

# Cranial vault reconstruction using computer-designed polyetheretherketone (PEEK) implant: case report

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## Abstract

**Background:** Reconstruction of the bones of the skull is a complex procedure and represents a challenge for the surgical team. It is generally performed in patients who have loss of the cranial vault secondary to chronic infection or uncontrolled osteoradionecrosis, indicating a greater chance of failure or rejection of the materials used for repair of the defect. Selection of material to replace the cranial vault is complex due to the diversity of existing products. The ideal material is inert, lightweight, easy to fit and adaptable to the defect, offering the best aesthetic and functional results. Computer design of the implant makes this process easier by providing an implant specific to each individual patient and defect.

**Clinical case:** We report the case of a patient who was diagnosed with esthesioneuroblastoma and was treated with anterior craniofacial resection and radiotherapy. Osteomyelitis and osteoradionecrosis were consequent complications with loss of the cranial vault in the frontal region. The defect was reconstructed with a polyetheretherketone (PEEK) computer-designed implant based on the defect evaluated by computed tomography. Results obtained are shown below.

**Conclusions:** The PEEK computer-designed implant is a safe and easy to use alternative with great adaptability to cranial vault defects.

**Key words:** cranial vault, reconstruction, PEEK.

## Introduction

The standard surgical approach for tumors that originate in the bulk of the centropacial region with invasion of the anterior cranial base is craniofacial resection using a combined approach (bifrontal-orbital-zygomatic and transfacial).<sup>1,2</sup> The most frequent complication of this procedure is leakage of cerebrospinal fluid followed by neurological sepsis and infection of the osteomyocutaneous flap.<sup>2-4</sup> In patients who receive radiation therapy

following surgical resection of the tumor, frontal osteoradionecrosis with formation of areas of osteomyelitis and bone sequestration at the craniotomy site should be seen as possible complications that may occur up to 15 years after the definitive treatment.<sup>4</sup>

Frontal osteomyelitis and osteoradionecrosis at the site of the craniotomy are difficult to control complications and usually require multiple surgical interventions such as surgical cleaning and debridement and sometimes involve partial loss of the cranial cavity. Treatment for these complications is complex and frequently disappointing because, despite multiple reinterventions, the compromised area intermittently presents the formation of bone fragments and osteomyelitis. Often there is a need to partially remove the frontal bone to eradicate the infectious process.

Upon removal of the bone fragments, the brain is covered only by the dura mater, subcutaneous tissue and the scalp, which means there will be both aesthetic and functional deficits. Seizure episodes occasionally occur as a secondary complication. The brain is left exposed to trauma and there is an increased possibility of meningitis.

Cranial reconstruction in these patients is difficult and represents a challenge for the medical team. It is accompanied by a high rate of postoperative complications due to the presence of adjuvant treatments after resection (associated or concurrent radio- or chemotherapy).

Various techniques have been described for reconstruction of the cranial cavity. Microtransported free fragments and alloplastic and hydroxyapatite materials are those most frequently used.<sup>5-7</sup>

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The use of loose fragments is a great option instead of bone reconstruction and although the coverage of the soft tissue is better, the brain remains exposed to risk of injury. Usefulness of these fragments remains limited to patients with skin loss from the scalp but with the cranial cavity intact or in patients undergoing surgical salvage after failure of radiotherapy or chemo-radiotherapy in order to reduce the most frequent complication, leakage of cerebrospinal fluid and, consequently, neurosepsis.<sup>5,8</sup> In these cases the reconstruction is done at the time of the oncological resection because the possibility of complications is greater, including the loss of the fragments, is more common in patients with prior radiation therapy. This phenomenon, although controversial, is seen in most series of patients who are reconstructed with free fragments, including our own experience.<sup>9,10</sup>

In order to be able to reconstruct the bones of the cranial cavity, having the soft tissue is insufficient. Alloplastic material that provides rigid protection to the central nervous system is required. Selecting the best material to reconstruct the skull depends on several factors, the most important being general health status of the patient, oncological prognosis, status of the overlying soft tissues of the cranial bone and cost of the procedures. Historically, reconstruction of the skull has limitations such as the material used for implantation, poor cosmetic results, rejection of the material used for reconstruction, prolonged surgery and the need for multiple reinterventions. Computer-designed implants have recently improved results.<sup>11</sup>

Computer-generated alloplastic implants have revolutionized the concept of bone reconstruction in patients who, due to various reasons, have partial loss of the cranial cavity.<sup>12,13</sup> This design permits physicians to create accurate models for each defect, with predictable results and shorter surgical time.<sup>11</sup>

The purpose of this study is to report to the medical community a case of computer-designed cranial implant reconstruction using polyetheretherketone (PEEK). The patient presented complications from a prior craniofacial resection with frontal bone loss.

