

# Individual Replacement of the Frontal Bone Defect: Case Report

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**Abstract:** The objective of the skeletal defects reconstruction using individual implants is an attempt to replace lost and damaged anatomical bone structures, renew their original function, and at the same time, to restore the original aesthetic visual aspect. This work is focused on a demonstration of the design methods, fabrication and surgical techniques of the custom-made replacement of a large defect of the frontal bone on the skull.

The patient was a 30-year-old woman with a defect of the frontal bone in the size of 7×3×2 cm after a serious polytrauma. The size and character of the defect excluded the use of commonly supplied augmentations. The geometry of the individual replacement was designed on the basis of a 3D model of the defect obtained from a series of CT scans. After verification of the shape accuracy of the defect made from plastic on a 3D printer, the individual replacement was fabricated from an ultra high molecular weight polyethylene (UHMWPE) by machining with the use of the CNC technology. The success of the augmentation depends on the accurate and precise fabrication of the individual replacement, which is highly demanding on the used advanced technologies.

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## Introduction

The aim of the reconstruction using individual implants is achievement of full function and perfectly natural visual aspect. The objective of such reconstruction is an optimal replacement of the lost anatomical structure, maximum restoration of the damaged function, and at the same time, improvement of the aesthetic visual appearance of the individual. Currently, the world trend in fabrication of implants is inclined to the development of individual implants for a particular patient instead of unified implant sizes and shapes, which the surgeon has to adjust during the surgical procedure. The scope of using such method covers maxillo-facial surgery, neurosurgery, orthopaedics, but also aesthetic surgery [1, 2, 3]. The necessary condition is the use of absolutely safe technical materials suitable for long-term implantation [4, 5] in the human body. At present, materials available for this purpose are plastics (UHMWPE – ultra high molecular weight polyethylene, PEEK – poly-ether-ether-ketone), metal alloys (titanium Ti6Al4V ELI), and synthetic resins (PMMA – polymethylmethacrylate).

To achieve high-quality replacement of the defect, it is necessary to ensure optimum conditions for integration of the implant. The success of the reconstruction of the defect using individual implants depends on thorough examining of the patient, supplemented by high-quality diagnostic image, on correct indication and choice of treatment, and perfect surgical procedure and prosthetics. Very close cooperation among the surgeon, technician, producer, and also the patient is important not only during the treatment in itself, but also during the following patient's convalescence and rehabilitation.

## Case report

As a car passenger in 1998, the patient suffered a serious polytrauma, among other, with fronto-basal injury with defect fracture of the frontal bone in the size of about  $7 \times 3 \times 2$  cm. The patient had been repeatedly treated using conventional augmentation procedures, whether with solid bioceramics replacement covered by resorbable membrane, or using bioactive bone granules separated from the soft



Figure 1 – View on the defect of the frontal bone (a) preoperative (b) intraoperative.

tissue by the Bioguide resorbable membrane. Probably due to the unsatisfactory shape and character of the replacement, the implant was rejected and subsequently the surrounding tissue was scarred. Therefore, a fairly new method of fabrication was used for making an individual 3D replacement of this defect, made from a block of ultra high molecular weight polyethylene Chirulen 1020, on the basis of a virtual model obtained from the CT scans of the skull and the bone defect.

Implantation of this very accurate individual replacement of the bone was performed 10 years after the beginning of the treatment. The implant was fixed by 4 titanium self-tapping screws (Figures 1 and 2). The wound was healed *per primam intentionem* (Figure 3).

### Fabrication

The geometry of the individual replacement on the frontal bone was modelled on the basis of the model of the defect obtained from CT scans. The model of the bone defect was made in the Laboratory of Biomechanics, CTU in Prague, using automatic segmentation of image data completed in programme Mimics (Materialise®). The series of CT scans (Figure 4) were taken on the Siemens



Figure 2 – (a) View on the insertion of the implant (b) postoperative situation.



Figure 3 – Patient six month after surgery.

Emotion 16 device with resolution  $12 \times 512$ , the size of a pixel was 0.682 mm, and the distance between partial slices was 1 mm. The three-dimensional geometric model of the damaged part of the skull, which covered all neighbouring bones (Figure 5) was made from ABS plastics using the Rapid Prototyping technology. The reconstruction of the original shape of the missing frontal bone was achieved by computer simulation, by mathematical approximation of contact surfaces to filling the defect. The geometric models created in this way were exported as STL files for further editing. The final geometric model of the individual replacement was exported into DXF file used primarily for creating an individual replacement model from technical plastics for verifying the implant shape by the surgeon. After adjustment and checking of the shape by the surgeon, the individual implant was released for fabrication.

