CASE REPORT

FRONTAL BONE CRANIOPLASTY USING CUSTOMIZED IMPLANTS THROUGH A 3D PROTOTYPE: CASE REPORT

CRANIOPLASTIA DO OSSO FRONTAL COM A UTILIZAÇÃO DE IMPLANTES CUSTOMIZADOS ATRAVÉS DE PROTÓTIPO 3D: RELATO DE CASO

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ABSTRACT

Cranioplasty for the treatment of cranial bone defects has as its main objective the three-dimensional and functional reconstruction of the skull. Computer-assisted surgeries (CAS) have been used since the 1990s efficiently and bring improvements and optimization in reconstructive craniofacial surgical approaches, especially in large bone defects. This clinical case report addresses virtual planning and CAD/CAM technology in secondary craniofacial reconstruction using polymethylmethacrylate (PMMA). A 48-year-old male patient had two bone defects in the frontal region with skin dehiscence into the frontal sinus. A computed tomography was performed with 1mm slices and converted into a 3D model of the frontal bone and in the mold of the bone defect in real size. To address the bone defects, a neurosurgeon was involved in the treatment of dura mater, cranialization of the frontal sinus, and obliteration of the nasofrontal duct, and was completed by the oral and maxillofacial surgery team. After the surgery, a tomographic exam was performed, and a perfect adaptation between the prosthesis and the bone contours and a great anatomical contour of the frontal bone were observed, making it satisfactory to the initial surgical planning. The use of virtual planning and the CAD/CAM system resulted in greater predictability and greater safety for the craniofacial reconstruction procedure, as well as a reduction in the perioperative time. The material used, PMMA, presented itself as a material of easy manipulation, low cost, and with perfect adaptation to bone contours.

Keywords: PMMA, Bone transplantation, Maxillofacial Prosthesis, Cranioplasty, Customized implants.

RESUMO

A cranioplastia para os tratamentos de defeitos ósseos cranianos tem como o seu principal objetivo a reconstrução tridimensional e funcional da calota craniana. As cirurgias assistidas por computador (CAS) vem sendo utilizadas desde os anos 90 de forma eficiente e trazendo melhorias e otimização nas abordagens cirúrgicas craniofaciais reconstrutivas, principalmente em grandes defeitos ósseos. Este relato de caso clínico aborda o planejamento virtual e de tecnologia CAD/CAM na reconstrução craniofacial secundária com a utilização de polimetilmetacrilato (PMMA). Paciente de sexo masculino, 48 anos, apresentava dois defeitos ósseos em região frontal com deiscência da pele para dentro do seio frontal. Foi realizada uma tomografia computadorizada com cortes de 1mm e convertidos em um modelo 3D do osso frontal e no molde do defeito ósseo em tamanho real. Para abordagem dos defeitos ósseos, houve a participação de um neurocirurgião para o tratamento em dura-máter, cranialização do seio frontal e obliteração do ducto naso-frontal, sendo finalizada pela equipe de cirurgia bucomaxilofacial. Após a cirurgia, foi realizado um exame tomográfico sendo observados uma perfeita adaptação entre a prótese e os contornos ósseos e um ótimo contorno anatômico do osso frontal, tornando-se satisfatório ao planejamento cirúrgico inicial. A utilização de um planejamento virtual e do sistema CAD/CAM resultou em uma maior previsibilidade e maior segurança ao procedimento de reconstrução craniofacial além de redução do tempo transoperatório. O material utilizado, o PMMA, apresentou-se como um material de fácil manipulação, baixo custo e com perfeita adaptação aos contornos ósseos.

Palavras-chave: PMMA, Transplante ósseo, Prótese Maxilofacial, Cranioplastia, implantes customizados.

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How to cite this article: : Maia EE, Turéli B, Louzada GP. Frontal bone cranioplasty using customized implants through a 3d prototype: Case report. Nav Dent J. 2023; 50(1): 9-14.

Received: 24/03/2023
Accepted: 05/05/2023

INTRODUCTION

The traumatic and non-traumatic injuries that affect the maxillofacial region often become a real challenge for treatment due to their complexity. In these cases, it is extremely important that the surgeon is able to perform a three-dimensional anatomical reconstruction of the affected areas so that eventual sequelae are minimized (1). These facial injuries can vary greatly depending on the region, economic condition, and culture of the patients. For example, an exponential increase in traumatic injuries is observed due to the increase in violence and different types of transports. On the other hand, there are non-traumatic injuries that may be associated with bone defects caused by tumors, infections in the cranial region, and brain decompression (1,2,3).

