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ALLOKRANOIPLASTY WITH 3D IMPLANTS FOR SKULL DEFECT

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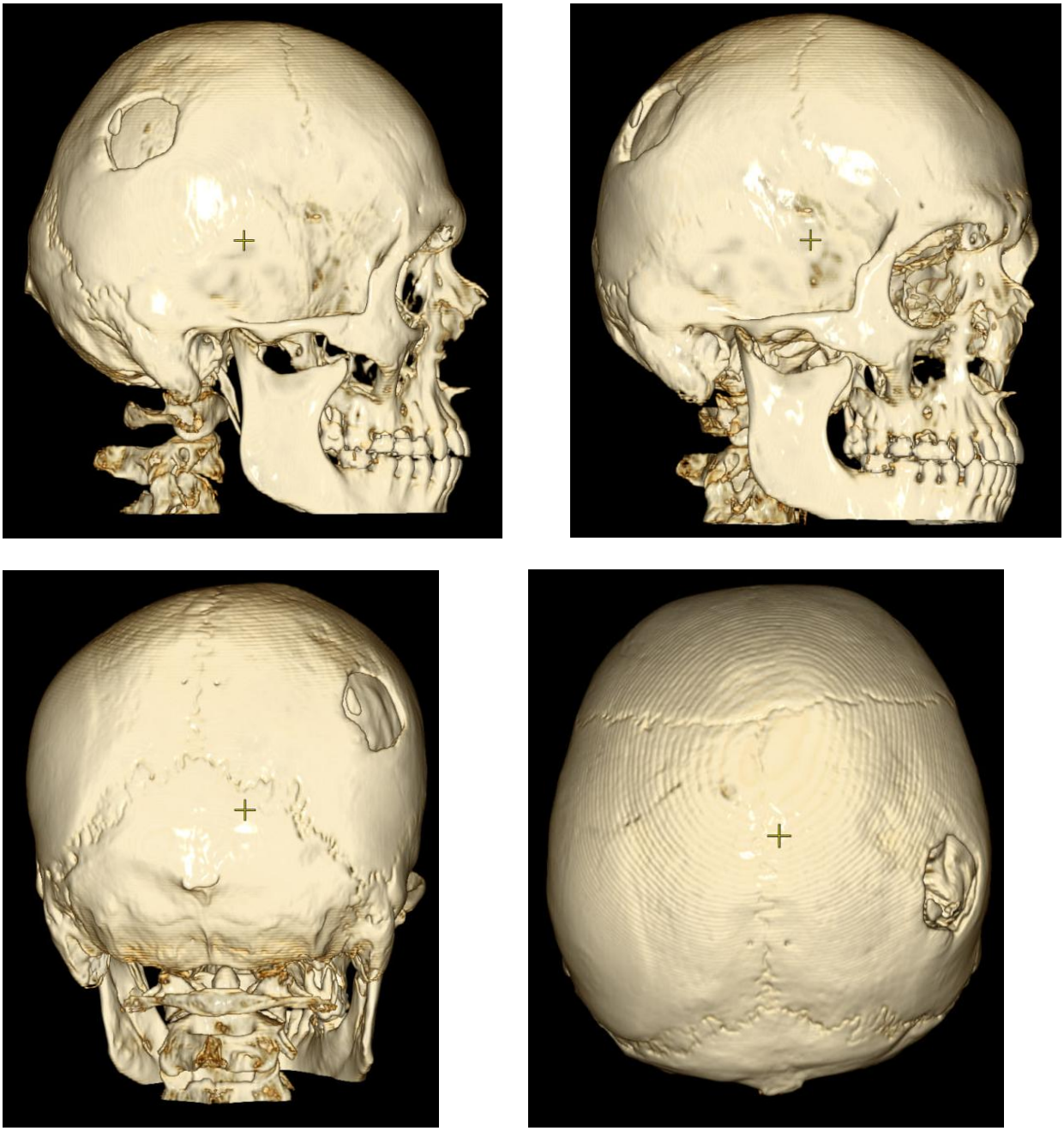
Abstract: Currently, the introduction of the principles of minimally invasive microneurosurgery, the use of modern neuroimaging methods, and comprehensive adequate neuroreanimation intensive care have reduced mortality in severe traumatic brain injuries and brain tumors, but do not reduce the number of patients with post-trepanation skull defects [1,8]. Despite the long history of study, at the moment the problem of choosing a method for restoring the integrity of the skull after resection trepanations, removal of space-occupying lesions affecting the bones of the vault and base of the skull is still relevant [2]. Violation of the tightness of the skull leads to the formation of a new pathological condition - "trepanned skull syndrome". The inability of the post-trepanation defect to spontaneously restore bone tissue, functional and organic disorders that occur in patients serve as reasons for cranioplasty [2,3].

