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COMPARATIVE ANALYSIS OF METHODS FOR RECONSTRUCTION OF BONE TISSUE OF THE ORBIT AND MIDDLE FACIAL ZONE DEPENDING ON THE AMOUNT OF POST-TRAUMATIC DEFORMITY

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SUMMARY

The purpose of the study is a comparative analysis of methods for reconstructing bone tissue of the orbit and midface depending on the amount of post-traumatic deformity using 3D technologies when planning operations. It was found that the use of 3D technologies for surgical planning and the manufacture of individual implants to eliminate defects in the orbital walls and replace bone structures makes it possible to perform effective reconstructive surgeries for patients with complex combined deformities, as well as reduce the time and cost of their rehabilitation. The correct choice of implantation material and method of reconstruction of bone tissue of the orbit and midface, taking into account the volume of deformations to be eliminated, ensures high quality of medical and social rehabilitation of patients.

KEY WORDS: *reconstruction of orbital bone tissue, post-traumatic deformation of the orbit, 3D technologies when planning operations, reconstructive surgery*

ABSTRACT

The aim of the study is a comparative analysis of methods for reconstructing orbital and midface bone tissues depending on the volume of post-traumatic deformation using 3D technologies in planning surgeries. It was found that the use of 3D technologies for planning surgery and the manufacture of individual implants to eliminate orbital wall defects and replace bone structures allows for effective reconstructive surgeries for patients with complex combined deformities, as well as to reduce the time and cost of their rehabilitation. The correct choice of implantation material and method for reconstructing orbital and midface bone tissues, taking into account the volume of deformities to be eliminated, ensures high quality medical and social rehabilitation of patients.

KEY WORDS: *orbital bone tissue reconstruction, post-traumatic orbital deformity, 3D technologies in planning surgeries, reconstructive surgery.*

RELEVANCE

The orbital-maxillary-zygomatic complex (OMZC) located in the midface plays an important functional and aesthetic role, which creates great difficulties for surgical reconstruction and correction of deformities in this area. A large-sized wounding agent with high kinetic energy causes a fracture of not only the orbital rim and floor, but also other facial bones, up to the formation of panfacial fractures [2; 3]. Such injuries require a special approach in the tactics of treating victims [7; 8]. Reconstructive surgeries on the orbital structures are performed by various specialists: neurosurgeons - on the frontal-orbital region [10; 17; 21], ophthalmologists - on the lower wall of the orbit [5; 6; 9; 20]; maxillofacial surgeons - on the middle zone of the facial skeleton [1; 14; 31]. Performing any one task by a specialist improves the quality of work, but in cases of combined deformations of the area in question, it leads to an increase in the number of interventions and the patient's rehabilitation period [15; 30]. Isolated or combined with fractures of other facial bones, deformations of the orbital walls are among the most common fractures of the midface [12]. The incidence rate is 10-25% of the total number of facial fractures and is most common in the age group from 30 to 40 years [13]. Up to 70% of orbital fractures are associated with some damage to the eyeball or other facial bones.

Restoring the unique and complex anatomy of the orbit requires the production of implants with complex shapes [11; 24; 29]. New technologies in the field of visualization and computer-aided surgical planning can assist the surgeon in solving this problem [4; 37]. One such technology is the use of computer-aided planning to create a mirror image overlay (MIO) on the CT scan of the area to be restored. This requires duplicating the opposite, uninjured area of the face and superimposing its skeleton on the area of the displaced fracture [25; 32]. The use of mirror visualization methods using three-dimensional computed tomography (3D CT) scanning and 3D printing for orbital fracture reconstruction can improve the outcome and recreate the injured orbit in the most functional and aesthetic way [19; 22; 23; 26; 27; 28; 34; 35].

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OBJECTIVE

To conduct a comparative analysis of methods for reconstructing bone tissues of the orbit and midface depending on the volume of post-traumatic deformation using 3D technologies in planning operations.

MATERIALS AND METHODS

The study included 23 patients with anophthalmic syndrome with concomitant posttraumatic fracture of one or both orbital walls in combination with cosmetically noticeable deformations of the bone structures of the midface. Patients applied to the Department of Ophthalmoplastic, Reconstructive Surgery and Ocular Prosthetics of the Republican Specialized Scientific and Practical Medical Center for Eye Microsurgery and Private Eye Clinic "SAIF OPTIMA" in Tashkent, Uzbekistan. The age of patients ranged from 18 to 75 years, on average, 47±2 years.

