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ORIGINAL RESEARCH

SILOXANE THREE-DIMENSIONALLY DESIGNED MIDFACIAL EPITHESES: A RETROSPECTIVE ANALYSIS OF PATIENTS WITH ORBITAL DEFECTS.

Artavazd E. Kharazyan[1], Viktoriia O. Dzhuganova[1], David N. Nazaryan[1], Stanislav V. Yarantsev[1], Akbar A. Shodiev[1], Mikhail M. Chernenkiy[1], Olga I. Danishuk [2]

[1] The National Medical Research Center for Otorhinolaryngology of the Federal Medico-Biological Agency of Russia, Moscow, Russia

[2] LLC «Danishuk's clinic», Moscow, Russia

Corresponding Author: Viktoriia O. Dzhuganova The National Medical Research Center for Otorhinolaryngology of the Federal Medico-Biological Agency of Russia, Moscow, Russia e-mail viktorijadzhuganova@gmail.com

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Abstract

Backgraund: Midfacial defects involving the orbital region are among the most complex challenges in reconstructive surgery. Globally, the incidence of malignant orbital tumors—and subsequent orbital defects—is around 3.39 cases per million person-years. Due to anatomical and functional limitations, traditional microsurgical techniques cannot fully restore both function and aesthetics in this area.

Aims: To enhance the quality of life in patients with midfacial defects using computer-assisted 3D planning for simultaneous extracranial implantation and silicone facial prostheses.

Materials and methods: his retrospective study analyzed 63 patients (32 men, 31 women; aged 21–84) treated for midfacial defects at the National Medical Research Center of Otorhinolaryngology (FMBA of Russia) between 2007 and 2025. The etiologies included malignant neoplasms (n=5), post-resection defects after oncological surgeries (n=55), trauma (n=2), and inflammation (n=1).

Surgical procedures included placement of cranial implants in the orbital region (n=60), use of a free fibular bone flap with cranial implants (n=2), combination of free fibular flap, free anterolateral thigh flap, and cranial implants (n=1). Patients underwent Magnetic Resonance Imaging (MRI), Multi-Slice Spiral Computed Tomography (MSCT), and 3D computer modeling (Amira and Blender) for pre- and postoperative planning. Outcomes were assessed using modified ECOG questionnaire,VHNSS 2.0,and Holger's scale (PEQ).Data analysis was conducted using Excel and Statistica 8.

Results: 3D modeling significantly improved implant accuracy and aesthetic outcomes (average patient satisfaction: 9/10). The cranial implant survival rate was 98%. Comparative analysis of VHNSS 2.0 and ECOG showed enhanced quality of life and aesthetic satisfaction post-rehabilitation. Holger's scale confirmed usability and patient satisfaction with the prostheses.

Conclusions: Computer-assisted 3D planning significantly improves surgical precision and aesthetic predictability in midface reconstruction. The integration of 3D technologies has enabled the simultaneous performance of surgical and prosthetic procedures, enhancing rehabilitation outcomes for patients with orbital defects.

Keywords: Orbital defect, cranial implant, silicone facial prosthesis, 3D planning.

INTRODUCTION

Defects of the midface involving the orbital region are among the most challenging areas for surgical reconstruction. The eyeball is an organ for which achieving functional (visual) and esthetic parameters is not feasible using microsurgical techniques. Loss of orbital and midfacial structures as a result of oncologic resections, trauma, or congenital conditions may lead to severe functional and esthetic alterations, profoundly affecting the patient's self-esteem, psychosocial well-being, and quality of life.

Acquired orbital defects arise as a consequence of surgical treatment of orbital tumors or due to the spread of tumors originating from the paranasal sinuses, nasal cavity, oral mucosa, and skin[1]. In the study by Tyers

A.G., 80–90% of orbital exenterations were performed because of tumors, of which 40–50% were associated with eyelid or periorbital skin malignancies[2]. According to statistics reported by Zhang W. et al., the global age-standardized incidence rate of malignant orbital tumors is approximately 3.39 per million person-years [3]. Traditional methods for reconstruction of midfacial defects include the use of local tissues or free autogenous grafts[4]. The closest analogue for reconstruction of midfacial defects is the transplantation of a free soft-tissue flap followed by high-precision tattooing [5]. The use of tattooing on transplanted split-thickness skin grafts and pedicled flaps in the head and neck region was first reported by Louis T. Byars in 1945 [6]. The advantages of this method include the possibility of selecting an almost unlimited range of colors to create complex pigmentation.

