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Case Report
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Subtotal Reconstruction of the Cranial Vault: Case Report and Technical Considerations in Planning and Finalizing Custom-Made Undercorrected Cranioplasty

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Abstract

Introduction: The aim of this report is to introduce the concept of undercorrection in CAD-CAM cranioplasty in the context of patients who underwent subtotal Decompressive Craniotomy (DC).

Case Report: A case of a young patient, who underwent bilateral post-traumatic DC of 40% of the cranial vault and successive custom-made cranioplasty, is reported in this article. The patient's case was studied 13 months after DC through high-resolution CT, assessing brain, skull and scalp data, that were used for virtual Three-Dimensional (3D) analysis and planning, in order to produce hypoprojected PEEK implants that prevented both an excessive tension on the severely scarred scalp and an excessive intracranial dead space. The patient was treated with a one-stage cranioplasty that reconstructed 208 cm^2 of the cranial vault while obtaining tensionless scalp closure; a total of 46 cm^2 of skull surface in the lower temporal areas were left unreconstructed as they could work as a warning sign for the rise of ICP in case of swelling. The 12-months follow-up showed satisfactory aesthetic and structural results.

Discussion: Whether it's for treatment of the syndrome of the trephined or for aesthetic purposes, the need to reconstruct calvarial defects remains a challenge, especially for very large defects (>150 cm^2) which are rarely described in literature. To overcome the potential intra- and extracranial complications to the procedure, available surface-guided CAD-CAM programming represents an optimal solution.

Conclusion: In this report, use of undercorrection in planning and finalizing subtotal custom-made cranioplasty, appears able to restore skull integrity and aesthetics while avoiding excessive skin tension and reducing intracranial dead space.

Keywords: Cranioplasty; Subtotal cranioplasty; Custom-made cranioplasty; Decompressive craniectomy; Traumatic brain injury

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Introduction

In cases of large skull defects, reconstruction currently represents a necessity, with the aim to provide structural protection for the underlying brain, a barrier against infection, and the solution to correct aesthetic deformities [1]. These skull defects are frequently the result of Traumatic Brain Injury (TBI) -related Decompressive Craniectomy (DC); in other cases, craniectomy is performed due to intracranial aneurysm, Arteriovenous Malformations (AVM), cerebral abscess, ischemic stroke-related cerebral edema, and tumors [2].

Since ancient history, great efforts have been made to solve the problem of skull defects, but it was only after World War I that cranioplasties were performed in greater number [3]. Between the reasons that support reconstruction, the main one is undoubtedly the treatment of the Syndrome of the Trephined [4] which consists in the rapid neurological deterioration while changing the posture of the patient is specific positions (from orthostatic to horizontal or Trendelenburg position), together with modifications of Cerebral Blood Flow (CBF) and Cerebrospinal Fluid (CSF). In these patients, cranioplasty has a therapeutic effect in preventing these sudden neurological symptoms by avoiding the flaccid scalp portion covering the cranial defect from being sensitive to atmospheric pressure, causing direct force over the cortex [4]. Thanks to the vast knowledge of materials and design refinements while programming a Computer-Aided Design and Computer-

Aided Manufacturing (CAD-CAM) cranioplasty, it is now possible to perform subtotal cranioplasties, although uneventful results still represent a challenge. This work has been reported in line with the Scare Criteria [5].

Case Presentation

Informed written consent was obtained from the patient's legal guardian for the writing and publication of this case report. A 22-year-old patient was sent to the Emergency Room of our III[rd] level University Hospital 1 h after a 7-meter fall from a roof while working. Neurological examination assessed a Glasgow Coma Scale (GCS) score of 6, and the patient underwent a brain CT scan (Figure 1) that showed bilateral cerebral swelling with multiple cerebral contusions and a suspected intracranial right carotid artery rupture.