According to the Declaration of Helsinki, all patients were informed about the scope of the study and signed an informed written consent form.

Ophthalmological symptoms were assessed during the initial visit and dynamic observation, after reconstructive interventions on the orbital structures and the manufacture of an individual ocular prosthesis. The ophthalmological examination included standard and additional research methods.

Preoperative assessment of the symmetry of the orbital structures included the following clinical projections: direct, looking up, lateral and semi-profile.

All patients underwent MSCT of the orbit and midface with a slice thickness of 2 mm. Dystopia of the soft and bone tissues of the orbit and midface was determined in three planes (axial, frontal and sagittal).

To determine the nature, localization, and severity of damage to the bone structures of the orbit and midface, the classification of G.A. Grebnev et al. (2022) [5] was used.

PATIENT INCLUSION CRITERIA

1. age over 18 years;
2. presence of severe penetrating trauma to the eyeball, anophthalmos, or subatrophy of the eyeball;
3. traumatic deformity of the orbit and midface;

PATIENT EXCLUSION CRITERIA

1. Patients under 18 years of age;
2. Pregnancy;
3. Lactation;
4. The presence of concomitant diseases of the body that may affect the results of diagnostic studies;
5. Patient participation in other clinical studies within the last 30 days;
6. Lack of informed written consent of the patient to participate in the clinical study.
7. inflammatory and degenerative diseases of the organ of vision,
8. autoimmune and syndromic diseases of the eye,
9. congenital anomalies of the organ of vision.

The examined patients were divided into groups according to the selection criteria.

In Group I (12 patients, 12 orbits), reconstruction was performed using polytetrafluoroethylene implants for bone tissue defect replacement (IBT) and spherical orbital insert implants (SOI) "ECOFLON".

In Group II (11 patients, 11 orbits), implants were manufactured using the 3D method of mirror visualization with the healthy side and printing a prototype skull model on a 3D printer. The implant was made of acrylic cold polymerization plastic for orthodontic appliances. In all cases of enucleation or delayed formation of the OCD, SOI "ECOFLON" were used. These implants were registered with the State Center for Expertise and Standardization of Medicines, Medical Devices and Medical Equipment of the Republic of Uzbekistan (registration numbers TV/X 04262/03/21 and TV/X 06309/06/23, respectively).

Fig. 1. Spherical orbital implant-liner (SOI) "ECOFLON".

Fig. 2. Implant for replacement of bone tissue defects (IBT) "ECOFLON"

The production of the implant model for the midface and orbital zone was carried out using rapid prototyping systems with the use of FDM (Fused Deposition Modeling) additive manufacturing technology, according to the technology proposed by Azizov M.M. and co-authors [11]. FDM technology involves the creation of three-dimensional objects by applying successive layers of material that repeat the contours of the digital model. A heating head with dies (extruder) melts a thin plastic thread and lays it layer by layer according to the data of the mathematical 3D model [11].

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To assess the effectiveness of rehabilitation measures before and after the treatment, a study of their quality of life was conducted using a questionnaire developed by us (17).

We divided the criteria for assessing the effectiveness on a five-point scale into two groups: the first was assessed by an ophthalmologist, and the second by the patient himself. Data was collected by directly questioning patients at the following times: before surgery, 6 months after surgical treatment immediately after the production of an individual eye prosthesis, after 12 months and after 3 years of wearing the prosthesis.

An ophthalmologist recorded the results of the examination of each patient who came for eye prosthetics. Then the patient is asked questions about his subjective feelings and the answers are recorded in the card. During the testing, the patient is asked to express his attitude to each question by choosing one of the answers. The sum of points for all items of the questionnaire is the "total indicator of quality of life", which allows us to judge the degree of decrease in QOL as a whole. The higher the number of points, the higher the QOL.

To assess the quality of life of the patients included in the study, methods were used that were divided into clinical, cosmetic and psychological.
Clinical methods assess the condition of the conjunctival cavity, its vaults and the quality of the musculoskeletal stump (KonP and ODC). The maximum score is 38.

From a cosmetic point of view, the symmetry of the prosthetic and fellow eye (SimP) and satisfaction with the feeling of comfort (SSC) were assessed. The maximum score when assessing SimP is 90. When assessing SSC, the maximum score was 65.

The psychological component of health (PCH) consists of assessments of mental health; role functioning due to the emotional state; social functioning and life activity. The maximum score is 85.