Keywords: trepanation, defect, implant, reconstruction

The aim of our research is to improve the results of surgical treatment of patients with complex skull defects, reducing the degree of disability by introducing reconstructive surgeries with the installation of an implant for cranioplasty, using modern biotechnological materials, and applying three-dimensional computer modeling.

Materials and methods: This article presents the clinical experience of the neurosurgery department of the Multidisciplinary Clinic of the Samarkand State Medical University in 2023-2025. More than 100 reconstructive surgeries with the installation of a 3D implant were performed. At the outpatient stage, patients underwent computed tomography (CT, MSCT) of the brain, with mandatory processing of scans in bone mode, the slice thickness of no more than 1.0 mm. The obtained patient data were recorded on an electronic medium and transferred to the manufacturer of the 3D implant. Then the implant manufacturing process took place according to the following algorithm: Neuroimaging (CT) files from the DICOM format were processed in 3D software environments (Figure 1), such as SOLIDWORKS (SW), 3DMax (Figure 2, 4), Zbrash, with subsequent conversion to the Autodesk format (Figure 3) for 3D printers. The method for manufacturing implants using 3D printing is as follows: at the stage of designing the press mold (Figure 5, 6), a comprehensive industrial design of the press mold is laid down, taking into account the engineering analysis of strength, stability and data on the size and volume of the implant (Figure 7).

Fig. 1. Post-resection skull defect in the parietal region on the right



In our case, we used individual high-precision implants made of PEEK-Optima polymer (polyetheretherketone), manufactured using CAD/CAM technologies on CNC milling machines from a single block of material (Fig. 2). The use of individual prefabricated flaps manufactured using CAD/CAM technologies significantly simplifies the task of performing one-stage reconstruction aimed at eliminating complex defects and deformations of the upper and middle areas of the face, ensures a significant reduction in the operation time and predictability of a good functional and cosmetic result [4,5].

