AMERICAN Journal of Pediatric Medicine and Health Sciences
*Volume 3, Issue 10, 2025 ISSN (E): 2993-2149*

# Cranioplasty: Using 3D Implants for Skull Defect Cranioplasty

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**Abstract:** Currently, the implementation 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 have not reduced the number of patients with post-trepanation skull defects. Despite a long history of study, the problem of choosing a method for restoring the integrity of the skull after resection trepanations and the removal of space-occupying lesions affecting the bones of the vault and base of the skull remains relevant [1]. A violation of the skull's hermeticity leads to the formation of a new pathological condition - "trepanned skull syndrome." The inability of a post-trepanation defect to spontaneously restore bone tissue, as well as functional and organic disorders that arise in patients, serve as reasons for cranioplasty [2,3].

**Keywords:** trepanation, defect, implant, cranioplasty.

**The aim of our study.** The goal of 3D printing is to improve surgical treatment outcomes for patients with complex cranial defects and reduce disability through the use of reconstructive surgery, including cranioplasty implants, using modern biotechnological materials and 3D computer modeling. The implant manufacturing method using 3D printing is as follows: At the mold design stage, a comprehensive industrial design is developed, taking into account engineering analysis of strength, stability, and data on the implant's dimensions and volumes. The implant is manufactured from polymethyl methacrylate-based biocement. The implant manufacturing accuracy is 0.1 mm. The finished implant allows surgeons to plan the operation in advance. They can clearly see the extent of the defect, make the necessary preparations, thereby reducing the patient's time on the operating table [4, 5, 6].

## Materials and methods

The clinical observation was conducted at the Department of Neurosurgery of the Samarkand State Medical University of the Ministry of Health of the Republic of Uzbekistan. The subject of the study was patient M, born in 1989, 36 years old. The patient has been considered ill since February 1, 2025, when he received a severe traumatic brain injury as a result of a road traffic accident (hit by a car). Initial hospitalization was carried out at the district central hospital. Diagnosis on admission: Severe brain contusion. Comminuted fracture of the cranial vault in the left parietotemporal region. Linear fracture in the left parietal- Occipitotemporal region. Subdural hematoma with brain compression and displacement of midline structures to the right. Subcutaneous hematoma. Contusion of the right shoulder. Pyelonephritis.

On February 2, 2025, the patient underwent emergency craniotomy, including removal of impacted bone fragments, evacuation of epidural and subdural hematomas, and placement of an epidural drain. He remained in treatment until March 1, 2025.

Subsequently, for the purpose of further observation and treatment, the patient was referred to the neurosurgery department of the Samarkand State Medical University, where he underwent repeated examinations and courses of treatment under the supervision of Associate Professor M.A. Aliyev.

On July 30, 2025, due to the development of post-traumatic occlusive hydrocephalus, ventriculoperitoneal shunt surgery was performed with the installation of the adjustable MEITHKE ProGAV 0–20/+25 system.

Main diagnosis: post-resection bone defect in the left frontal-parietal-temporal region after decompressive craniectomy. ICD-10: M95.2.

Associated post-traumatic changes: Encephalopathy. Cystic-cicatricial, gliotic, and encephalomalacia processes in the left hemisphere of the brain. Post-traumatic hydrocephalus (ICD-10: G91.1). Subdural hygromas in both frontal lobes. Prolapse of brain tissue through a bone defect with lateral displacement. Right-sided hemiparesis. Sensorimotor aphasia.

Frequent epileptic seizures.

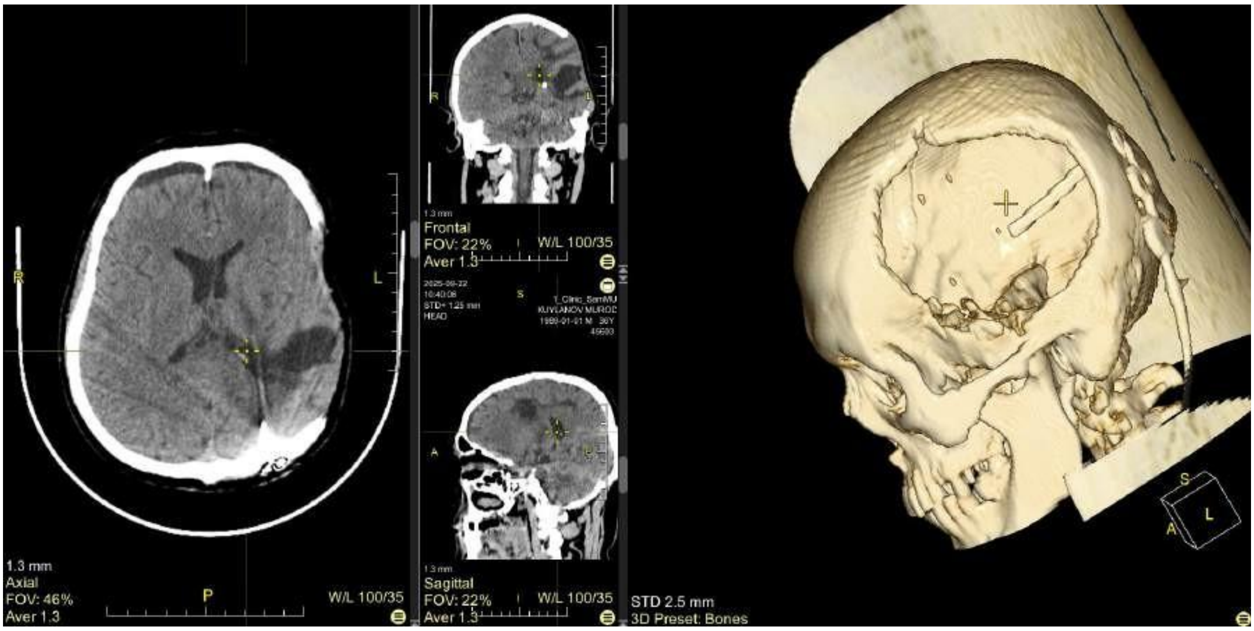
Complaints of the patient and his relatives: severe headaches, dizziness, seizures, weakness in the right arm and leg, speech impairment, inability to move independently, general weakness.