The results are presented as scores in points, compiled in such a way that a higher score indicates a higher level of QOL. The possible maximum total score for all tests is 278, which corresponds to 100% quality of life.

Based on the completed studies, a computer database was created in the EXCEL-2017 system.
All the obtained material was subjected to statistical processing, carried out using the STATISTICA 10.0 (Stat Soft) program.

RESULTS AND DISCUSSION

The analysis of the obtained results showed that in all cases the eyeball was lost as an organ. In 9 cases (39.1%) the eye was absent. In 14 cases (60.8%) it was subatrophied to varying degrees. The injury was the result of a traffic accident in 7 of them (30.4%), a domestic injury to the orbital area - in 4 (17.4%), a fall from a height - in 3 patients (13.1%), orbitocranial or cranio-orbital injury at work in 9 (39.1%). The age of the victims at the time of injury varied from 4 to 45 years (median = 26 years), males predominated (M-17; F-6).

Table 1.
Characteristics of damage to the bone structures of the orbit and midface by groups

Bone structure of the orbit and midface	**Group 1 (ECOFLON plates)**		**Group 2 (3D acrylic implants)**	
	patients	**%**	**patients**	**%**
	12	**100**	**11**	**100**
Inferior wall (A4)	12	100	11	100
Medial wall (D2)	5	41,6	8	72,7
Inferior orbital rim (A3)	-	0	10	90,9
Outer orbital rim (A2)	1	8,3	4	36,7
Malar bone fusion (A1)	1	8,3	5	45,4

Deformation of the orbital floor was present in all cases in both groups. Medial orbital wall fracture was detected in 5 patients (41.6%) in the first group and in 8 patients (72.2%) in the second group. Deformation of the lower orbital rim was not detected in the first group, while it was detected in almost 91% of cases (10 patients) in the second group. Deformation of the outer orbital rim was detected in only one patient (8.3%) in the first group and in 4 patients (36.78%) in the second. Displacement of the midface bones was diagnosed in 5 cases (45.4%) in the second group and in only one patient in the first group (Table 1).

Table 2.
Characteristics of combined injuries of bone tissues of the orbit and midface by groups

Number of simultaneously damaged bone structures	**Group 1 (ECOFLON plates)**		**Group 2 (3D acrylic implants)**	
	Patient	%	**Patient**	%
	12	100	11	100
4	-	-	3	27,7
3	1	8,4	7	63,7
2	2	16,6	1	8,4
1	9	75	-	-

As can be seen from Table 2, the majority of patients in the first group (75%) had deformation of only one structure, while 91.4% of patients in the second group had significant displacements of three or more bone structures of the orbit and midface.

The MSCT data in DICOM format were sent to the manufacturer to create an implant of the corresponding design together with the engineers. The final version of the implant design was agreed upon with the operating surgeon. The production of the implants is presented in the Material and Methods section.