He was transferred to the emergency operating room and under general anesthesia, he underwent right temporoparietal DC. After 24 h, the patient's Intracranial Pressure (ICP) was still high (23 mmHg) and a left temporoparietal DC was performed (Figure 2). The patient's Glasgow Coma Scale score was 6 on postoperative day 11 and continued until discharge. Due to the trauma, the patient suffered irreversible traumatic brain damage, and despite the DC, a long-term outcome of Extended Glasgow Outcome Scale (GOS-E) = 2 was assessed.

The patient suffered 3 episodes of skin flap dehiscence along different parts of the surgical incisions, that healed by secondary intention with the aid of medicated dressings.

A High-Resolution CT of the craniomaxillofacial complex was acquired (Siemens SOMATOM Definition AS+, Siemens, Erlangen, Germany), assessing both the brain and the skull data (Figure 3, 4), which were processed using Materialise's Interactive Medical Image

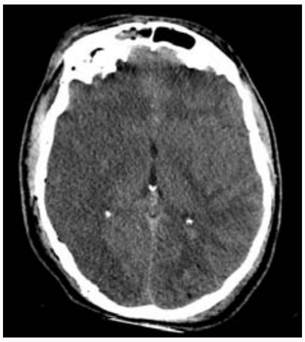

Figure 1: Emergency CT scan assessing post-traumatic bilateral cerebral swelling and multiple cerebral contusions.

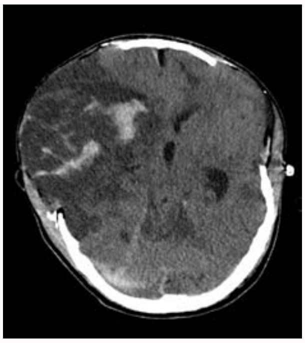

Figure 2: Brain CT scan after bilateral DC.

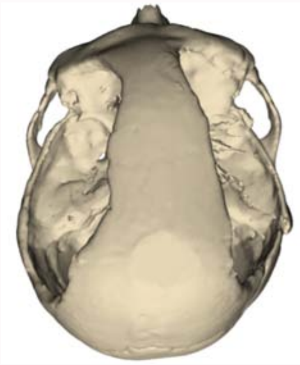

Figure 3: 3D reconstruction of the patient's skull before cranioplasty, missing of 40% of the cranial vault.

Figure 4: CT scan showing cerebral volume 13 months after trauma.

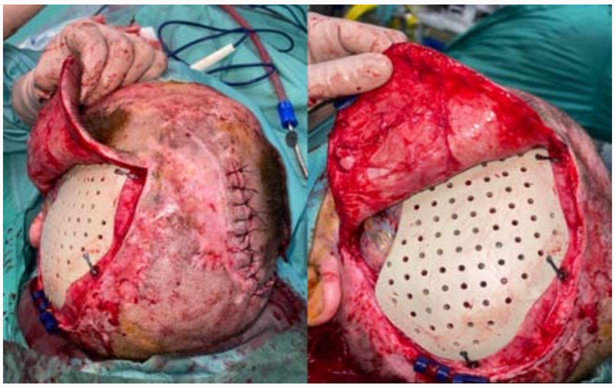

Figure 5: a) Intraoperative photograph showing left custom-made implant positioning (left); b) the photographic detail shows the unreconstructed temporal area, that will work as a warning sign for the rise of ICP in case of swelling (right).

Control System 10.0 (Materialise, Leuven, Belgium).

All data regarding the surface of preoperative and postoperative cranial defect were acquired, together with the scalp surface and the intracranial dead space between the brain and the scalp. Using this data, 16 months after decompressive craniotomy, the patient underwent bilateral Polyether Ether Ketone (PEEK) custom-made cranioplasty (implants were fabricated by 3dific, Perugia, Italy) for the skull defect along the original incision approach (Figure 5). After discharge, the patient was checked at the 1-week, 2-weeks 1-month, 6 and 12 months clinical and radiological follow-up.