PEEK is an aromatic polymer with ether and ketone chains. It is resistant to high temperatures, chemicals, radiation, and is

biologically safe.<sup>13</sup> The design of an implant using this material is individualized using a computer, beginning with evaluation of the bone defect to the topographical reconstruction, known as PSI (patient-specific implant).<sup>12</sup>

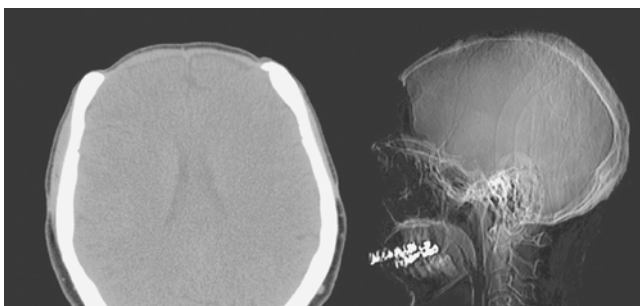
## Clinical Case Report

We present the case of a 63-year-old female who sought medical consultation due to symptoms of nasal obstruction and bilateral epiphora. Computed tomography demonstrated a tumor that originated in the anterior and posterior ethmoid, infiltrating the lamina cribrosa, lisaba the anterior base of the skull and penetrating the cranial cavity. MRI ruled out any disease in the dura mater. A biopsy was performed through the nasal passage with a report of olfactory esthesioneuroblastoma and classified as Kadish stage C. Anterior craniofacial resection was performed using widened coronal and sublabial approach. There were no post-operative complications.

The patient received adjuvant radiotherapy to the cranial base. After the seventh session of radiotherapy, there was initiation of erythema, increase in volume, hyperalgesia and frontal area was malodorous. The patient was treated with analgesics and antibiotics known to be DNA gyrase inhibitors. Radiotherapy was suspended. Bone exposure of the cranial surgical site was still present.

As mentioned earlier, the patient was subjected to surgical cleaning, debridation and “sequestrectomy” of the osteomyelitic areas. She received antibiotic treatment based on antibiograms; however, despite using these, there was recurrent local infection.

Finally, and due to the poor response to conservative treatment, the patient was subjected to resection of the frontal bone fragment leaving a defect of  $\sim 10.5 \times 6.4$  cm (Figure 1). The brain remained in contact with the unprotected frontal skin flap without bone protection and there was collapse of soft tissue (Figure 2).



**Figure 1.** Computerized tomography showing frontal bone defect secondary to osteoradionecrosis. Oncological diagnosis was esthesioneuroblastoma (Kadish stage B).



**Figure 2.** Preoperative clinical appearance. Frontal depression due to the absence of frontal bone.



**Figure 3.** External drilling in order to affix the polyetheretherketone (PEEK) (left). PEEK implant fixed with osteosynthetic material 2.0 (right).

Six months later when the local infection was cleared, we proposed frontal bone reconstruction of the defect using PEEK. CT was performed with axial and coronal cuts of the skull and we requested the completion of a three-dimensional model of the defect that allowed the design of the implant. In order to obtain this, we followed the manufacturer's instructions that recommended performing tomographic scanning of 1-mm increments, beginning at 2 cm above the defect and 2 cm below it. This was done with a matrix of 512 × 512 and with high-resolution and three-dimensional reconstruction with DICOM slices. This imaging material is recorded on a compact disc (CD), which is then sent to the prosthetic design team.

The prosthesis was sterilized and fixed to the parietal, frontal and centroparietal massif bones with mini-plates of reconstruction and self-drilling screws (Figure 3). Despite frontal radiodermatitis, viability of the skin flap was confirmed and skin coverage of the bone replacement material was unnecessary.

The procedure was performed by a multidisciplinary team and was evaluated intraoperatively by the neurosurgeon due to lack of compromised dura mater secondary to prior treatments and risk areas for cerebrospinal fluid fistula. Immediate intra- and postoperative evolution was satisfactory and no complications were reported.

We achieved an adequate replacement of the missing bone and a satisfactory craniofacial contour (Figure 4). The patient was followed-up for 5 months without evidence of complications.

## Discussion

The loss of cranial bones is a complication secondary to trauma such as osteoradionecrosis or postsurgical infection. The area of the skull must be rebuilt and alloplastic implants are the best option because they provide rigid and adequate coverage with good aesthetic and functional results. The advent of computer-generated design for implants promotes adaptability and facilitates the reconstruction process. PEEK is a material that makes these implants possible and is a safe alternative in the reconstruction of the cranial cavity.



**Figure 4.** Second postoperative month. Integration of osteosynthesis material is complete. No postoperative complications were reported and the aesthetic restoration is evident.

In patients with a history of radiotherapy or persistent osteomyelitis, it is important to carefully assess the quality of the skin and soft tissue for coverage of the new skull. Severe radiodermatitis may favor exposure of the implant; therefore, at the time of reconstruction we must decide if it is necessary to place a local flap to provide quality coverage to the new cranial cavity.<sup>14</sup>

This is the first case reported in Mexico of a PEEK reconstruction in an oncology patient, demonstrating that this material is safe, easy to use and lightweight. When generating a computer-based design according to the individual defect of the patient, this gives us an advantage of accurate adaptability to the reconstruction area, facilitating the process. The material is inert and does not produce artifacts on tomography or magnetic resonance, which makes the oncological follow-up possible. The computer-generated PEEK implant is a very useful alternative for reconstruction of the cranial bones.

Reconstruction of the cranial cavity depends on the site and extent of the defect, the causes which originated it and the patient's own environment. There is no routine method to define the "ideal or standard." This should be adapted for each individual patient. It is a multidisciplinary process that should include experts in imaging and in reconstruction materials.<sup>15</sup>

PEEK reconstruction is an excellent option in patients with large facial and cranial bone defects. Advantages for its use are less surgical time and it is highly adaptable because of its design "ex profeso." It does not require remodelations as is sometimes necessary when using bone or methyl methacrylate. If it eventually has to be replaced, it can be sterilized and used again.

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