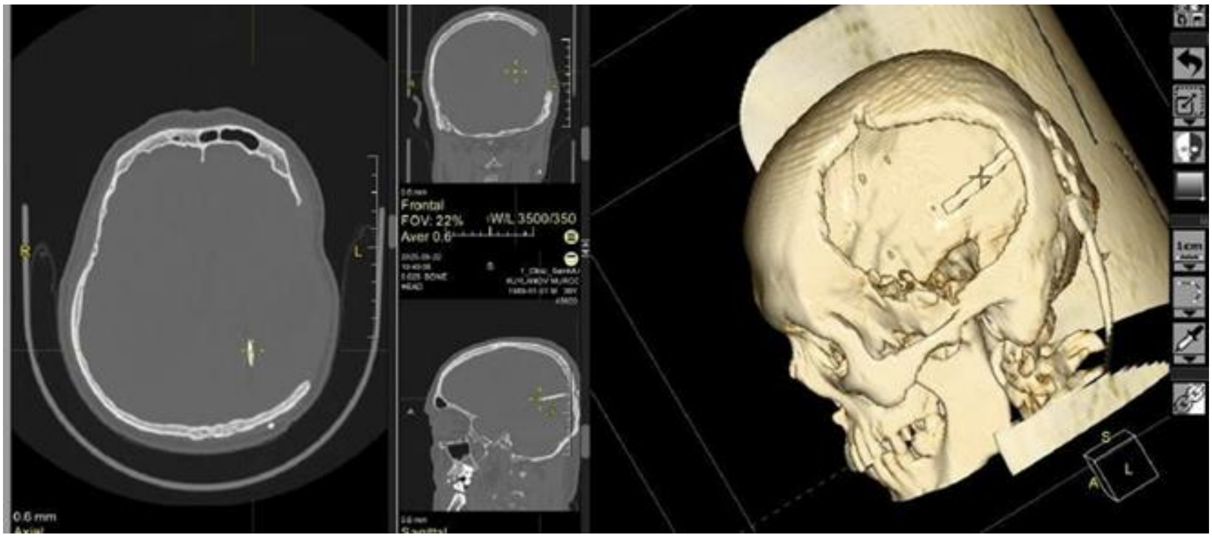
Due to the worsening of clinical manifestations and an increase in the frequency of epileptic seizures, in October 2025 the patient was re-hospitalized for additional examination and a decision on further surgical treatment.

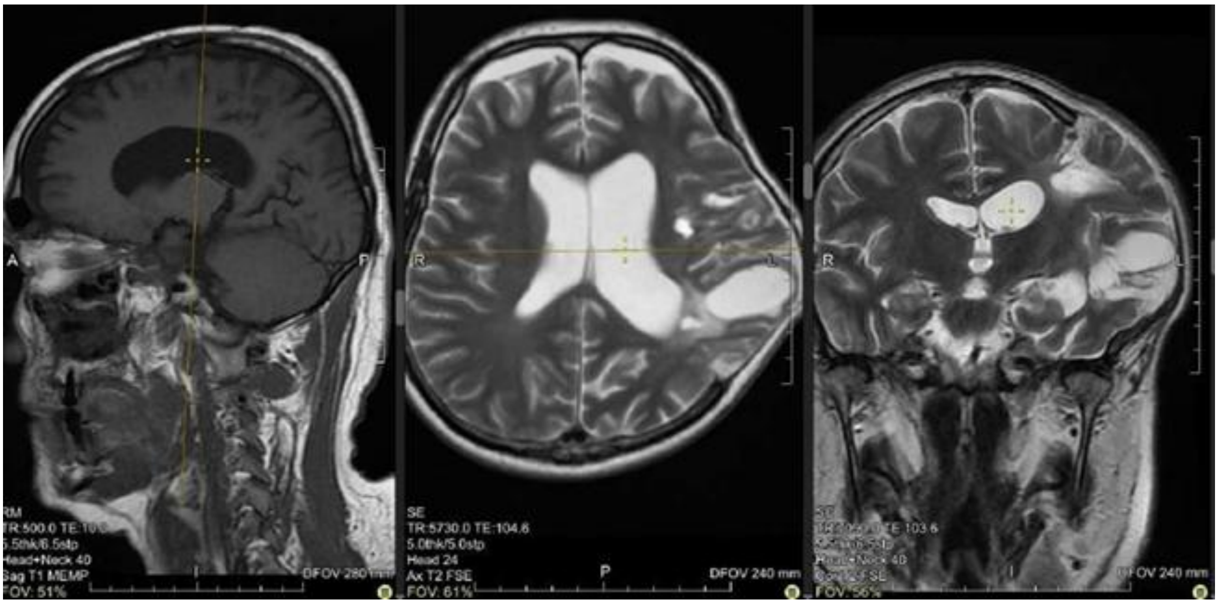
The diagnostic examination included: Multispiral computed tomography (MSCT), Electroencephalography (EEG), MRI of the brain, clinical neurological examination, including assessment of motor, speech and cognitive functions, laboratory tests.

