain injury is the most common cause of cranial defects. Cranioplasty is the surgical intervention performed to repair cranial defects. The purpose of a cranioplast is to protect the underlying brain tissues, reduce pain, and improve calvarial contour and symmetry. **Patient Concerns:** This case report describes the management of an ambulatory aided patient who met with a road traffic accident and had undergone decompressive craniectomy. **Diagnosis:** Noncontrast computed tomography confirmed the frontal cranial defect and was planned for decompressive craniectomy. **Treatment Plan:** An innovative multi-camera three-dimensional (3D) face-scanning software (Bellus 3D) was used for facial scanning to obtain a 3D face model and fabrication of 3D model using rich presence technology. **Outcomes:** The wax pattern was then fabricated on a 3D-prototyped model and a customised polymethylmethacrylate cranioplast was fabricated. **Take-Away Lessons:** This method with the added advantage of rapid prototyping technology resulted in prosthesis with good aesthetics and better fit.

Keywords: Cranioplast, decompressive craniectomy, graft, polymethylmethacrylate

Introduction

There are various causes of cranial defects including trauma, tumours, congenital deformities, or postoperative defects due to the surgical procedure itself.[2] Cranioplasty is the surgical repair of acquired or congenital cranial defects. The cranioplasty includes protection of brain tissues, providing aesthetics, and reconstruction of the deficit anatomical cranium. Rehabilitation in these patients requires a multidisciplinary approach requiring neurosurgeons, plastic surgeons, and prosthodontists. Various techniques of skull reconstructions with material from the patient's own body (autologous), implants of natural origin (allogenic), as well as artificial (alloplastic) substitutes[2] are used. Alloplastic reconstruction can be done using polymethyl methacrylate (PMMA), titanium, silicone, polyethylene, polytetrafluoroethylene, and polyetheretherketone (PEEK).[1] This clinical report describes the rehabilitation of a patient with a cranial frontal defect subsequent to a road traffic accident. A new digital three-dimensional (3D) face-scanning software (Bellus 3D) was used to scan the face to obtain 3D face model of the patient. The use of this innovative facial scanning software (Bellus 3D), rapid prototyping, yielded success in terms of precision and aesthetics and reduced treatment time for the rehabilitation.

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Case Report

A 54-year-old male reported to the Department of Prosthodontics for rehabilitation of cranial defect. A detailed history revealed that the patient was involved in a road traffic accident six months ago. Cranial decompression was planned which led to a frontal defect [Figure 1a]. Due to the presence of tenderness at the defect site, it was difficult to go for the conventional functional technique for recording accurate impressions. Hence, rapid prototyping was planned to fabricate 3D model.

Fabrication of three-dimensional model

Bellus 3D was used to scan the face to obtain 3D model of the patient [Figure 2a]. It allows the export of 3D face model to Standard Tessellation Language (STL) format [Figure 2b]. The

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STL images were transferred to computer-aided design (CAD) Software to generate a virtual model of the complete skull using CAD software (Autodesk Meshmixer). This software enabled 3D visualisation of the defect [Figure 2c].

To assess the accuracy of facial scan, intercanthal distance of the patient is compared with the intercanthal distance of 3D virtual model. Then, these STL format images were transferred to the 3D printer. In this technique, resin material of polylactic acid was used to fabricate the prototyped skull [Figure 3a]. Two layers of modeling wax were adapted over this defect area to get the contour of the final prosthesis. Wax was carved and contoured [Figure 3b]. The wax pattern was extended 5 mm beyond the bony edge in anticipation of changes caused by polymerisation shrinkage to ensure good marginal integrity. The final wax trial was done on the patient to ensure symmetry, fit, and aesthetics [Figures 1 and 3d and e].