Cranioplasty, for the treatment of cranial bone defects, has as its main objective the three-dimensional and functional reconstruction of the skull. In addition, cranioplasty is indicated to prevent changes in cerebrospinal fluid dynamics, improve cerebral blood flow, prevent neurological disorders, and serve as cranial protection (4). There are different materials that can be used to correct these bone defects and they are divided into two major groups: bone grafts, which are found in different origins such as autogenous, allogenous, xenograft, and alloplastic grafts (4,5).

From the group of alloplastic materials, the main ones we can mention are Titanium, porous polyethylene, hydroxyapatite, and polymethylmethacrylate (PMMA). In the cranioplasty procedure, PMMA's main advantages are low cost, little inflammatory reaction, easy and quick availability, and a great adaptation, besides good long-term stability (6,7,8). The main disadvantages of this material are high bacterial adhesion, low tolerance to infection, and low osteoconduction (7,9).

The stages of treatment for the correction of bone defects can be divided into 3 phases: virtual planning, the printing of prototypes/modeling of the biomaterial, and the surgical phase. Virtual surgical planning uses software that interprets the images obtained by Cone-Beam Computed Tomography (CBCT), which are recorded in DICOM (Digital Imaging and Communications in Medicine) format and converted to STL (Standard Triangle Language) format, which allows its manipulation for the creation of surgical guide prototypes, customized parts or even biomodels from the association with CAD-CAM (computer-aided design/computer aided manufacturing) technology. In the modeling phase, surgical guides are fabricated to be used perioperatively, with the aim of restoring three-dimensional anatomy. At this point, the alloplastic implants are prefabricated using CAD-CAM. After printing, they will be tested and adapted to the bone defects pre-surgically in prototyped models. Once the biomodels are correctly made according to the virtual planning, they will be taken to sterilization to be used in the surgical procedure (10,11). In the last phase, which is the surgical stage, bone reconstruction occurs with alloplastic implants.

The main advantage of computer-assisted surgeries (CAS) consists in their predictability of outcome, reduction of operative time, and the reduction of sequelae since the entire procedure can be visualized by preoperative virtual surgical planning (10,11,5,12).

The objective of case report is to show a secondary craniofacial reconstruction using PMMA, with virtual planning and CAD/CAM technology.

CASE REPORT

A 48-year-old male was referred to the emergency department of the Adão Pereira Nunes Hospital, in the city of Duque de Caxias (Rio de Janeiro), Brazil, presenting myiasis, which caused a cavitary infestation on the anterior wall of the frontal sinus by Diptera larvae, associated with a gasoline burn in the region. The burns were caused by the application of gasoline, by the patient himself, in an attempt to eliminate the myiasis that was present inside the defect in the frontal region.

At the first moment, the case was approached by the neurosurgery (NS) and oral and maxillofacial surgery team to stabilize the condition, in an attempt to preserve the bone of the structures present and to debride the necrotic tissue caused by the inflammatory reaction process caused by the presence of the larvae. This case was described after approval by the Research Ethics Committee of the Carlos Chagas Institute with protocol number 68259523.4.0000.0251 and the patient's signing of an informed consent form.

After discharge by the NS, the patient was admitted to the oral and maxillofacial surgery unit. He was conscious, all vital signs were within normal patterns, airways were preserved, there were no comorbidities, and his general condition was stable. On physical examination, it was observed two bone defects in the frontal region with dehiscence of the skin into the frontal sinus. Interestingly, the lack of protection of the brain in the frontal region was observed and, consequently, it was possible to visualize the pulsating dura mater (Figure 1). During the consultation, the patient reported that he had undergone a post-trauma osteosynthesis of the frontal bone 8 years earlier and, 2 months postoperatively, dehiscence of the skin wound occurred, remaining open for years, until he received the new surgical approach.

Figure 1 - *Initial clinical image showing the bone defects.*

On computed tomography (CT) examination, with axial, sagittal, and coronal sections and 3D tomographic reconstruction, the large bone defect of the anterior wall and posterior wall of the frontal bone with plate and screw debris from the previous surgery was assessed (Figure 2).