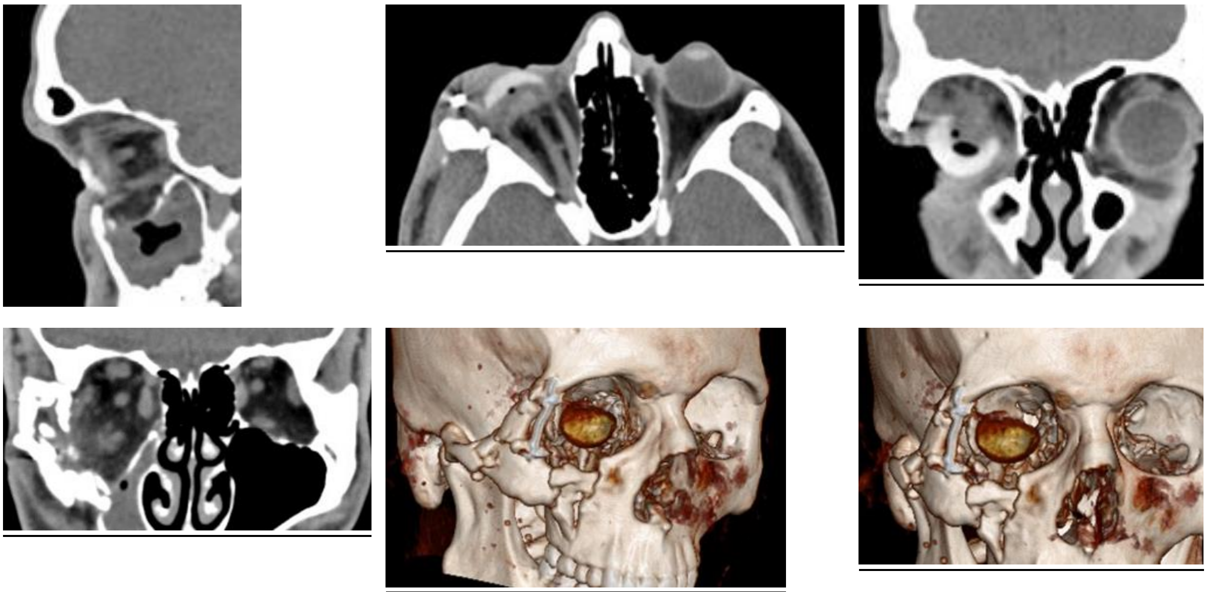

Fig. 3. MSCT Image of Bone Tissues of the Orbit And Midface

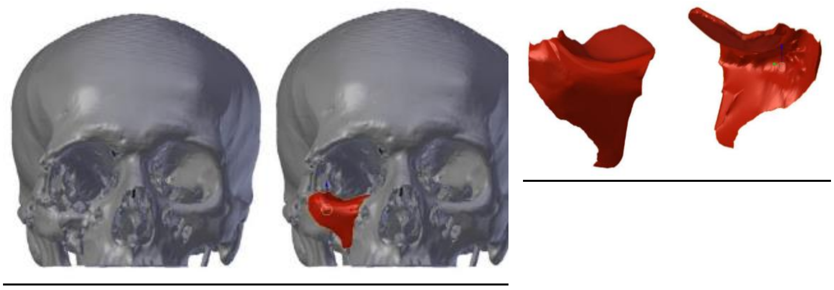

Fig. 4. Digital 3D model of the implant for reconstruction of the lower wall and lower edge of the orbit

Table 3.
Structure of performed operations for reconstruction of bone tissues of the orbit and midface by groups

Surgery to reconstruct the bone structure of the orbit and midface	Group 1 (ECOFLON plates)		Group 2 (3D acrylic implants)	
	Patient	%	Patient	%
	12	100	11	100
Inferior wall	12	100	11	100
Medial wall	5	41,6	6	54,5
Inferior orbital rim	-		10	90,9
Outer orbital rim	-		6	54,5
Zygomatic bone	-		5	45,5
Delayed formation of ODC (Ecoflon insert)	9	75	-	-
Enucleation with formation of ODC (Ecoflon insert)	3	25	11	100

Table 3 presents data on the performed operations on reconstruction of bone tissues of the orbit and midface. Analysis of the obtained data showed that in the first group, despite the presence of deformations of orbital structures having a complex anatomical shape, such as the orbital margins and zygomatic bones (Table 1), their restoration was not performed.

Fig. 6. Patient D., 26 years old. Group 1. Condition before surgery. Anophthalmos. Fracture of the lower, medial walls of the orbit, outer and lower edges of the orbit, displacement of the zygomatic bone

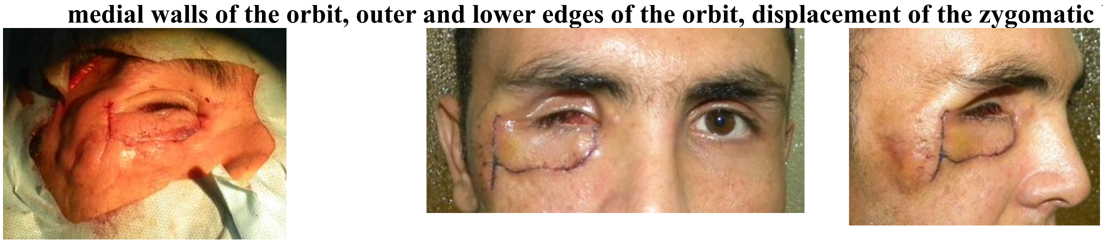

Fig. 7. Patient D., 26 years old. Group 1. Condition after surgery. Reconstruction of the lower wall of the orbit was performed. Delayed formation of the ODC. Filling the temporal and zygomatic zones with implants modeled from ECOFLON bone tissue replacement plates.

