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Technical Note

Polymethylmethacrylate cranioplasty implant customized using a polylactic acid mold and prepared with a 3D printer: an example case

3 boyutlu yazıcı ile hazırlanan polilaktik asit kalıbı kullanılarak özelleştirilen polimetilmetakrilat kranioplasti implantı : Örnek Vaka

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Abstract: In recent years, the use of three-dimensional imaging and modeling methods has become increasingly frequent, replacing two-dimensional studies. Three-dimensional images, which are widely used in medicine, provide surgical facilities, especially in neurosurgical practice. Surgery for epilepsy, cranioplasty, vascular and intracranial lesions could be shaped based on three-dimensional images. The main purpose of cranioplasty is to replace bone tissue loss due to previous surgery or trauma to protect brain tissue. For this purpose, autologous grafts could be used as well as materials such as polymethylmethacrylate. In this study, a PLA mold was produced using a three-dimensional printer for the patient who was planned for cranioplasty and cranioplasty was performed with PMMA. The perioperative observation of the patient revealed that the mold was fully seated. The patient was satisfied cosmetically in the follow-up. With the advancement of technology, the use of three-dimensional printers in neurosurgery practice will further increase, individual treatment methods will be developed and better results will be obtained with less cost and complication rates.

Keywords: 3D printing, Cranioplasty, Mold, Polylactic Acid, Polymethylmethacrylate

Özet: Son yıllarda kullanımı gittikçe yaygınlaşan üç boyutlu görüntüleme ve modelleme yöntemleri, iki boyutlu çalışmaların yerini almaktadır. Tıp alanında da yaygın kullanımı olan üç boyutlu görüntüler özellikle nöroşirurji pratiğinde cerrahi açıdan kolaylıklar sağlamaktadır. Üç boyutlu görüntüler esas alınarak epilepsi, kranioplasti, vasküler ve intrakranial lezyonların cerrahisi şekilllendirilebilmektedir. Daha önceki ameliyata ya da travmaya bağlı olarak kemik doku kaybının yerine konup, beyin dokusunun korunması kranioplastinin asıl amacıdır. Bu amaçla otolog greftler kullanılabileceği gibi polimetilmetakrilat gibi maddeler de kullanılmaktadır. Bu çalışmada kranioplasti planlanan hasta için üç boyutlu yazıcı kullanılarak PLA kalıbı üretilmiştir ve PMMA ile kranioplasti işlemi gerçekleştirilmiştir. Hastanın perop gözleminde kalıbın tam olarak oturduğu görülmüştür. Hasta takiplerinde kozmetik açıdan memnundu. Teknolojinin ilerlemesi ile birlikte üç boyutlu yazıcıların nöroşirurji pratiğinde kullanımı daha da artacak, kişisel tedavi yöntemleri geliştirilecek, daha az maliyet ve komplikasyon oranları ile daha iyi sonuçlar elde edilecektir.

Anahtar Kelimeler: 3D Yazıcı, Kranioplasti, Kalıp, Polilaktikasit, Polimetilmetakrilat

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1.Introduction

Craniectomy could be performed for brain edema, skull fractures, intracranial infections, tumors or trauma [1, 2]. The main purpose of cranioplasty is to replace bone tissue loss after craniectomy, cosmetic repair, and protection of brain tissue.

In recent years, three-dimensional models using imaging software and robust cranioplasties with the advanced design and technology of bio models have begun to be performed. Three-dimensional modeling procedures started with the compilation of computed tomography (CT) images due to their superiority in bone structure imaging.

Use of autologous bone grafts for bone defects is considered the gold standard because of the conjoining of the defected site and immunological compliance [3, 4]. While autografts have disadvantages such as infection, limited availability, and risk of absorption, the use of alloplastic or synthetic materials offers advantages such as ease of use and unlimited supply [5].

Polymethylmethacrylate (PMMA) is still the most commonly used material due to its good biocompatibility, lightweight, low radiopacity, strong resistance to functional stress, easy handling and low cost [2, 6]. In a comparative study about autologous bone grafts, patients with autologous bone tissues were more likely to have re-operations [7].

To date, PMMA implants have been manually shaped according to the defect in the skull, causing poor cosmetic results [8, 9]. Although reconstruction with titanium mesh has achieved both better cosmetic and infection results, their high cost was a disadvantage. The use of PMMA, a less costly material, was combined with three-dimensional technology; shortened surgical time and lower complication rates were achieved successfully at low cost [10].

Here we describe the implantation of a PMMA implant using polylactic acid (PLA) mold made by 3D modeling in a patient with cranial bone defects after the Syrian war.

Patient

A 22-year-old male patient was operated 9 months before his reference to us due to buckshot hit in his head in the Syrian war, and a craniectomy was performed on his left frontoparietal region. The patient, who had no neurological deficit, referred to us for the repair of cranial defect for cosmetic purposes. Preoperative thin-slice brain tomography (0.5 mm) was performed for the cranioplasty planning (Siemens Somatom Definition) (Figure 1).