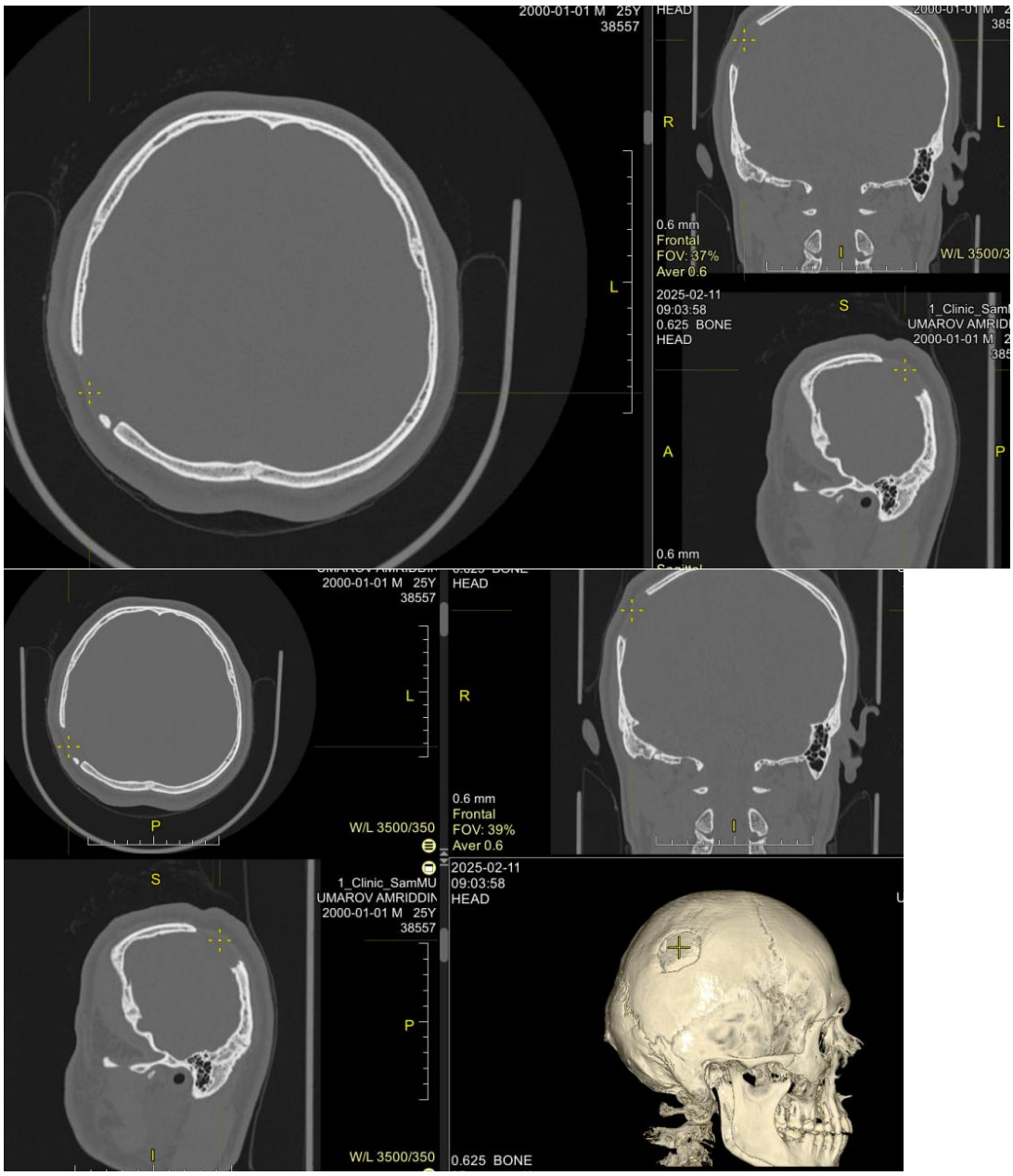
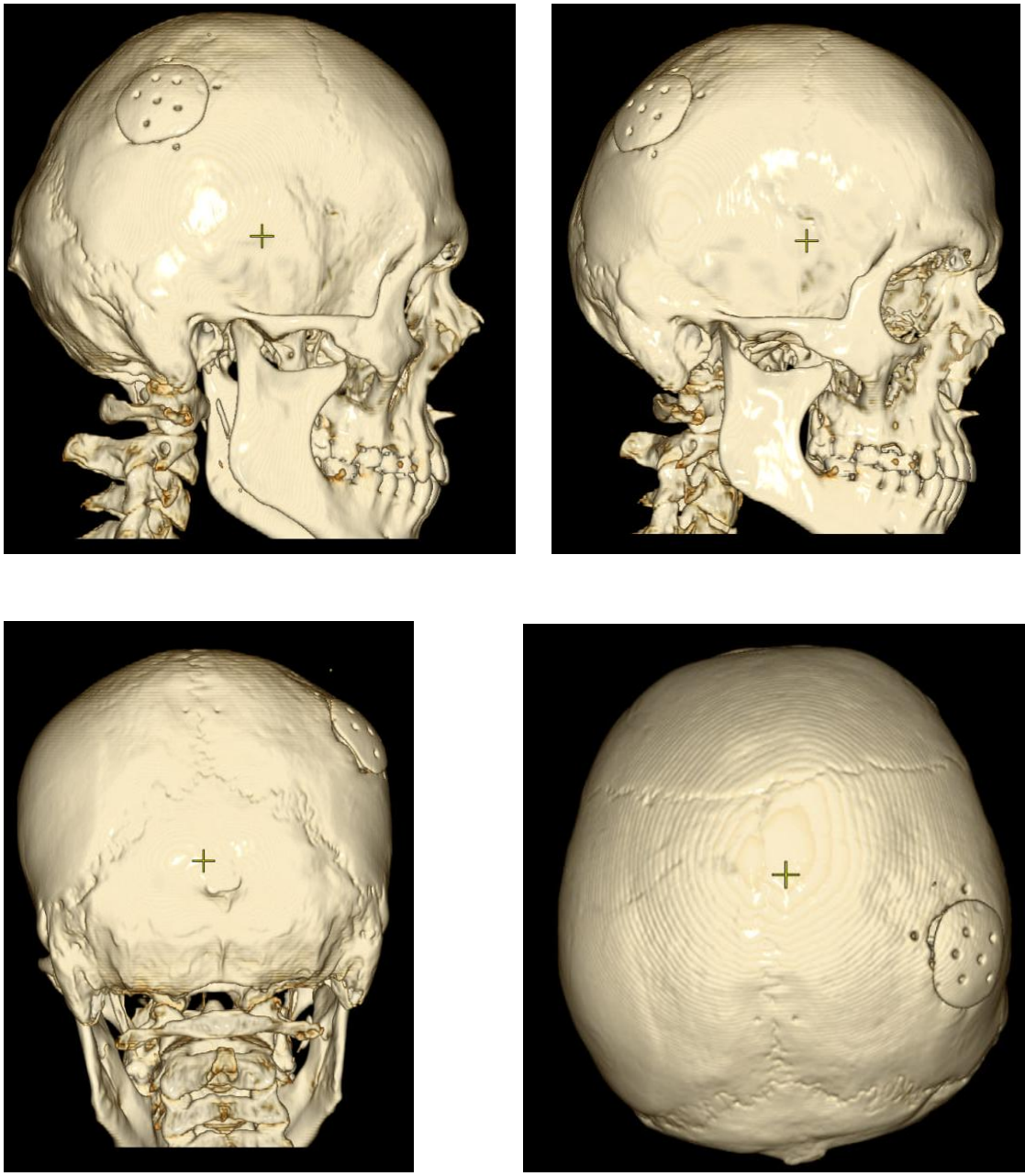