In cases where it is not possible to close the defect using autologous grafts because of anatomical limitations or patient comorbidities, the method of choice is a facial prosthesis supported by cranial implants [7,8,9].

Reconstruction of midfacial defects using silicone prostheses is a safe and rapid method for the rehabilitation of patients of working age. The introduction of osseointegrated extraoral implants revolutionized the management of complex facial defects by providing reliable mechanical retention of facial prostheses and restoring both appearance and functional aspects without the use of adhesives. Placement of cranial implants into intact bone at the time of ablative surgery, particularly before adjuvant radiotherapy, has been shown to improve prosthetic outcomes even in anatomically demanding regions such as the orbit [8,10].

Historically, adhesive materials have been used for retention and edge camouflage of facial prostheses, either alone or in combination with camouflaging devices (e.g., spectacles). It has been noted that adhesive compositions were employed to retain facial prostheses and mask their margins, sometimes together with additional camouflage tools such as glasses. An important role in the development of maxillofacial rehabilitation was played by the work of Professor P.I. Brånemark, who in the late 1970s introduced the concept of osseointegrated implants [11]. The original Brånemark implant became the foundation for fixation of modern craniofacial prostheses and has undergone numerous modifications over the years. In 2010, the Vistafix system (Cochlear, Gothenburg, Sweden) was developed—a facial prosthetic implant system providing safe, reliable retention and excellent cosmetic outcomes [10]. The high long-term osseointegration rates of these implants (90–95% at ten years) have revolutionized maxillofacial rehabilitation by ensuring superior stability and fixation of prostheses without the need for adhesive materials.

With the development of digital technologies, CAD/CAM planning has become a key tool in medicine, improving the design and fabrication of medical instruments and surgical guides [12,13]. Since the late 1990s, computer-aided design systems have been used for planning dental implant placement, and recent advances have extended their application to the maxillofacial region. Virtual surgical planning integrates CT and MRI data to generate three-dimensional models of defects and healthy tissues. This allows precise determination of implant position and angulation, design of surgical guides, customized facial prostheses and retention systems, and prediction of esthetic outcomes before surgery.

We present a retrospective analysis of the treatment of patients with midfacial defects rehabilitated using complex prosthetic reconstruction supported by cranial implants, based on computer-assisted 3D planning of both the surgical and prosthetic stages.

OBJECTIVE

Improvement of the quality of life of a patient with a midfacial defect resulting from removal of an orbital meningioma using computer-based 3D planning for one-stage extracranial implantation and prosthetic rehabilitation.

TASKS:

1. To analyze the known methods for reconstruction of midfacial defects.
2. To develop a treatment algorithm for patients with midfacial defects using facial epitheses retained by cranial implants.
3. To evaluate the effectiveness and convenience of silicone epitheses supported by cranial implants, fabricated with the aid of digital technologies, according to the criteria of implant survival, esthetics, comfort, and patient satisfaction.

MATERIALS AND METHODS

A retrospective analysis of treatment outcomes in the Department of Maxillofacial Surgery of the National Medical Research Center of Otorhinolaryngology, FMBA of Russia, was carried out based on data from 63 patients with midfacial defects treated from 2007 to 2025, 32 men and 31 women aged from 21 to 84 years (Table 1).

Table 1. Distribution by age and gender (n=63).

	Age	20–30 years	31–40 years	41–50 years	Over 51 years	Total
Gender	Men	3 (5%)	1 (2%)	5 (8%)	23 (36%)	32
	Women	3 (5%)	3 (5%)	3 (5%)	22 (34%)	31
	Total	6 (10%)	4 (6%)	8 (13%)	45 (71%)	63

The etiology of the defects included malignant neoplasms (5 cases), status after resection of the midface due to malignant disease (55 cases), post-traumatic defect (2 cases), and inflammatory disease – 1 case (Table 2).