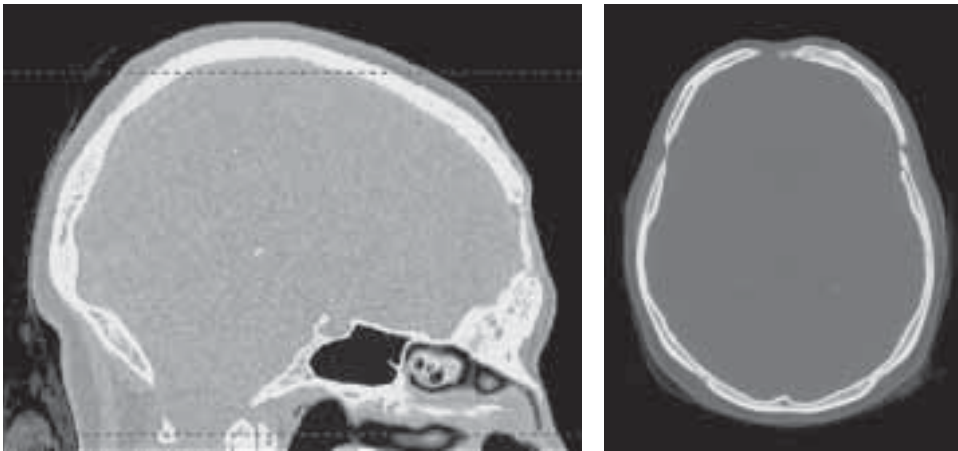


Figure 4 – Example of CT scans with the defect of the frontal bone.

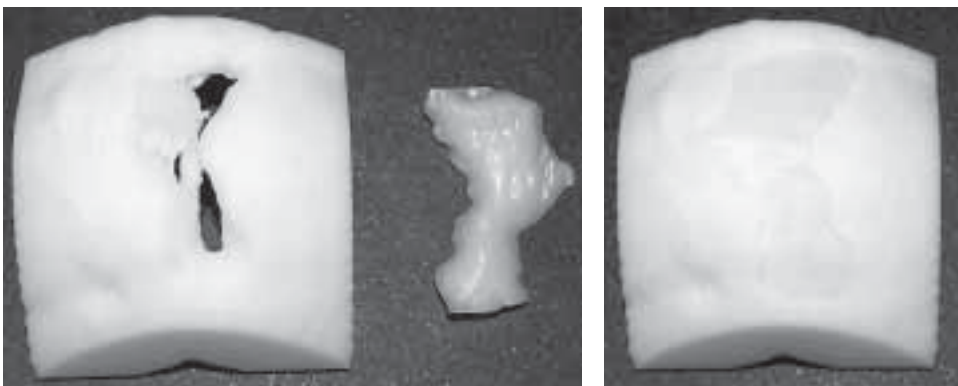


Figure 5 – (a) Model of the defect of the frontal bone (left) made from ABS plastics with individual implant made from UHMWPE (right), (b) example of tight fit of the implant into the model of the defect.

The individual implant was fabricated by DUO CZ, s.r.o. engineering company, in cooperation with ELLA-CS s.r.o., from biomaterial Chirulen 1020 (ultra high weight molecular polyethylene UHWMPE), which has been used in clinical practice, and meets all requirements for a long-term implant material. The main input for fabrication of the individual implant was a data file of the 3D model of this implant. Using volume modelling in CAD (Computer Aided Design) programming were determined the size and position of the semi-finished product together with the fixing aids enabling effective fixation of the material. The implant was fabricated by conventional machining on 4-axis machining centre.

## **Discussion**

Replacing large bone defects, especially in revision surgical procedures, is quite a difficult task [6] for clinical practice. The large replacements using bone homografts can cause problems related to their integration and infection resistance. Commonly supplied augmentations have often unsatisfactory size or shape. Massive cement fillings are biomechanically and biologically unsuitable and fail within short time. The way out of these situations are custom-made individual implants or their components [7].

The main benefit of individual augmentation in comparison with commonly used methods is the accuracy of the implant, which exactly copies the shape of the defect. Another indisputable benefit of the individual replacements is achievement of the optimum visual effect for the patient after the surgery. Last but not least, it also reduces the time of the surgery because additional adjustment of the implant by the surgeon is not necessary, though it is possible. The individual augmentation also allows getting over defects, which would not be possible to solve using common augmentations due to their shape or size. It minimizes the layer of used bone cement, and in future, we can predict furnishing its contact surface with micro porous structure enabling direct Osseo integration.

The disadvantage of the individual augmentation is higher demands for its fabrication resulting in its higher cost. The higher demands for fabrication are especially in the preparation of the individual implant and the defect 3D model for planning the surgery and verification of the final set up [8, 9, 10]. The next item is the cost of preparing the necessary software, machining time and tools needed for machining the used biomaterial on a special machine tool. Another disadvantage is the necessity of thorough pre-operational planning and a certain latency period between the order for fabrication and the time of using it during the surgery. Standardizing of the procedures of specific data collection, preparation of the software and the fabrication allows reducing the time necessary for fabrication of the implant for several days. With regards to the facility of the machining and the weight of the implant in case of large defects, it seems very prospective to use special plastic biomaterial poly-ether-ether-ketone (PEEK), which has very similar mechanical properties as the bone tissue. It is easily machined, and if needed, it

is possible to adjust its shape even during the surgery. This advanced material has been used for some time for fabrication of intervertebral replacements (cages), bone screws, etc. [11]. Another inconvenient factor limiting wide usage of PEEK remains still its fairly high cost.

## Conclusion

Custom-made augmentation is one of the possibilities for optimal and fast solution of large bone defects. The length of the surgery is reduced and the aesthetic effect for the patient after the surgery is improved. A satisfactory material for fabrication of these implants is at present ultra high molecular weight polyethylene (UHMWPE), and prospectively also PEEK, which is more suitable for machining and its mechanical properties are similar to the bone tissue. The disadvantage of the individual augmentations is its higher demands for fabrication and higher cost, and also demands on preparation and planning of the surgery.

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