Fig. 2. Condition after surgery of allocranioplasty of a skull defect with a 3D implant



Results: Based on the conducted research, the following basic principles and provisions for surgical treatment of victims with cranio-orbital injuries were formulated [6,7].

1. In case of complex post-traumatic defects and deformations of the cranio-orbital region, computer modeling using stereolithographic models for planning operations leads to an increase in the effect of surgical treatment, a decrease in the time of the operation, and a decrease in the frequency of repeated interventions.
2. In frontal bone fractures extending to the walls of the frontal sinus, the key point is the surgeon's decision to preserve the frontal sinus or eliminate it by obliteration or cranialization, which should be made on the basis of a thorough analysis of clinical and CT data at the preoperative planning stage and adjusted intraoperatively.
3. The scope and complexity of surgical intervention depend on the extent of fronto-orbital lesions on the anterior base of the skull and/or the middle and lower zone of the face, the presence of intracranial pathology. Reconstructive surgery of the cranial-orbital region should be aimed at restoring the three-dimensional anatomy of the orbit, delimiting the orbital cavity with the cranial cavity and surrounding paranasal sinuses, ensuring reposition of the eyeball, normal eye function and cosmetic effect.

4. Active surgical tactics for treating victims in the acute period of trauma with primary reconstruction and the use of craniofacial osteosynthesis techniques optimizes treatment results and prevents complex problems of late or secondary reconstruction.
Primary reconstructive interventions should be performed simultaneously with neurosurgical ones in the acute period, or as a second stage after stabilization of the patient's general condition in the early stages after injury. Reconstructions in the later stages often require repeated corrective interventions aimed at eliminating deformation of the contours of the upper and/or middle zone of the facial skeleton, repositioning the eyeballs. The complexity of the implementation and the decrease in the effect of late and secondary reconstructions are determined, among other things, by the severity of cicatricial atrophic changes in soft tissues. In most cases, reconstructive interventions for cranio-orbital injuries require the use of various plastic materials.
Bone autografts from the cranial vault are the material of choice for reconstruction of all parts of the cranial orbital region. Thus, an interdisciplinary approach and sequential operations, a combination of neurosurgical techniques and modern methods of craniofacial and plastic surgery allow achieving optimal functional and cosmetic results of reconstructive interventions for victims with cranio-orbital trauma (Fig. 3).