Table 2. Distribution of ɜatients with midfacial defects by etiology.

Neoplasms (n=60)		Other causes (n=3)	
Malignant (n=5)	Postoperative defect following oncologic resection (n=55)	Post-traumatic defect (n=2)	Inflammatory diseases (n=1)
8%	87%	3%	2%

The operative treatment methods included: placement of cranial implants in the orbital region (60 patients); reconstruction of midfacial defects using a free revascularized fibular bone autograft in the area of the maxillary defect and cranial implants in the orbital region – 2 patients; reconstruction of midfacial defects using a free revascularized fibular autograft in the maxillary region, a free revascularized anterolateral thigh flap (ALTF) for soft-tissue facial reconstruction, and cranial implants in the orbital region – 1 patient (Table 3).

Table 3. Types of treatment methods for midfacial defect reconstruction.

Cranial implants	Fibular free flap + cranial implants	Fibular free flap + anterolateral thigh flap+ cranial implants
60 (95%)	2 (3%)	1 (2%)

The mean follow-up period was 2 years.
The following implant systems were used: NobelSpeedy Shorty RP, size 4 × 7 mm (46% of cases); Southern Implants Extraoral, implant diameter 4 mm and length 3–6 mm (40% of cases); Renova Altracore Biomedical 3.75 × 10 (14% of cases) (Table 4).

Table 4. Types of extraoral implant systems utilized in patients with midfacial defects.

Brands of implants	Number of patients with midface defect	Implant success rate
NobelSpeedy Shorty	29 (46%)	99%
Southern Implants Extraoral	25 (40%)	99%
Renova Altracore Biomedical	9 (14%)	97%

Using this method, we demonstrate the result of the clinical observation of a 63-year-old female patient with a meningothelial meningioma of the right orbit (WHO grade 1). In the preoperative stage, the patient underwent instrumental and clinical-laboratory investigations according to a standardized protocol (MSCT of the head and neck with contrast administration, MRI of the head and neck with vascular contrast enhancement), as well as anthropophotometric imaging. Follow-up MSCT and MRI of the maxillofacial region after treatment were performed at 1, 3, 6, and 12 months. Computer simulation of the surgical procedure was carried out using Amira and Blender software. As a result of preoperative planning, a set of intraoperative guides was designed for use by the surgical team during the operation. The guides were printed on an Elegoo Saturn 2 3D printer.
In the postoperative period, the prosthetic phase was performed, including analogue impression taking with silicone.

3D-model-based and traditional laboratory techniques were used for the wax try-in and fabrication of the final silicone epithesis.