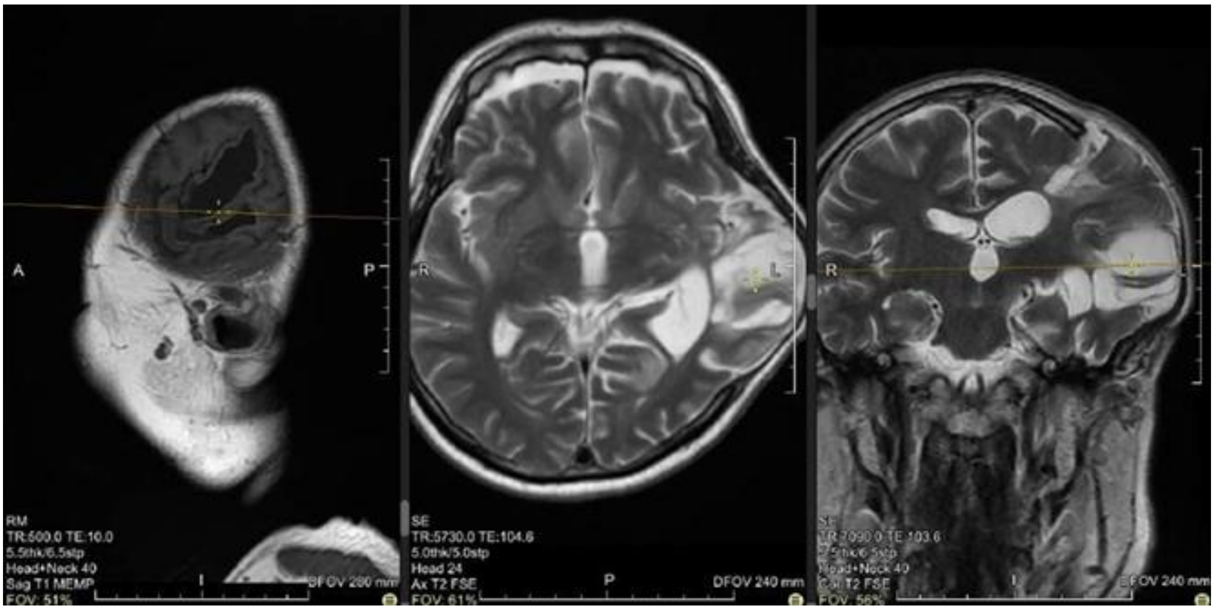
The purpose of observation and treatment was to assess residual neurological disorders and craniocerebral changes, develop tactics for further surgical treatment, including cranioplasty and correction of the shunt system, as well as drug therapy to control the epileptic syndrome.

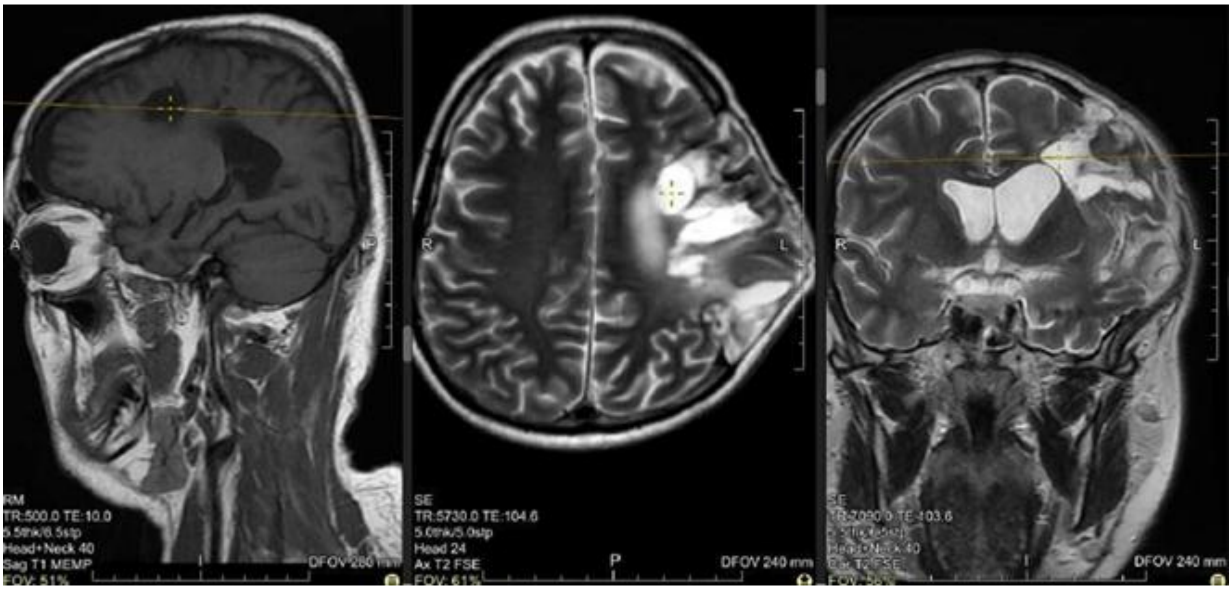
Pic 1. Preoperative MSCT of the brain




R
L
Frontal
FOV: 22%
W/L 3500/350
Aver 0.6
0.6 mm
S
A
L

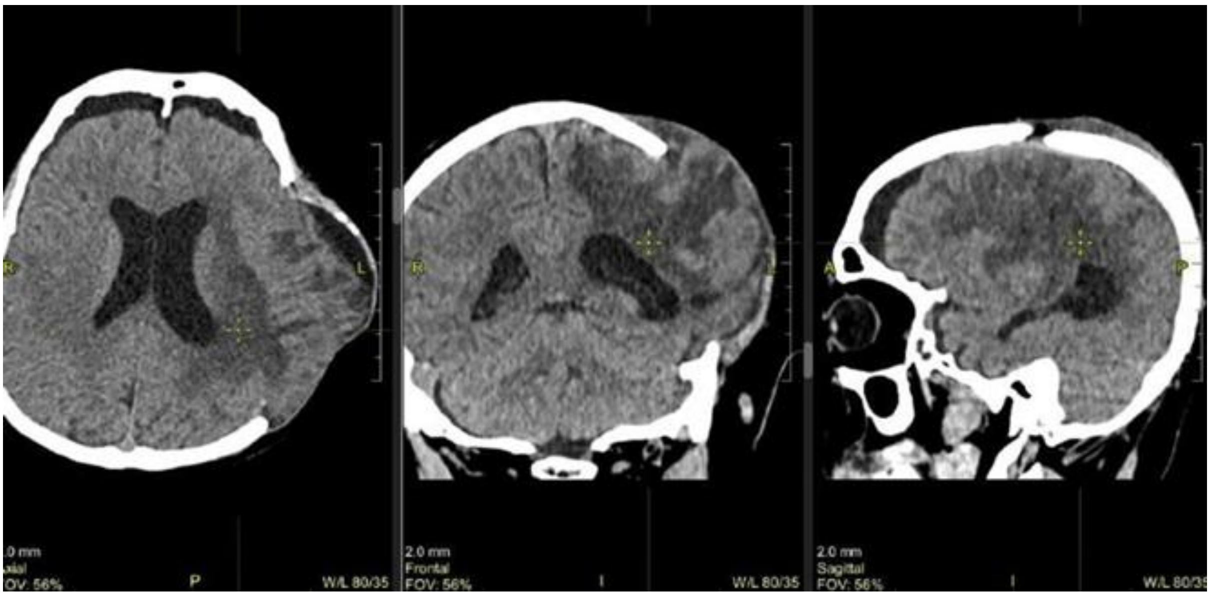

A
P
R
L
RM
Head+Neck 40
Sag T1 MEMP
FOV: 51%
SE
TR:5730.0 TE:104.6
5.0thk/5.0stp
Head 24
Ax T2 FSE
FOV: 61%
DFOV 240 mm