The data details regarding the area of skull surface reconstructed

Table 1: Pre- and post-operative patient data.

Skull surface **before DC**	**651** cm²	**Skull** surface **after DC**	**397** cm²	**Skull** surface **after cranioplasty**	**605** cm²
Scalp surface **before DC**	**686** cm²	**Scalp** surface **after DC** – multiple flap dehiscence events	**663** cm²	**Scalp** surface **after cranioplasty**	**664** cm²
/	/	/	/	**Total** area reconstructed	**208** cm²
/	/	/	/	Area **left unreconstructed**	**46** cm²

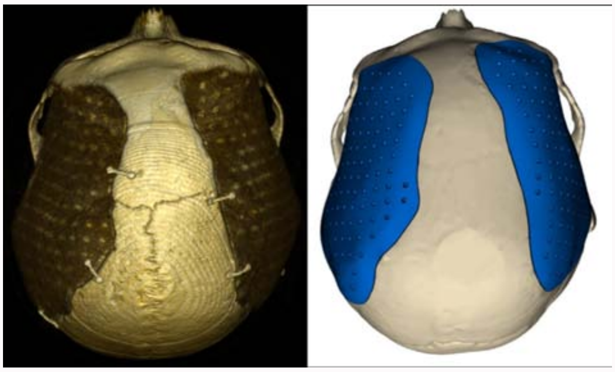

Figure 6: a) 3D reconstruction of the results of cranioplasty (left); b) CAD-CAM model used for implant realization (right).

Figure 7: Physical appearance in frontal view of the patient before (left) and after (right) cranioplasty.

are summarized in Table 1. The data acquired from the CT scan prior to the cranioplasty and processed with virtual Three-Dimensional (3D) analysis showed a total cranium surface of 397 cm², compared to 605 cm² after surgery, with the implants representing a total of 208 cm² of skull surface. Bilaterally, in the temporal region, a total of 46 cm² were non-reconstructed for reasons that will be discussed below. The patient did not show any complications related to cranioplasty and was discharged 7 days after surgery. At the 12-months clinical and radiological control (Figure 6, 7), no implant loosening or dislocation were noted, and the aesthetic aspect and the structural strength of the cranium were restored.

Discussion

Under the circumstances of brain insults, such as trauma or intracranial hemorrhage, inflammatory cascade, impaired osmolyte transport and oxidative stress, combined to the eventual direct injury, lead to serious brain swelling and subsequent damage [6]. It is not a coincidence, in fact, that the first neurosurgical operation performed was indeed a trephination, performed by the Incas over 3000 years ago, probably with the purpose to treat the consequences of a trauma. However, we will have to wait the sixteenth century to see the first description of a cranioplasty, done by a Flemish physician named Fallopius [7].

In modern times, treatment of such harmful events as TBI

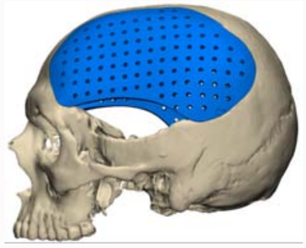

Figure 8: Virtual 3D model of the implants showing the bilateral temporal unreconstructed "window".

includes, in the first instance, DC together with a specific medical treatment and, in the case of really extended TBI, bifrontal or bilateral craniectomy is advised. Even though current guidelines do not specify nor the extension of the craniectomy neither the optimal time to perform subsequent cranioplasty [8], some authors suggest that at least 60 cm² of cranial vault should be removed for DC [8] and Hawryluk et al. conclude that a large fronto-parieto-temporal (15 cm in diameter) DC should be preferred over a smaller DC in order to reduce mortality and improve neurological outcomes [8].

However, whether it's for treatment of the syndrome of the trephined or for aesthetic purposes, the need to reconstruct calvarial defects remains a challenge, especially for very large defects (>150 cm²) which are rarely described in literature.