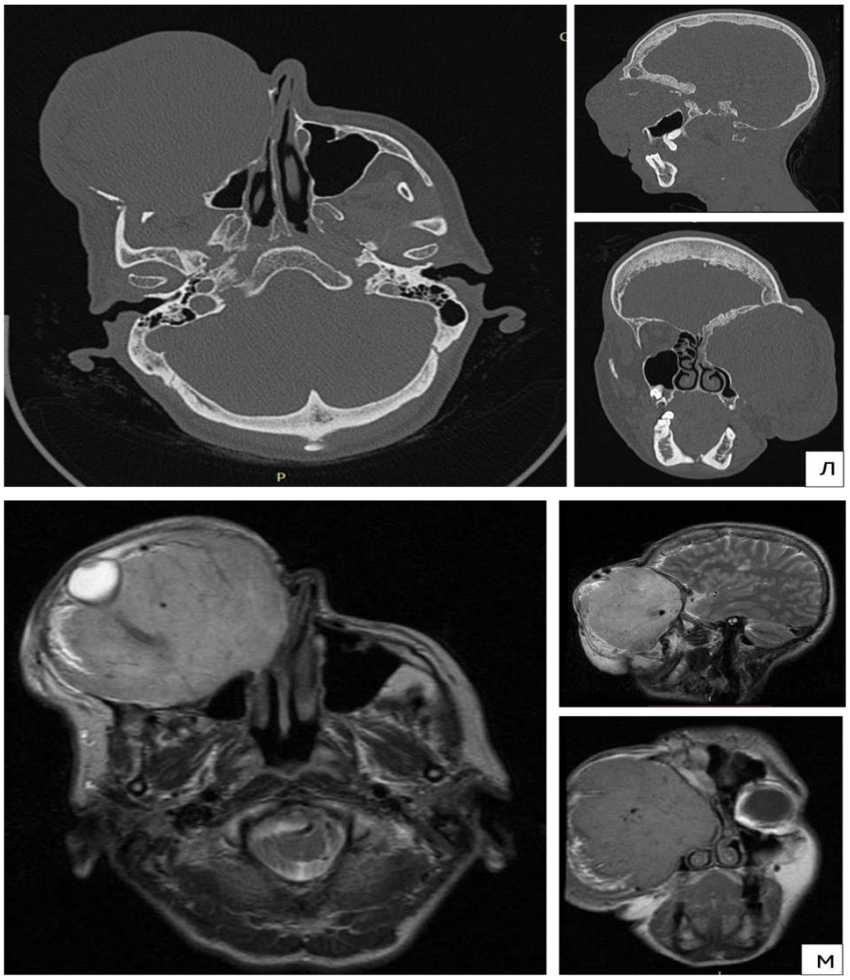
To assess treatment effectiveness and quality of life, the patient was evaluated in the preoperative and postoperative stages using a patient-reported questionnaire after treatment: ECOG in the author's modification for patients with maxillofacial deformities (D.N. Nazaryan), and VHNSS 2.0 (the Vanderbilt Head and Neck Symptom Survey version 2.0). Evaluation of the epithesis was carried out based on selected criteria from Holger's scale (PEQ). Convenience of use (comfort and weight of the epithesis) and appearance were taken into account. Instead of an interval scale (0 to 100), an ordinal scale with a set of statements — "poor", "fair", "good", "very good", "excellent"- was used. The assessment of appearance and fit was based on visual inspection and subjective sensations. The weight of the epitheses was measured directly. The condition of the soft tissues around the abutments was evaluated according to Holgers' scale. Database processing was performed using Excel and Statistica 8.

RESULT OF THE CLINICAL OBSERVATION

Using this method, we demonstrate the result of a clinical observation in the Maxillofacial Surgery Department of the National Medical Research Center of Otorhinolaryngology, FMBA of Russia, in a 63-year-old female patient with a meningothelial meningioma of the right orbit (WHO grade 1). According to the patient, the lesion had appeared 30 years earlier, and she had not previously sought medical care. The patient complained of deformation of the right half of the face, the presence of a painless extensive mass of the right orbit, complete loss of vision in the right eye, and difficulty of nasal breathing through the right nasal passage.

On examination by a maxillofacial surgeon, the patient presented with a change in the configuration of the right half of the face due to a large mass of the right orbit measuring 9 × 10 cm; on the anterior surface of the mass the eyeball and surrounding eyelids with adjacent skin areas were located. The palpebral fissure was deformed, and the visible mucosal surfaces were hyperemic. The cornea was opaque, and the pupil was not distinguishable. During facial expression tests, contraction of the orbicularis oculi muscle on the right side was observed (Fig. 1A–Z).

At the preoperative stage, the patient underwent instrumental and clinical-laboratory examinations according to a standardized protocol. Imaging diagnostics included MSCT of the head and neck with contrast administration and MRI of the head and neck. Imaging methods made it possible to visualize the skull bones, soft tissues (integrity, structure, shape, size, position), the dentoalveolar system, and salivary glands with assessment of their parenchyma and surrounding soft tissues, as well as to identify additional inclusions. Data collection was based on anthropophotometric images (study of facial esthetic proportions). MSCT and MRI of the maxillofacial region revealed a soft-tissue mass of the right orbit measuring 9 × 8 × 10 cm with a solid structure. Deformation of the facial skeleton was noted, involving the walls of the right orbit and the lateral wall of the nasal cavity (Fig. 1I–M).