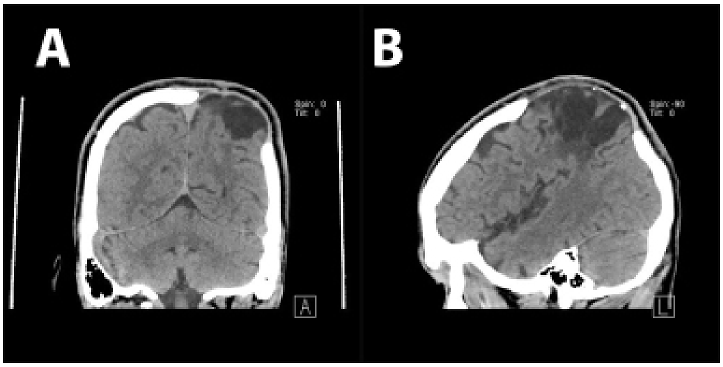

Figure 1 - Anterior and Posterior CT Views Before Surgery

Producing the mold

The data of CT images were saved in the standard format DICOM (Digital Images and Communications in Medicine) which authorize creating an interface between the medical equipment and other devices to visualize the images. The 3D Slicer generated a three-dimensional reconstruction of all the CT cross-sectional images, using the DICOM viewer.

The construct was created using the software of the computer-aided design (CAD) Mesh mixer because 3D Slicer is only capable of viewing. The volumes underwent a boolean operation. The mold design must have a perfect shape and volume according to the patient's cranial anatomy. Finally, the data was exported in a stereolithography extension file (STL) and sent to the printer. Custom made 3D printer (Dokuz Eylül University, BiomechanicsLab.) was used to print out the PLA mold from the STL file using a fused deposition model using a 1,75 mm filament at a 260 °C extruder temperature. Once the printing process was finished, which takes about 5 hours, the mold was then taken to the biomechanics laboratory. The mold was with an internal and an external surface impression.

Customized PMMA implant molding

Intraoperatively, PLA mold was covered with a double layer nylon bag. The reason for being double-layered is that PMMA, which would adapt to the mold, melts the single-layer nylon bag due to the exothermic reaction. The mold was then shaped at the 5th minute after PMMA (High Fatigue G®; Zimmer, Dieburg, Germany) components were mixed. PMMA spreading in the mold cavity was corrected to be of equal thickness and the edges were cut with the help of a knife. At 8th minute, the PMMA hardened so as not to deform and was removed from the mold to complete the exothermic reaction.

The edges of the PMMA implant were corrected with the help of a rongeur to ensure a perfect fit for the defective area. 3 to 4 holes were drilled into the implant to prevent sub-implant fluid collection and infection before the PMMA was placed to the defective area (Figure 2). Dura center sutures were placed to prevent epidural fluid accumulation. The implant was attached to the intact bone with thick suture materials.

Figure 2 - PMMA implant

2. Findings

The patient had no clinical defect in the postoperative period and his cosmetic results were excellent. Early postoperative thin section brain tomography revealed complete implant placement on the defective area (Figure 3). The patient was satisfied with the cosmetic results at 1st month postoperatively. No signs of infection and complications were observed in the 6th month after cranioplasty.

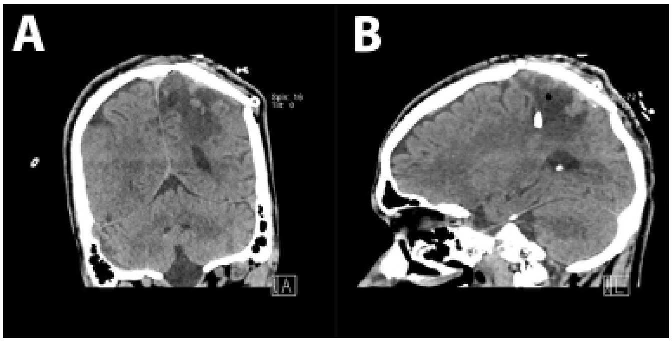

Figure 4 - Anterior and Posterior CT Views After Surgery

Cranioplasty is performed with the aim of calvarial shaping and preserving intracranial structures. Various materials are used in cranioplasty operations to cover bone defects occurred due to numerous causes [11].

In patients planned for cranioplasty, three-dimensional printers could be used to produce models and molds appropriate to the patient's current defect by using computer-assisted modeling integrated with pre-operative thin-section brain tomography. In this way, better cosmetic results and satisfaction for the patients, surgical time saving and surgical facilities were provided. Pre-operative simulation has demonstrated efficacy in terms of surgical planning [12].

In comparative studies between autologous bone grafts and methylmethacrylate use, re-operations were more commonly seen in patients with autologous bone grafts [7]. There is a possibility of infection up to 30% depending on the type of material used in cranioplasty operations [10].

In one study, the mean operation time was shown to be 72 minutes in cranioplasty using porous polyethylene [13]. It was observed that this duration was shorter in our patient who underwent surgery by forming a mold with a three-dimensional printer.

As in our case study, surgical planning using a three-dimensional printer shows shorter and more comfortable operation durations, customizable molds, low cost, and low infection rates. With the developments in 3D printer technology, preoperative surgical planning will contribute to the development of simulation methods, and therefore to the development of private treatments.

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