Historically, replacement of the patient's stored autologous bone flap has represented the first-line treatment for reparation of post-decompressive skull defects, usually taking place between 6 and 12 months after surgery. However, complications like bone resorption, infection or chronic scalp wounds can result in a composite skull defect that should be approached by alternate means [9].

Nowadays, multiple options for restoring skull integrity following DC or previous autologous bone repositioning failure have been described, and in these cases, reconstruction planning should consider previous scalp incisions, to avoid scalp vessel damage that could bring to necrosis. Moreover, a thorough study of the scalp surface available should be performed, to obtain a tensionless closure. In an article of Nout et al. a CAD-CAM implant for parietal reconstruction was slightly decreased in projection, in order to facilitate wound closure [10]. In these cases, CAD-CAM surface measurement can help predict the total skull surface before and after surgery, allowing to prevent potential complications such as skin dehiscence, or in cases when it is most suitable, to suggest the need for free soft tissue transfer or scalp expansion [9], as advised by Baumeister et al.

Another important factor to consider for a successful cranioplasty is the choice of the material, which should be carefully made: A recent systematic review reported a 20.64% risk of complications with alloplastic materials, but each of them has advantages and disadvantages that must be considered. Titanium offers low rates of infection (10.7%) and can be easily screwed directly to the adjacent bone; however, it has a higher extrusion rate compared to the other materials, and being radiopaque, it gives problems for tumor surveillance follow-up [11]. Polyether Ether Ketone (PEEK) offers the advantage that it is radiolucent and hypodense and does not cause radiographic artifacts on CT scans or MRIs [11,12]. It has a 7.3% infection rate and a lower overall complication rate (17.3% *vs.* 31.8% for titanium). Polymethylmethacrylate (PMMA) implants benefit from this material's strength, radiolucency and relatively low cost compared to the others. Prostheses made of PMMA can be modified intraoperatively using a bur, but, during handling and fixation, cases of prosthesis fracture are described, and account for an overall complication rate of 19% [10].

In our patient, a large bilateral DC was performed, bringing the total calvarial defect to 254 cm^2. Due to this impressive bilateral defect, which represented approximately 40% of the total neurocranium, the patient had to rest only in supine position, causing a high risk of pressure sores and making it difficult to move the patient during bed changes or daily hygiene. For these reasons, the patient could not be left to the care of his family and had to stay at a long-term care facility.

In the months following DC, several episodes of skin flap dehiscence along different parts of the surgical incisions occurred, treated by the neurosurgery and plastic surgery units. After complete healing of the scalp dehiscence, the maxillofacial surgery team was asked to reconstruct the calvarial defect, and with the aid of an engineering team, started programming the reconstruction, and two possible complications were highlighted. The first one is related to the skin quality and its surface; after several episodes of flap dehiscence, the skin resulted heavily scarred, thickened and contracted. The second potential complication is given by the dead space that would follow a cranioplasty which brings the calvaria to its original shape, while the brain would maintain its post-traumatic volume. Free tissue transfer was at first considered as a possible solution; it offers several benefits, including providing durable coverage for skull reconstruction, obliteration of dead space, and is of great benefit in revision cranioplasty patients with chronic overlying wounds lacking adequate soft tissue coverage [13]. However, free tissue transfer often limits the retention of native hair-bearing scalp skin at the defect site and would have necessitated a two-step surgery for both bringing soft tissue and calvarial custom reconstruction. Moreover, the relatives of the patient denied their consent to the free flap option to preserve a potential donor site from further surgery on such a delicate patient, and they preferred for us to find a solution for the problem without harvesting a free flap.