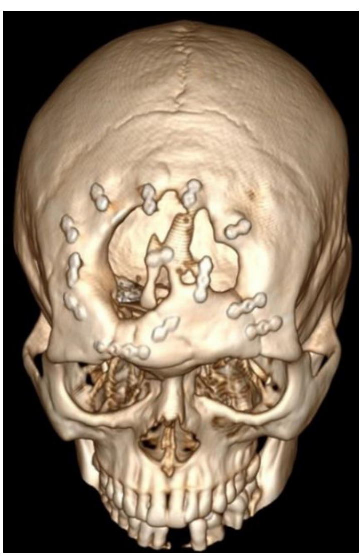

Figure 2 - *Clinical aspect after tooth preparation and adhesive procedure*

This surgery was performed with the main objective of reconstructing and bringing back the anatomical skull contour from previous unsatisfactory surgery, protecting the encephalon by means of a bulkhead, replacing the bone defect, and avoiding new cases of myiasis.

Clinical management to obtain the individualized prototype

During preoperative planning, a CT scan with 1mm slices was obtained and this data was recorded in DICOM format, converted to STL format, and sent to a 3D reconstruction printer (Sethi3D S4X) at the Renato Archer Institute. This printer has the function of taking the records in STL format and converting them into a 3D model of the frontal bone and the full-size resin mold of the bone defect. It is important to note that linear and objective measurements are collected from the CT scan for calibration in the printer software itself for conversion of the images into real size. The pieces were delivered to Hospital Adão Pereira Nunes 90 days after sending the CT data and sent moments before for sterilization (autoclave-saturated steam under pressure) to be used in the perioperative phase (Figures 3 and 4).

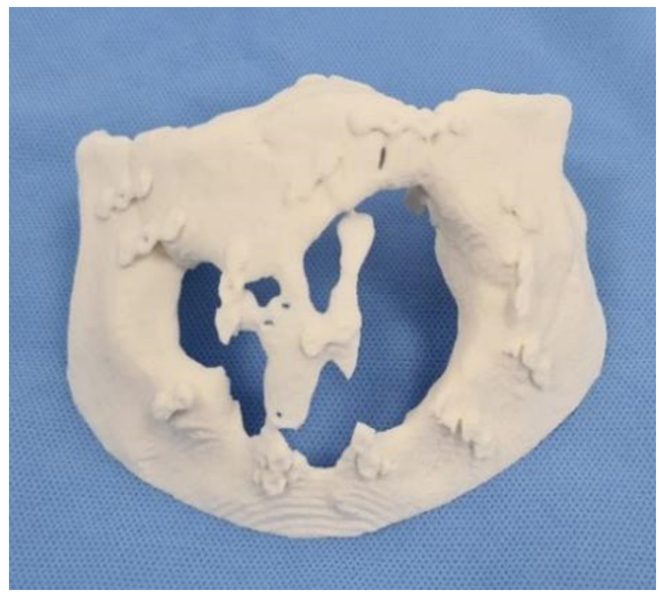

Figure 3 - *Image of the individualized prototype*

Figure 4 - *Image of the mold of the bone defects*

Surgical technique

To address the bone defects of this patient, a neurosurgeon was involved in the treatment of dura mater, cranialization of the frontal sinus, and obliteration of the nasofrontal duct with the use of periosteum, being finalized by the oral and maxillofacial surgery team. The surgical approach was through general anesthesia, orotracheal intubation, trichotomy, asepsis, and antisepsis of the operative field and bi-coronal surgical access. After exposure of the bone boundaries, removal of the residual plates and screws from the first surgery (Figure 5) and intervention in the frontal sinus by the NS were performed. Powder and liquid methylmethacrylate (Biomecânica Brasil) were manipulated and placed in the mold. After polymerization of the material, the PMMA prostheses were installed in the bone defects of the frontal bone and fixed with 2 straight plates of the 1.5 system and 10 screws 1.5x6mm (KM Materiais Médicos, Rio de Janeiro, Brazil) (Figure 6). A Blake 19fr drain (Drenoset, São Paulo, Brazil) was installed and the suture of the access was performed by internal planes with vycril 4-0 (Ethicon, Johnson & Johnson MedTech) and nylon 3-0 (Technofio, Goiânia, Brazil) in the skin region. For the skin defect in the frontal region, curettage of the edges and simple suture with 4-0 nylon (Technofio, Goiânia, Brazil) were chosen (Figure 7).