After biopsy of the lesion and immunohistochemistry, the diagnosis of meningothelial meningioma WHO grade 1 of the right orbit was established. The patient was offered treatment consisting of removal of the lesion with enucleation of the right eye and one-stage reconstruction of the defect using complex prosthetic rehabilitation supported by implants.Computer simulation of the surgical procedure was performed using Blender and Amira software. The 3D planning for the operation consisted of analysis of contrast-enhanced MSCT and MRI of the maxillofacial region and vessels of the patient. After virtual orbital exenteration, the optimal positions for placement of extracranial implants were determined. As a result, a set of intraoperative implant placement guides was planned. In addition, by extrapolating the left half of the face, an STL model of the epithesis was printed. The guides were printed on an Elegoo Saturn 2 3D printer (Fig. 1O–C).

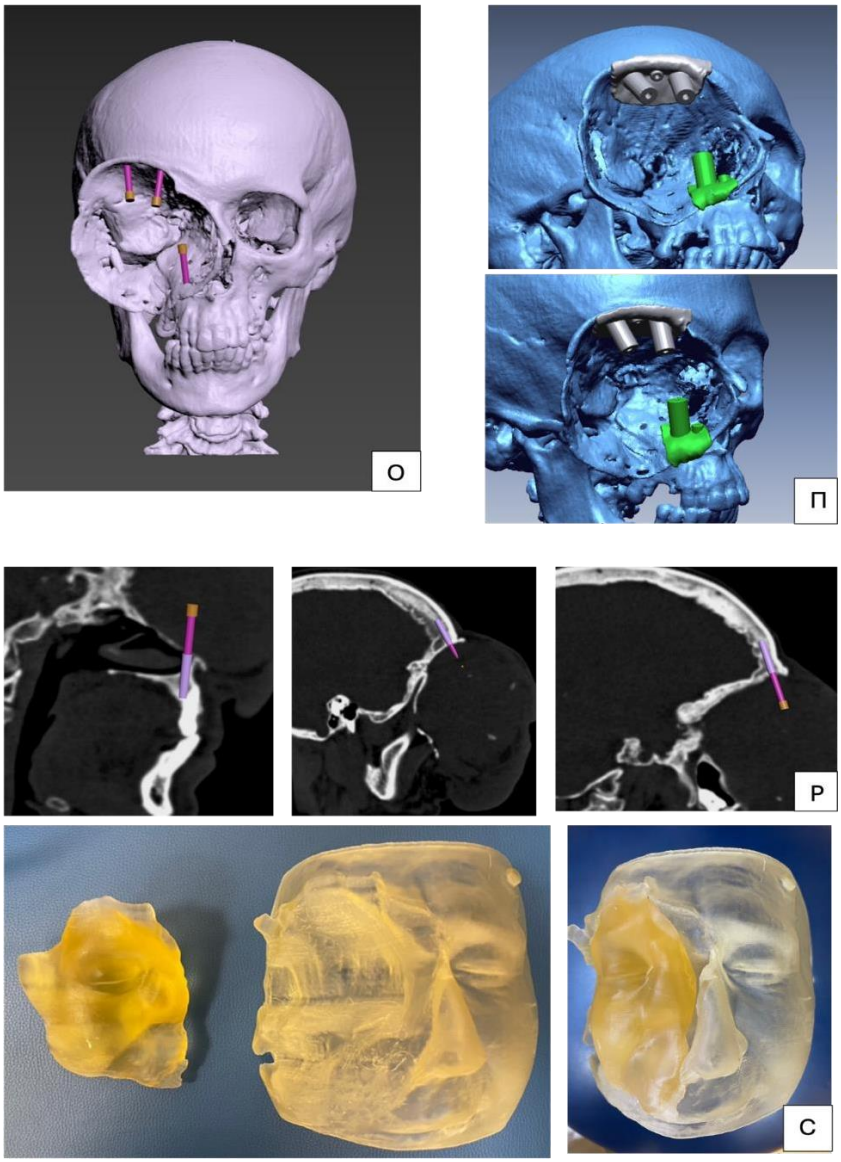


Figure 1. Photographs of the maxillofacial region before surgery (A–Z), MSCT (L), MRI (M), 3D modeling (O–C).