A
P
R
L
RM
TR:500.0 TE:10.0
5.5thk/6.5stp
Head+Neck 40
Sag T1 MEMP
FOV: 51%
SE
TR:5730.0 TE:104.6
5.0thk/5.0stp
Head 24
Ax T2 FSE
FOV: 61%
DFOV 240 mm

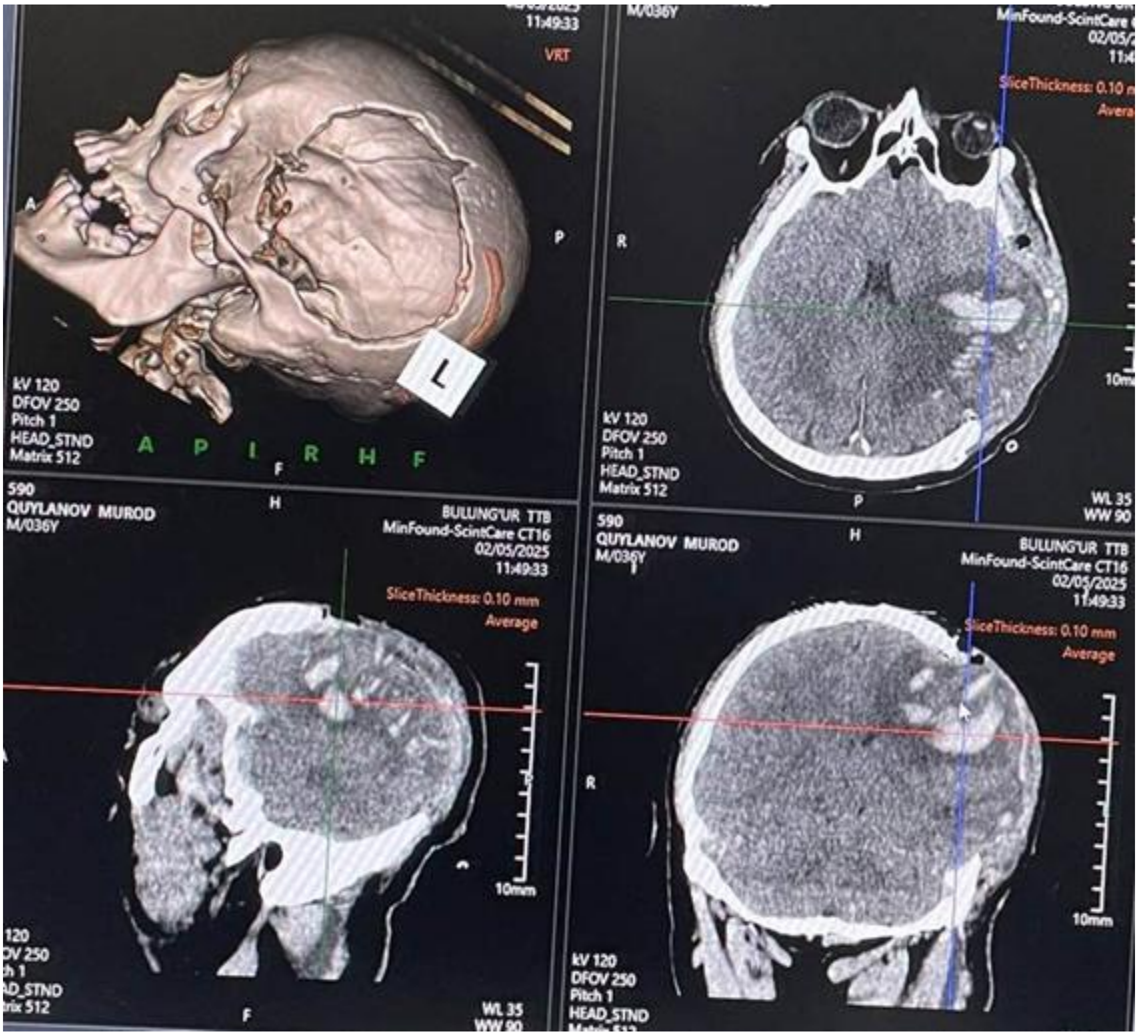


TR:500.0 TE:10.0
5.5thk/6.5stp
Head+Neck 40
Sag T1 MEMP
DFOV 280 mm
SE
TR:5730.0 TE:104.6
5.0thk/5.0stp
Head 24
Ax T2 FSE
DFOV 240 mm
R
L
P
TR:7090.0 TE:103.6
DFOV 240 mm