In order to overcome the potential complications to the procedure, the program of developing adequate implants for cranioplasty firstly focused on the scalp surface, that was measured in the 3D rendering of the TC, giving an estimate of the scalp available (663 cm^2). With this data, the biparietal implants for cranioplasty were designed to utilize all the skin surface available for cranioplasty without stretching the already scarred parietal skin, obtaining an undercorrected skull surface (Figure 5). Another concept that was taken into consideration was the volume of the dead space between the implant and the brain; by undercorrecting the custom-made implants, the amount of dead space was dramatically lowered. Despite the large area reconstructed with cranioplasty, the lower portion of the temporal area on both sides was not covered by the implant (Figure 8), since due to the presence of the zygomatic arch, it was the safest area to leave unreconstructed and could work as a warning sign for the rise of ICP in case of swelling.

Conclusion

Cranioplasty of large calvarial defects with poor soft tissue quality represents a challenge in which the surgeon could need to think "outside the box" to solve the problem he is put in front of. We have achieved durable aesthetic and functional results in this setting using undercorrected CAD-CAM PEEK implants for reconstruction, both reducing the risk of skin dehiscence and drastically reducing the intracranial dead space. For these patients, an accurate planning, that takes into consideration both soft and hard tissues is paramount. Further investigations are needed to better examine the long-term results of undercorrected CAD-CAM in cranioplasty patients.

References

1. Bonda DJ, Manjila S, Selman WR, Dean D. The recent revolution in the design and manufacture of cranial implants: Modern advancements and future directions. Neurosurgery. 2015;77(5):814-24.
2. Ashayeri K, Jackson EM, Huang J, Brem H, Gordon CR. Syndrome of the trephined: A systematic review. Neurosurgery. 2016;79(4):525-34.
3. Sanan A, Haines SJ. Repairing holes in the head: A history of cranioplasty. Neurosurgery. 1997:588-603.
4. Joseph V, Reilly P. Syndrome of the trephined: Case report. J Neurosurg. 2009;111(4):650-2.
5. Agha RA, Borrelli MR, Farwana R, Koshy K, Fowler AJ, Orgill DP, et al. The SCARE 2018 statement: Updating consensus Surgical Case Report (SCARE) guidelines. Int J Surg. 2018;60:132-6.
6. Klatzo I. Neuropathological aspects of brain edema. J Neuropathol Exp Neurol. 1967;26(1):1-14.
7. Mee H, Anwar F, Timofeev I, Owens N, Grieve K, Whiting G, et al. Cranioplasty: A multidisciplinary approach. Front Surg. 2022;9.
8. Hawryluk GWJ, Rubiano AM, Totten AM, O'Reilly C, Ullman JS, Bratton SL, et al. Guidelines for the management of severe traumatic brain injury: 2020 update of the decompressive craniectomy recommendations. Neurosurgery. 2020;87(3):427-34.
9. Baumeister S, Peek A, Friedman A, Levin LS, Marcus JR. Management of postneurosurgical bone flap loss caused by infection. Plast Reconstr Surg. 2008;122(6):195-208.
10. Nout E, Mommaerts M. "Considerations in computer-aided design for inlay cranioplasty: Technical note." Oral Maxillofac Surg. 2018;22(1):65-9.
11. Johnston DT, Lohmeier SJ, Langdell HC, Pyfer BJ, Komisarow J, Powers DB, et al. Current Concepts in cranial reconstruction: Review of alloplastic materials. Plast Reconstr Surg - Glob Open. 2022;10(8):E4466.
12. Punchak M, Chung LK, Lagman C, Bui TT, Lazareff J, Rezzadeh K, et al. Outcomes following Polyetheretherketone (PEEK) cranioplasty: Systematic review and meta-analysis. J Clin Neurosci. 2017;41:30-5.
13. Mundinger GS, Latham K, Friedrich J, Louie O, Said H, Birgfeld C, et al. Management of the repeatedly failed cranioplasty following large postdecompressive craniectomy: Establishing the efficacy of staged free latissimus dorsi transfer/tissue expansion/custom polyetheretherketone implant reconstruction. J Craniofac Surg. 2016;27(8):1971-7.