During surgery, orbital exenteration was performed. After fixation of the navigation guides, three zygomatic implants ZYGAN Southern Implants 4.0 × 35 mm were placed at an angle to provide three support points for the epithesis—two implants in the medial part of the superior orbital rim and one implant in the nasal floor of the anterior maxilla. A split-thickness skin autograft was fixed in the orbital floor region (Fig. 2A–G).

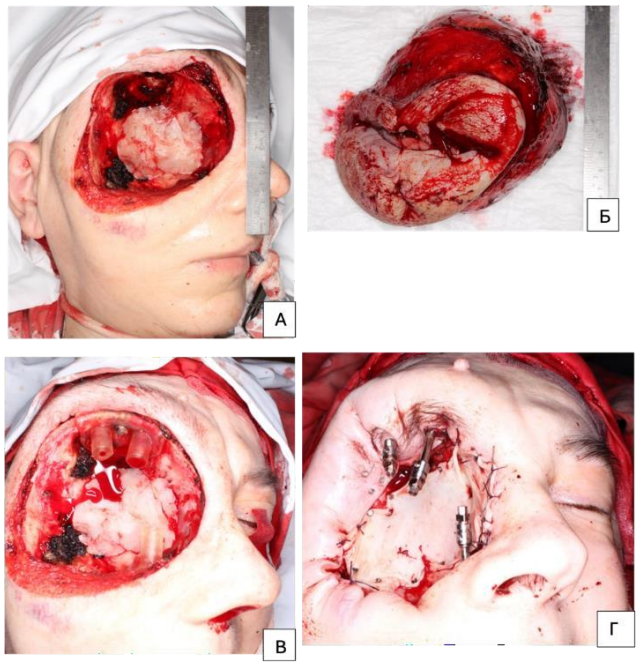


Figure. 2. Intraoperative photographs: view of the wound after orbital exenteration and excision of adjacent tissues (A); resected specimen (B); fixation of the navigational 3D template (C); view of the wound after placement of cranial implants and fixation of the split-thickness skin graft (D).

The duration of the surgical procedure was 4 hours. On postoperative day 14, the sutures were removed. Histological examination confirmed meningothelial meningioma WHO grade 1, and the resection was performed within healthy tissue.

Two weeks after surgery, the sutures were removed, after which impressions were taken using silicone. Traditional laboratory methods were used for the wax pattern and fabrication of the final epithesis. The prosthetic phase included fabrication and adjustment of the epithesis individually to the patient's anatomical structures. At this stage, correction and adaptation to the desired shape were performed, as well as assessment of the color shade, with maximum matching to the patient's skin tone.

The prosthetic process consisted of four stages:

1) taking an impression of the region intended for the epithesis (Fig. 3A–B);

The prosthetic process consisted of four stages:

1) taking an impression of the region intended for the epithesis (Fig. 3A–B);

2) try-in of the epithesis prototype designed according to archival photographs and the left half of the patient's face (Fig. 3G–E);

3) by designing the magnetic attachment in the medial part of the orbit, modeling of the epithesis in wax to obtain the final shape (Fig. 3Zh–L);

4) replacement of the wax model of the epithesis with intrinsically colored silicone, fixation of the epithesis, and training the patient in its use.

Figure 3. Prosthetic stage: impression taking (A–B); placement of the magnetic retainer (D); fitting and adjustment of the wax prototype (E–L).

A silicone epithesis with an acrylic supporting part was fabricated for the patient, individually designed considering the patient's anatomical features and the position of the installed implants. The final facial epithesis ensured color matching (Fig. 4 A–K). The total time from implant placement to fixation of the final epithesis was 14 weeks.

At the follow-up visit after 24 months, based on the quality-of-life questionnaire results during the postoperative period at the end of comprehensive rehabilitation according to the VHNSS 2.0 questionnaires, the patient was satisfied with her appearance. The analysis of the modified ECOG questionnaire revealed the patient's complete recovery. The evaluation of epitheses was carried out based on selected criteria from the Prosthesis Evaluation Questionnaire (PEQ). The patient was satisfied with the treatment and noted that she had "started life from a new page"; the treatment allowed her to return to a full social life. Objectively, the epithesis adhered tightly to the anatomical structures of the midface. The condition of the soft tissues around the abutments was assessed as 0 points on the Holgers scale, indicating good skin condition, absence of soft tissue inflammation, and granulation tissue formation.