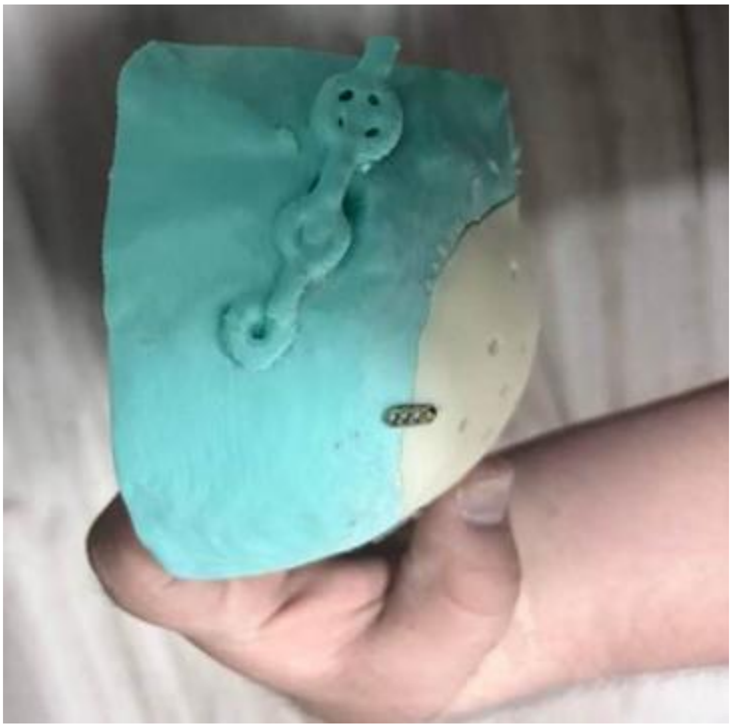

Marokand Hospital
KUYLAMOV MUROD
1989-04-15 M 35Y
BRAIN
A
R
L
P
S
I
TR:6250.0
HeadNeck_20_TCS
FOV: 62%

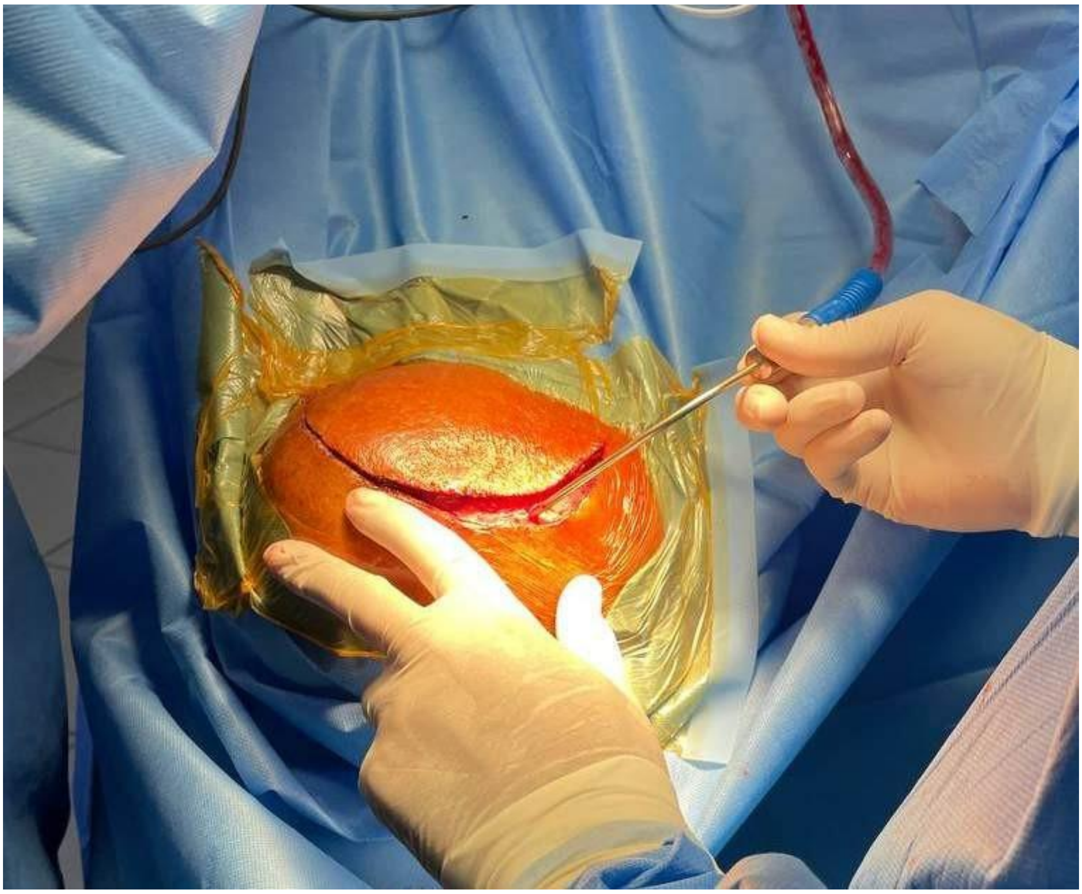
R
L
P
A
2.0 mm
Frontal
Sagittal
FOV: 56%
W/L 80/35