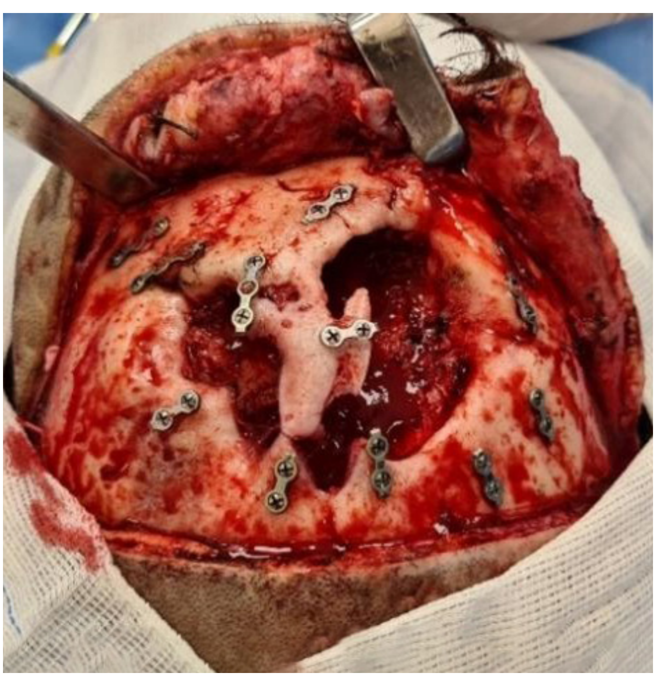

Figure 5 - *Residual plates and screws from the first surgery*

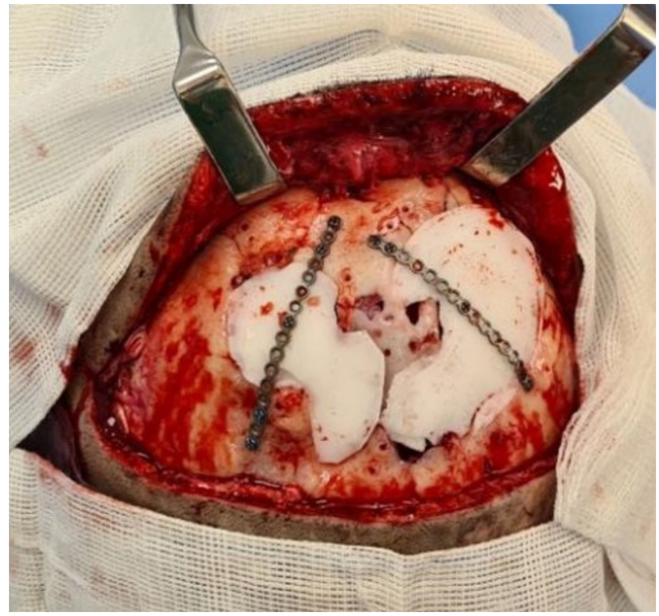

Figure 6 - *Fixing the PMMA prostheses*

Figure 7 - *Immediate postoperative image*

After surgery, a CT scan was performed to evaluate the prostheses (Figure 8). It was observed a perfect adaptation between the prosthesis and the bone contour and a great anatomical contour of the frontal bone, satisfying the initial surgical planning. The patient remained hospitalized and was followed up until his discharge by the oral and maxillofacial surgery team.

After hospital discharge, the patient followed a monthly outpatient follow-up, during the first 10 months postoperatively, with the plastic surgery team to evaluate the healing of the skin tissues that cover the frontal bone prosthesis, since rotation techniques of surgical flaps were used to enable the closure in the first intention of the tissues of the region.