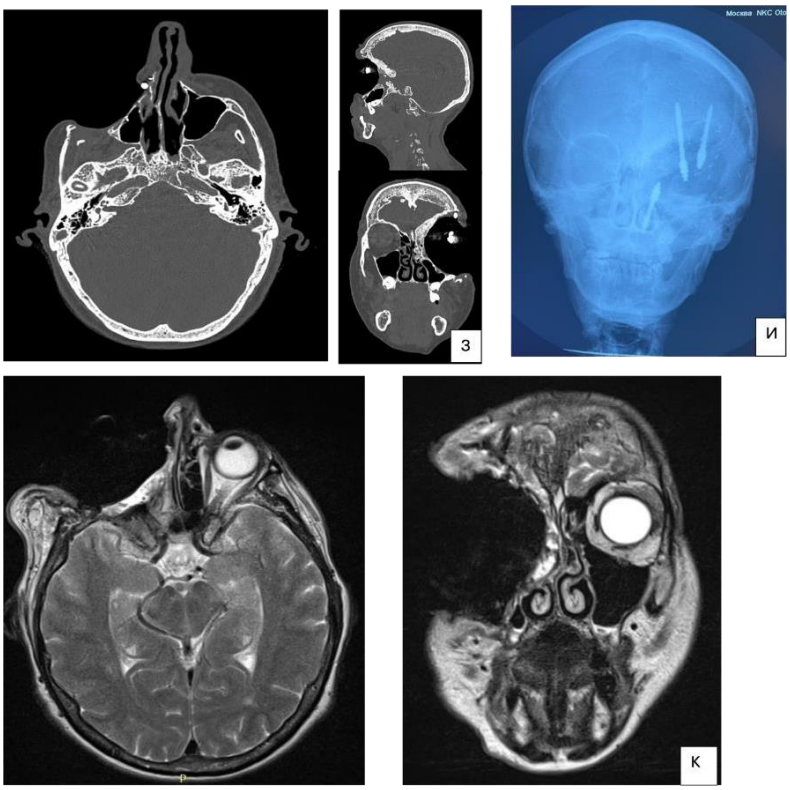


Figure 4. Photographs of the maxillofacial region after epithesis fixation (A–D), MSCT of the maxillofacial region (E, F), MRI of the maxillofacial region (G).

Thorough preoperative preparation and the use of 3D planning made it possible to achieve a predictable aesthetic result. The survival rate of cranial implants was 98.5%. The use of 3D modeling technologies is the key to precise implant positioning, which leads to an acceptable aesthetic result (survey result – 9/10). Based on the survey data, the patient rated her quality of life after surgical treatment as good. As a result of comparing the obtained VHNSS 2.0 questionnaire data, it was revealed that the combined treatment with total rehabilitation influenced the patient's quality of life and satisfaction with her appearance. The analysis of the modified ECOG questionnaire in patients revealed complete recovery (Table 5).

The Prosthesis Evaluation Questionnaire Holger's scale (PEQ) determined the comfort of using the prosthesis and the patient's satisfaction with the aesthetic outcome.

Table 5. Assessment of patient satisfaction with the treatment

Satisfaction with the treatment	54(85%)	excellent	2(3%)	poor	7(12%)	good
Satisfaction with appearance	44(70%)	excellent	1 (2%)	poor	18(28%)	good
Social life	44(70%)	fully restored	18(28%)	minor limitations	1(2%)	not restored

DISCUSSION

One of the treatment methods used to correct defects in the maxillofacial region is prosthetic rehabilitation supported by cranial implants. This method is primarily indicated for patients with extensive defects of the external ear, orbit, or external nose. It is particularly valuable in cases where reconstructive plastic surgery is not possible due to anatomical limitations or contraindications to general anesthesia, since implant

placement can be performed under local anesthesia.