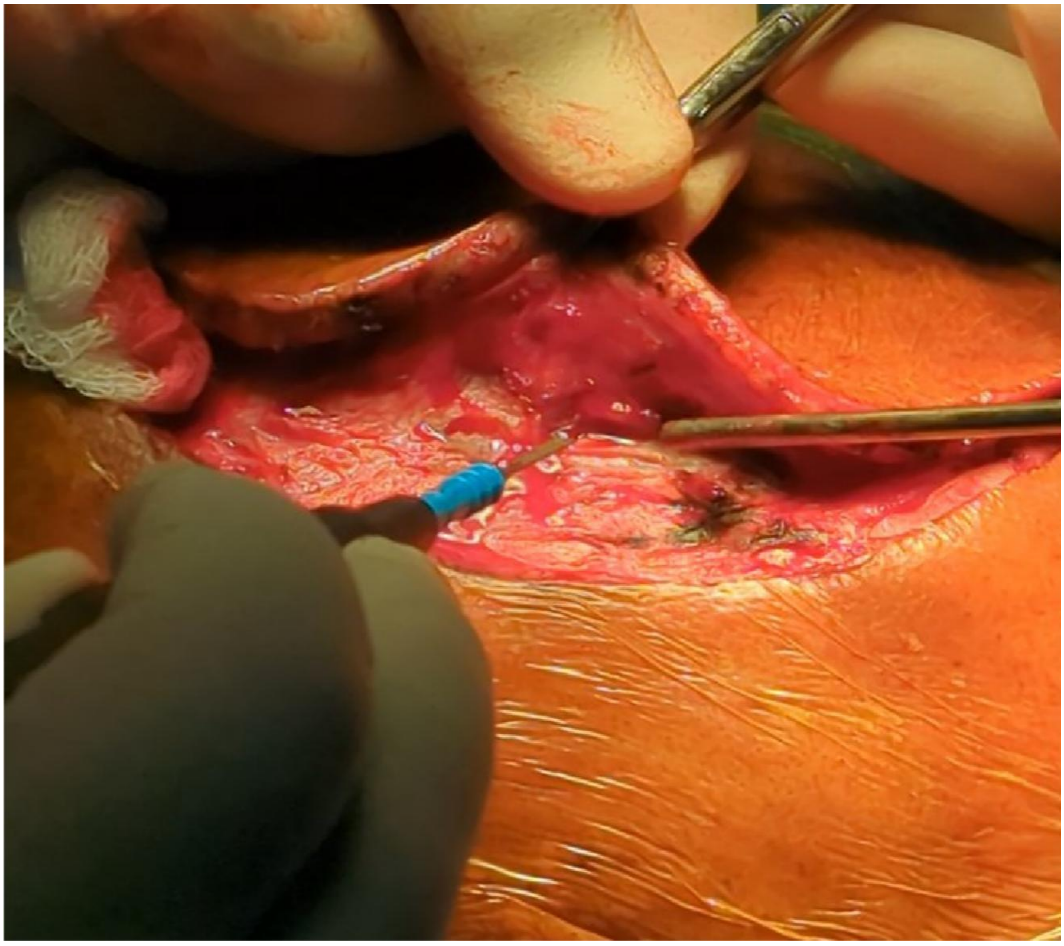


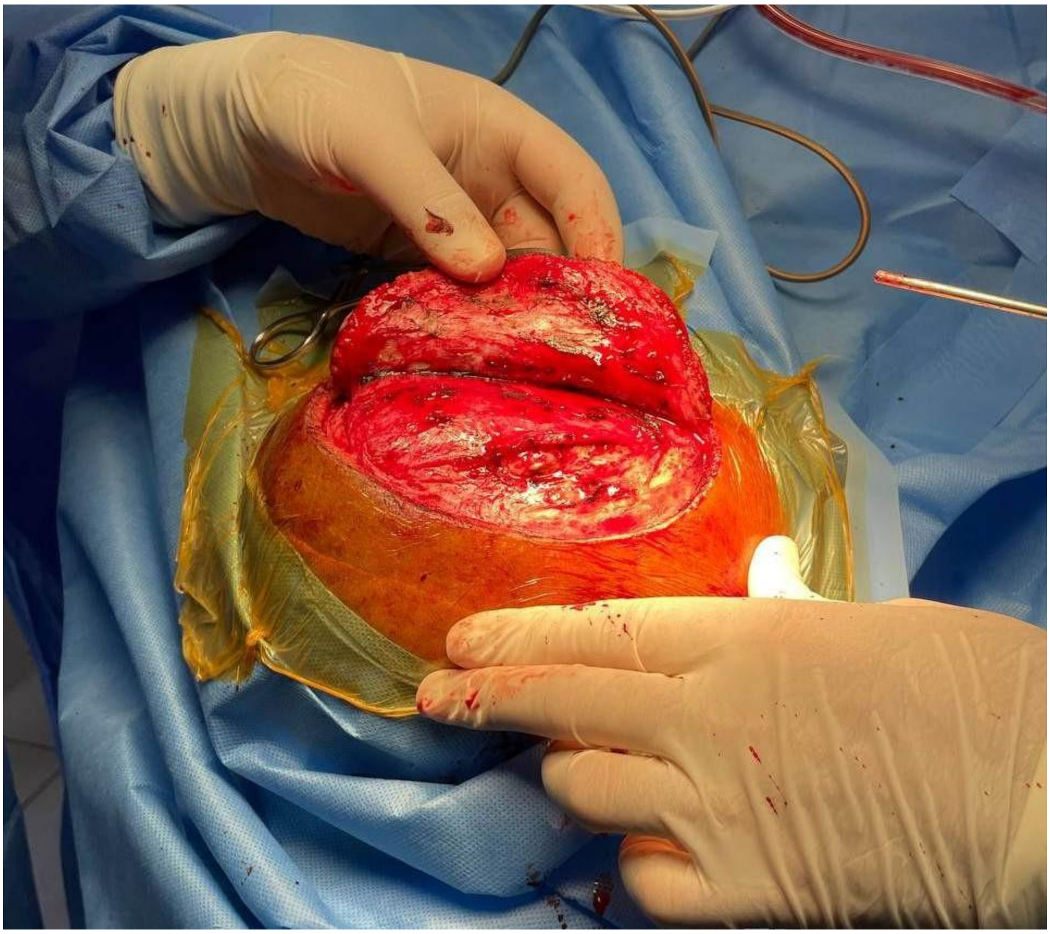

**Pic 2. Individual 3D implant**

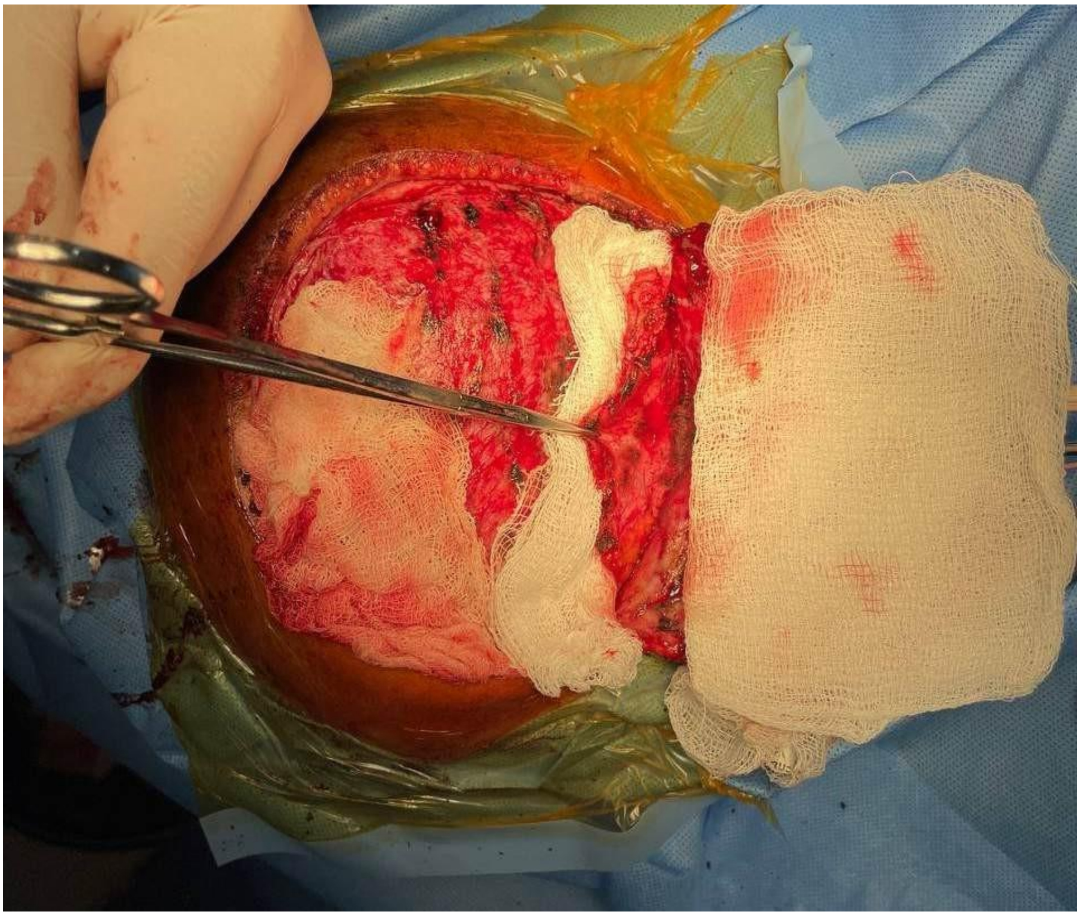


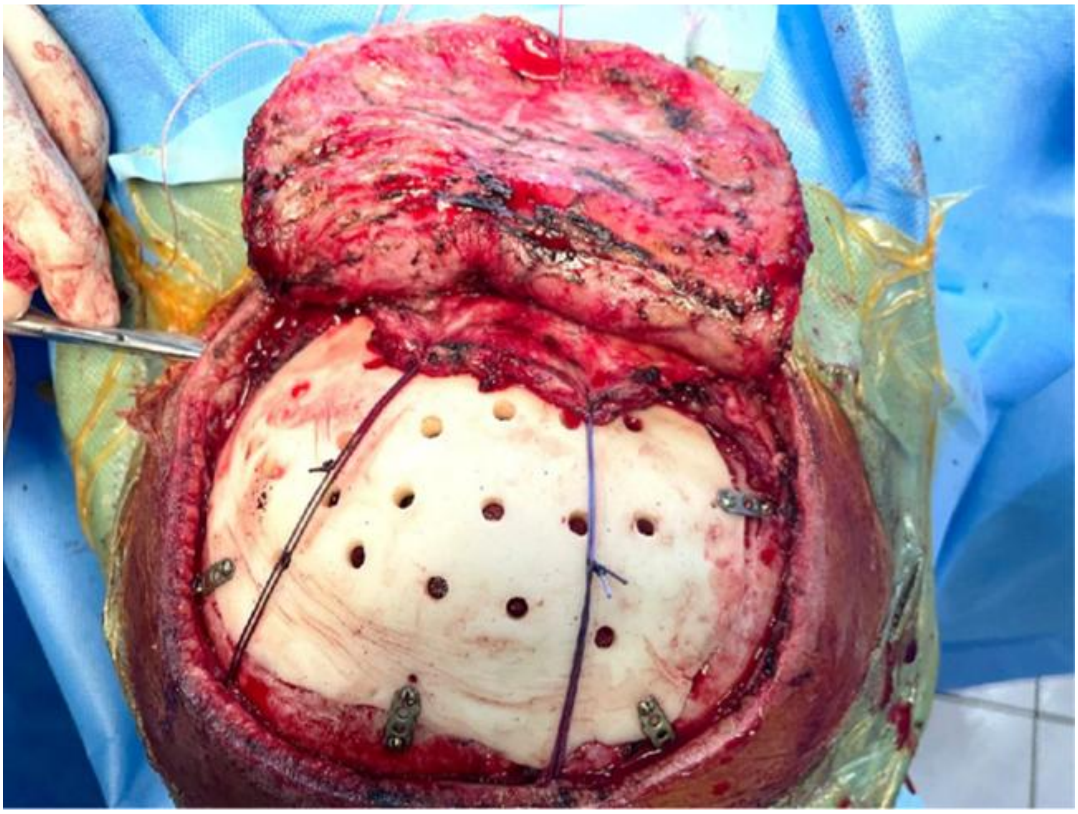
**Pic 3. The process of surgery**



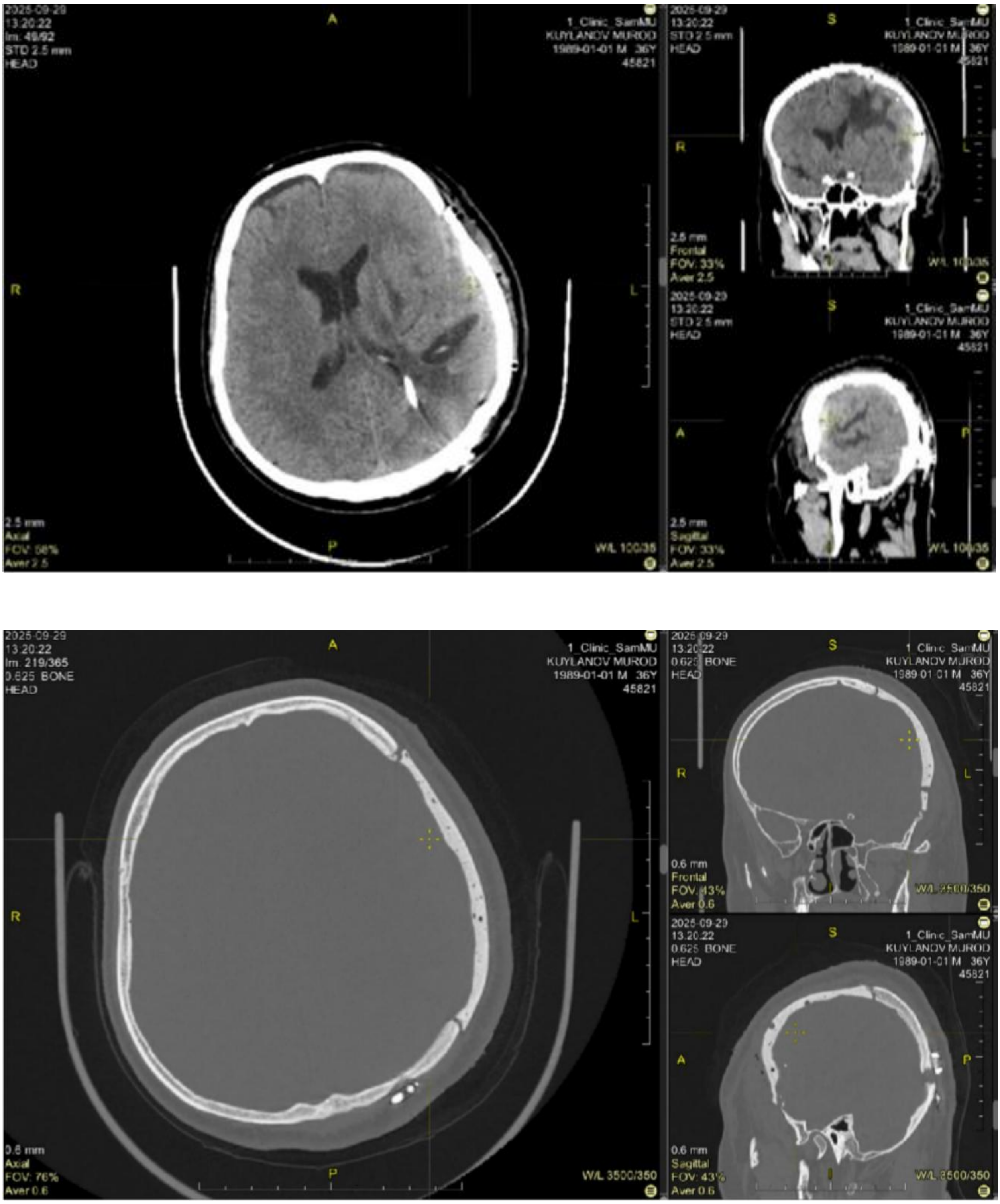


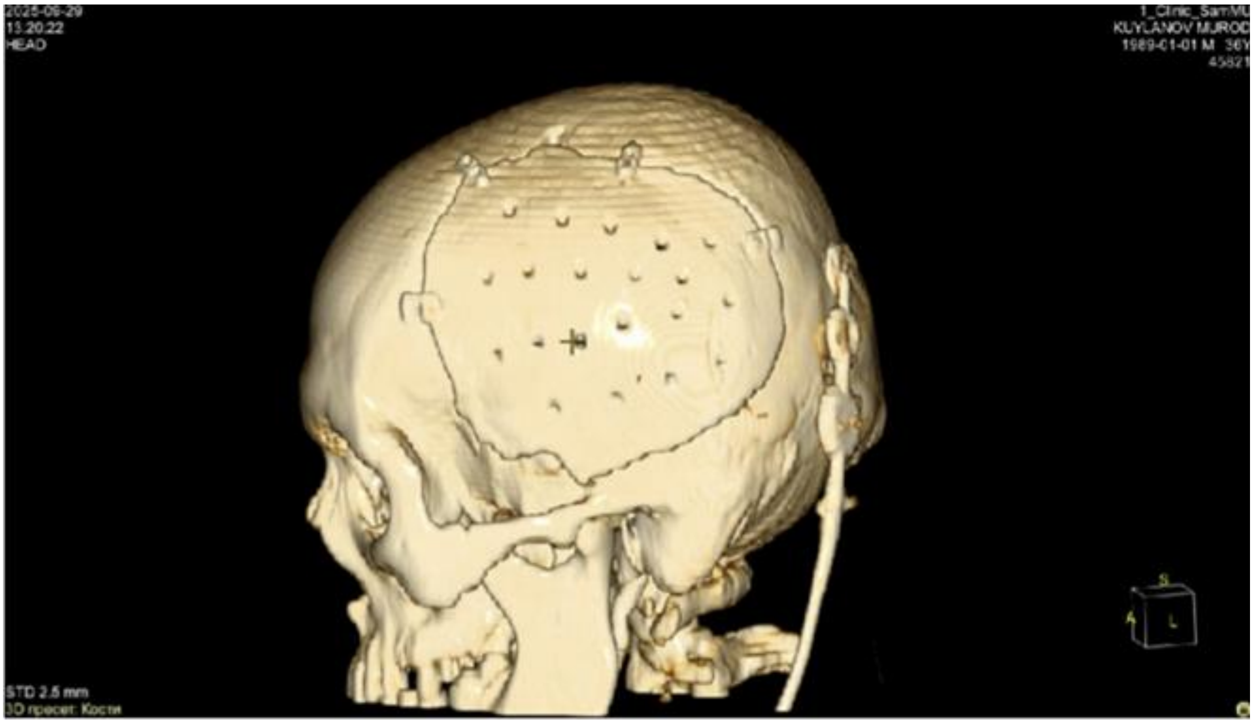






**Pic 4. Posoperative MSCT of the brain**






**Conclusion:**Cranioplasty using 3D computer modeling allows for the closure of cranial bone defects of any size and configuration, achieving superior cosmetic and functional results postoperatively, as the designed 3D implant closely matches the contours of the bone defect. The implant is manufactured prior to surgery, significantly reducing the duration of the procedure and reducing the risk of infectious complications. Reconstructive surgeries using modern biotechnology allow for the personalization of each clinical case, increasing the effectiveness of recovery and treatment, and providing patients with confidence in the doctor's individualized approach to their specific case.

The implants installed, made of polymethyl methacrylate and using 3D computer modeling technology, completely restore the integrity and shape of the skull.

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