Fabrication of polymethylmethacrylate cranioplast

A custom clamp and flask with interlocking spurs and having adequate height were fabricated using stainless steel. The wax pattern was invested in type II gypsum products followed by dewaxing and packing with clear, heat polymerising PMMA (Trevion; Dentsply Sirona). A long polymerization cycle was followed. The polymerised cranioplast was retrieved, finished, and polished. The marginal integrity was examined on the 3D skull defect, and the excess acrylic resin was trimmed to achieve a butt joint at the defect margin. Multiple 2-mm holes were made 1 cm apart in the cranioplast to prevent the development of an epidural haematoma, permit escape of underlying fluid, and its absorption by the lymphatics and allow for ingrowth of fibrous connective tissue and neoangiogenesis. The holes also provide the means for securing the prosthesis to underlying bone [Figure 3c]. Then, the prosthesis was immersed in distilled water at 37°C for 24 h to leach out any residual monomer followed by immersion in 2% glutaraldehyde for 48 h for sterilisation.

Surgical placement of cranioplast

The surgical procedure was carried out under general anaesthesia. The bicoronal scalp incision was made over the healthy tissues away from the defect. The entire dissection was performed to delineate the margins of the entire defect. The prosthesis was fixed firmly to the desired area by titanium miniplate fixation [Figure 4]. The closure was then performed in layers using a vicryl suture to close the underlying tissues, and finally, the skin was sutured. Postoperative care of the surgical site was given to the patient and follow-up appointments were scheduled weekly for four weeks to check for postoperative complications [Figure 5].

Discussion

The defects of the skull cause vulnerability of the brain to trauma, aesthetic disfigurement, and transmission of vibrations and pulsation of the brain toward the exterior surface. Subsequent cranioplasty may be required to

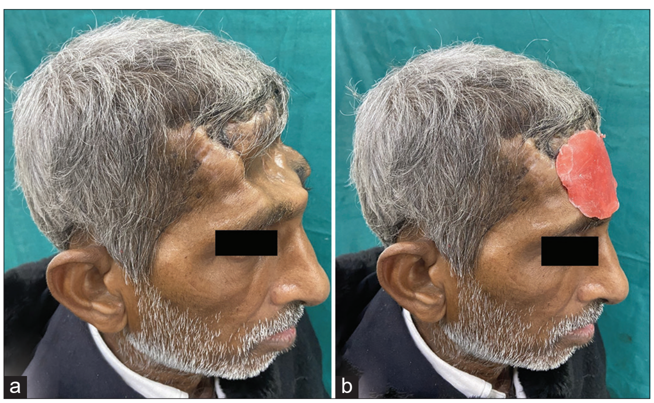

Figure 1: (a) Pretreatment lateral view (b) Lateral view along with wax up

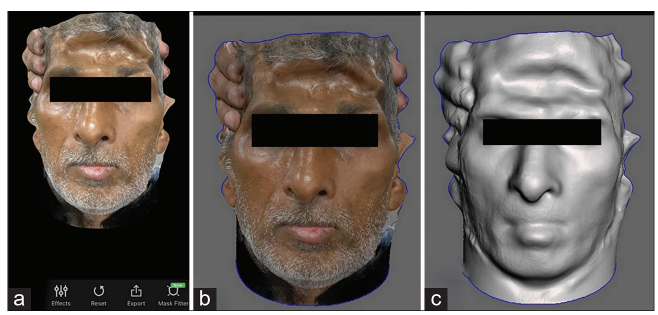

Figure 2: (a) Completed scan (b) Scan analyzed in CAD Software (c) STL file of the scanned 3D face. CAD: Computer-aided design, STL: Standard Tessellation Language