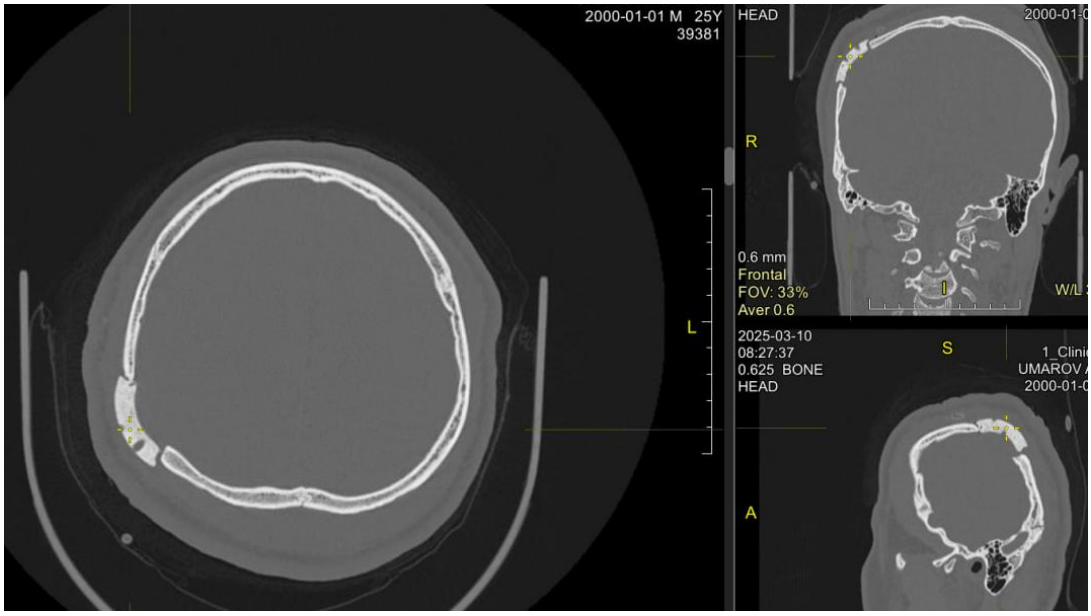
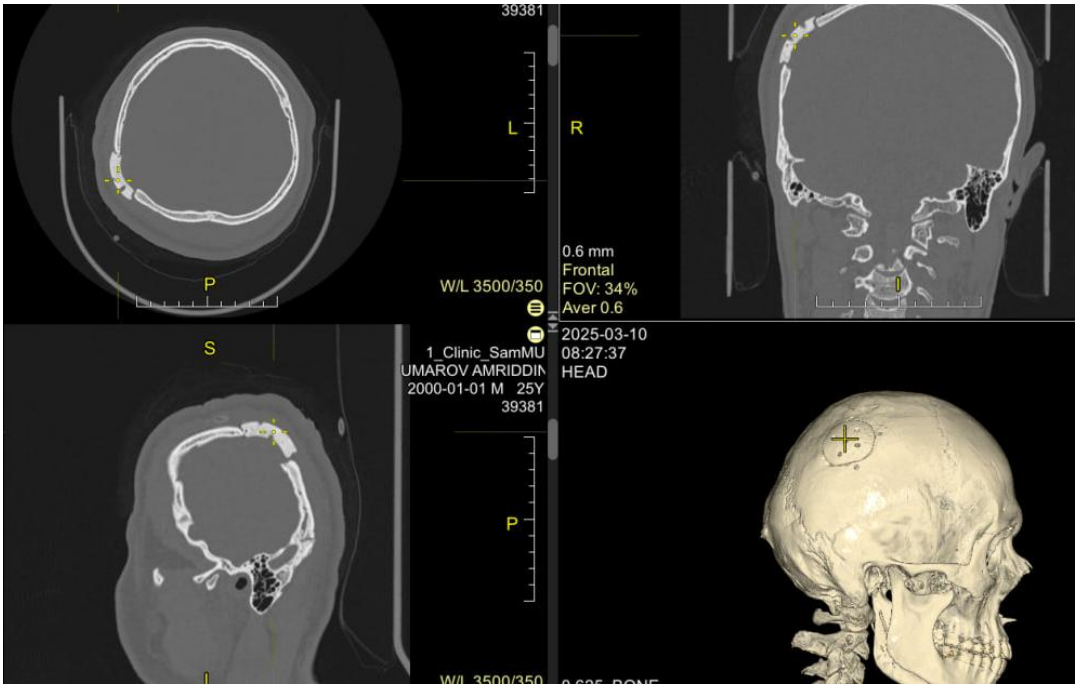


Fig. 3. MSCT of the skull with 3D reconstruction after surgery



Conclusions. Cranioplasty using 3D computer modeling allows for the closure of cranial bone defects of any size and configuration, and the best cosmetic and functional results are achieved in the postoperative period, since the designed 3D implant is maximally identical to the contours of the bone defect. The implant is manufactured before the operation, thus significantly reducing the duration of the surgical intervention and reducing the risk of infectious complications. Reconstructive surgeries using modern biotechnology allow for the personalization of each clinical case, which increases the effectiveness of recovery and treatment, and also provides the patient with confidence in the doctor's individual approach to a specific case. The installed polymethyl methacrylate implants using 3D computer modeling technology completely restore the integrity and shape of the skull.

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