As shown in studies by S. S. Subramaniam et al., extracranial implants significantly expand the possibilities of rehabilitation for patients with extensive soft tissue and bone defects of the face [14]. The overall survival rate of craniofacial implants with an average follow-up of 10.6 years was 79.5%. Implants placed for congenital defect correction demonstrated more predictable results (survival rate 98.9%) than those placed after oncologic resections (70.8%) or trauma (87.1%).

It should be noted that in the midface region, reliable implant fixation presents a significant challenge for the surgeon compared to other areas. This is due to the thinner bone in the middle third of the face, the peculiar configuration of bone structures, and the proximity of vital anatomical structures such as the eyeball, brain, cranial nerves, and blood vessels.

The introduction of digital technologies such as three-dimensional printing and virtual surgical planning has greatly increased the accuracy and predictability of cranial implantation and, consequently, facial epithesis fixation, allowing the creation of highly individualized solutions that closely resemble the lost anatomy. The advantages of digital methods include reduced operative time, fewer patient visits, and improved accuracy in epithesis fabrication. Virtual planning is used to determine the exact position and angle of implant placement, create surgical guides, design retention elements, and develop frameworks, custom implants, temporary, and final epitheses.

Despite the widespread use of traditional prosthetic methods based on manual impression taking and model fabrication, the introduction of digital technologies such as 3D printing and virtual surgical planning has opened new horizons in maxillofacial reconstruction. These innovations make it possible not only to reduce procedure time but also significantly improve the precision and individualization of epitheses, bringing them closer to the patient's natural anatomy. 3D printing technologies such as stereolithography (STL) convert digital models into physical objects—from surgical templates to silicone epitheses. Facial digitization using CT scanning was applied in the works of Bachelet et al., who used DICOM data to obtain a three-dimensional digital facial model of the patient, as well as by Sherwood and Cooke, who used CT images after reconstructive surgery to create a 3D-printed model that served as the basis for fabricating a silicone orbital epithesis. However, this method has technical limitations: incomplete color compatibility of silicone epitheses, difficulties in creating thin edges, and high equipment cost. Modern technical methods increasingly make it possible to replace manual epithesis fabrication with 3D printing, but epitheses created in this way may have lower facial fit accuracy. The main issue is edge adaptation, which is due to material thickness—0.4 mm, which is a serious limitation of the printing technology compared to thickness less than 0.1 mm achieved with traditional methods. To achieve a smoother transition of epithesis edges to the patient's skin, further improvement of manufacturing technologies is necessary.

Thus, modern methods of maxillofacial reconstruction based on the combination of classical and digital technologies make it possible to achieve high aesthetic and functional outcomes. However, further advancement in fabrication technologies and materials is required to improve the durability and usability of facial epitheses, which is especially relevant for patients with extensive defects of the midface.

CONCLUSION

In this clinical case, we demonstrated that with the improvement of technical aspects, performing the surgical and prosthetic stages simultaneously became possible. This technique, combined with the use of retention components (magnet bar, lock bar), ensures comfortable use for patients in the short postoperative period. The use of 3D printing and virtual planning at the surgical stage ensures more precise implementation of implant placement protocols and surgical correction of the prosthetic bed. It should be taken into account that the introduction of this method, as well as the use of free soft-tissue autografts combined with tattooing, requires going through a certain learning curve and developing specialized skills for routine application in clinical practice.

Alternative techniques include the use of camouflaging tools such as bandages, overlay glasses used together with a facial epithesis, silicone epitheses with adhesive fixation, and the use of revascularized soft-tissue autografts combined with high-precision artistic tattooing, which have more limited and individual applications compared to epitheses.

A treatment algorithm has been developed for patients with middle-face defects (using facial epitheses supported by cranial implants, including preoperative diagnostics, virtual planning, and creation of navigation surgical templates followed by prosthetic rehabilitation), which allows the restoration of patients with aesthetic and functional outcomes.

Modern digital surgical methods (3D planning, 3D printing) have significantly improved precision, individualization, and aesthetic outcomes compared to traditional approaches.

DECLARATION

FUNDING

This research did not receive funding from any agency or institution.

Conflict of Interest

None to declare.

Patients consent

All the patients in this study have given their informed consent for publication.

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