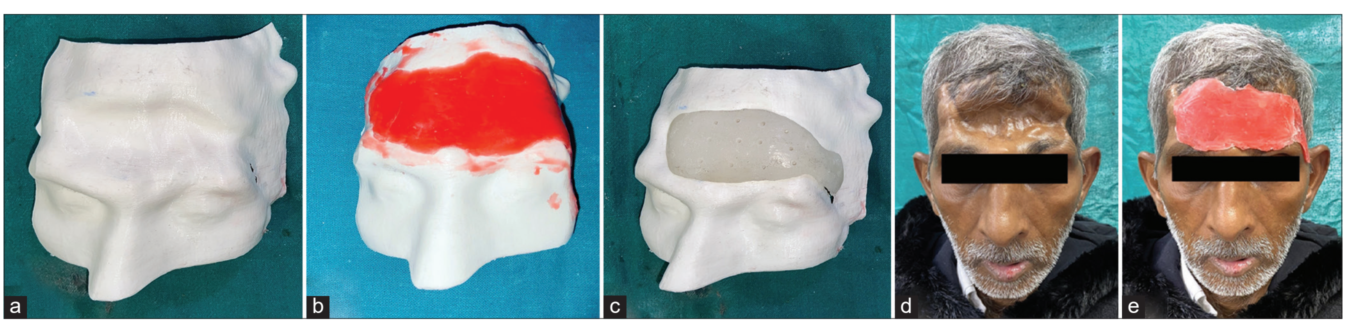

Figure 3: (a) 3D-printed face (b) Wax-up completed on 3D model (c) PMMA plate placed on 3D model (d) Pretreatment frontal view (e) Frontal view along with wax up. PMMA: polymethyl methacrylate, 3D: Three dimensional

Figure 4: Surgical placement of cranioplast

Figure 5: (a) Posttreatment frontal view (b) Posttreatment lateral view

compensate for the defect and to alleviate various signs and symptoms.[6] The cost effectiveness of the procedure represents a further important point. Cranioplast is classified as autograft, allograft, xenograft, and alloplast. Various metallic alloplasts are gold, titanium, and tantalum.[6] Nonmetallic alloplasts include polymethyl methacrylate (PMMA), polytetrafluoroethylene, carbon-reinforced polymer, and recently introduced PEEK.[6] The resection of autologous bone material is an invasive procedure with significant donor site morbidity.[4] Therefore, currently, alloplastic materials have nearly replaced these invasive procedures of harvesting distant autologous bone material for cranial reconstruction.[2] PMMA was used as an alloplastic cranioplast in this case. PMMA is preferred due to its moderate properties, easy handling and processing, and low costs.

PMMA is biocompatible, inert, deformation resistant, has good compressive strength, and is easily available. It is radio-opaque, nonferromagnetic, and highly economical compared to other alloplasts.[3] The only disadvantage of PMMA is its residual monomer content which may hamper the healing process at the deficit area and may cause a postoperative haematoma.[8]

The rehabilitation of nonambulatory patients after a craniectomy posed the problem of inability to have CT scan and tenderness present at the defect site making it difficult to go for conventional methods of recording functional impressions. The use of Bellus 3D and rapid prototyping generated an exact model of the face. The opportunity to view the model also helped the patient's relatives to have a better understanding of the procedure.

Bellus 3D ARC measures up to 500,000 3D points on your face to create a high-resolution and accurate face model in seconds using a mobile device. It only takes 10 seconds to create a high-resolution 3D face scan. Bellus 3D's high precision scanning detects the pupil distance and over 100 facial and ear landmarks. It is an easy-to-use, high-quality, and affordable 3D face scanning camera for mobile devices. It uses two infrared structured lights for high-resolution face scanning. More research is required in this field to have a better understanding for more promising clinical results. Furthermore, 3D printing and rapid prototyping provide more promising results when compared to recording with the conventional impression method.

The custom flask fabricated for this case helped to accommodate the entire wax pattern.[5] It allowed a uniform gypsum product around the wax pattern, thus avoiding distortion of the wax pattern.[7] It also ensures the proper polymerisation of heat cure PMMA without any water seepage and thus reduces porosities in the final prosthesis.

Conclusion

Bellus 3D is a new advanced software used to obtain accurate 3D facial scans with the click of a single button in seconds. Rapid prototyping along with reverse engineering is an advanced and predictive method for the fabrication of cranioplast. Hence, along with rapid prototyping, this method of facial scanning is an innovative, time saving, and easily accessible approach.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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