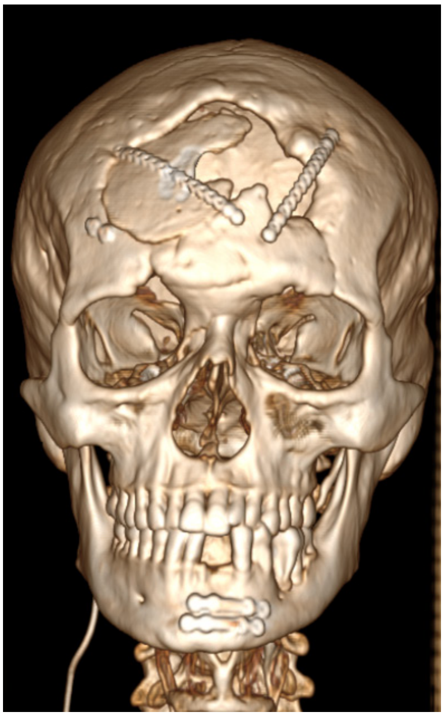

Figure 8 - *3D CT reconstruction performed postoperatively.*

DISCUSSION

In the hospital environment, there are many etiologies that cause bone defects requiring reconstruction in daily oral and maxillofacial surgery, predominantly caused by high-energy trauma, with sports accidents, physical aggression, and motorcycle accidents as the main etiological agents (13). These etiologies may require more complex reconstruction techniques, without renouncing autogenous grafts or biomaterials. In the case of this patient, we opted for the PMMA prosthesis due to the surgical practice of the oral and maxillofacial surgery team, and also due to the ease of handling, low cost, and execution of the procedure.

To treat the defects in this patient, the cranioplasty technique was used to establish anatomy, aesthetics, and protection of the neural tissue (2,7,13,14,15,16). Currently, alloplastic materials have become more popular and are used more frequently than autogenous grafts. Interestingly, despite the large frontal bone defect, the NS team evaluated the patient, and no neurological impairment was observed.

Among the alloplastic materials, titanium is highly biocompatible, with no risk of hypersensitivity or allergic reactions, has great resistance to corrosion, and promotes rapid three-dimensional restoration of the skull, but has a high cost compared to PMMA (14,17). There are also other materials, such as hydroxyapatite cement, which is a bioactive material, with a great capacity for osteoconduction and with potential to interact with the tissue where it was implanted, being chemically similar to the bone, which allows its biocompatibility (14,17,18). However, this material has a relatively high cost compared to PMMA.

The use of PMMA in cranioplasty has numerous advantages, among them ease of handling, non-degradable, low thermal conductivity, radiopaque, can be used with antibiotics such as gentamicin or tobramycin, impermeable, formation of a fibrous capsule occurs, and is not able to incorporate into the tissue (15,17,18). Gonzalez *et al.* and Cheng *et al.* consider PMMA to be the best alloplastic material for cranioplasty surgery in adults, but it is not indicated for use in children or young people because it is a material that does not adapt to skeletal development (6,19).

For an optimal result in cranioplasty with the use of alloplastic materials, preoperative follow-up by the neurosurgeon is extremely important to assess the need for craniolization, since the frontal sinus occupies the junction between the splenocranium and the neurocranium, located between the anterior cranial fossa and the nasolabial-ethimoidal region (20). Hence, serious complications can occur if the treatment is performed inappropriately, especially late sepsis, as well as recurrent sinusitis, osteomyelitis of the frontal bone, meningitis, encephalitis, or cavernous sinus thrombosis (21,22).

In the present study, computer-assisted techniques were used for craniofacial reconstructions, offering more precise surgical planning and technique, aiming to re-establish the anatomical characteristics of the patient (23). Currently, 3D images from CT scans are being used more frequently for the evaluation of craniofacial defects, traumas, and pathologies among maxillofacial surgeons, and through these images, individual prototyped models are obtained.

The virtual planning obtained from CT, 3D printing of prototypes, and synthetic materials, is a major advance in the field of surgery and a great benefit when employed in complex defect reconstructions.

With the technological resources that the CAD/CAM system can offer us, such as virtual planning and 3D printing, it is necessary that professionals be qualified with great knowledge to perform adequate and safe planning. However, using this technique may still be an inaccessible procedure for some patients due to the cost of making the models and guides (23).

CONCLUSION

The use of virtual planning and the CAD/CAM system resulted in greater predictability and greater safety for the craniofacial reconstruction procedure, as well as a reduction in the perioperative time. The material used, PMMA, presented as a material of easy manipulation, low cost, and with perfect adaptation to bone contours.

The authors declare that there are no conflicts of interest.

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