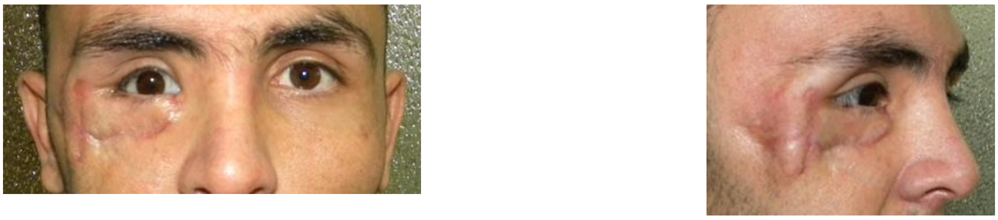

Fig. 8. Patient D., 26 years old. Group 1. Condition after individual eye prosthetics.

In the second group, the technology of manufacturing implants based on 3D technologies allowed to restore the normal contours of not only the walls of the orbit (lower - 11 (100%), medial - 6 (54.5%)) but also its edges. Thus, in 10 patients (90.9%), the contour of the lower edge of the orbit was restored and in 5 patients (45.5%), the zygomatic bone was reconstructed, which is one of the important elements that form the correct contours of the middle zone of the face.

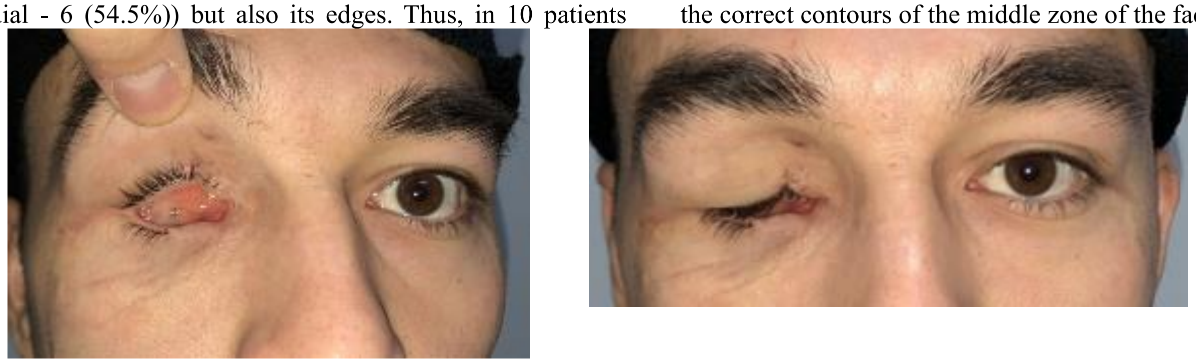

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Fig. 9. Patient O., 30 years old. Group 2. Condition before surgery. Anophthalmos. Fracture of the lower, medial walls of the orbit, outer and lower edges of the orbit, displacement of the zygomatic bone

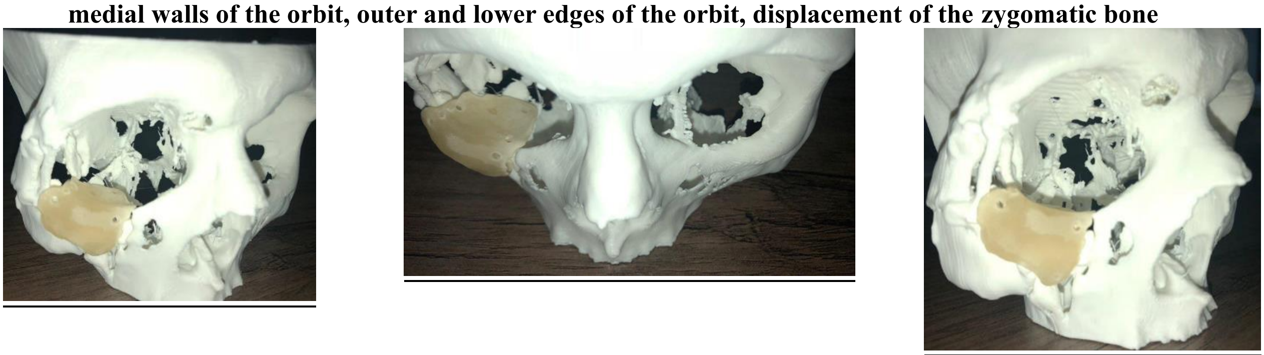

Fig. 10. The manufactured acrylic 3D model of the implant for reconstruction of the lower wall and lower edge of the orbit installed on the patient's skull model.

Fig.11. Patient O., 30 years old. Group 2. Condition after surgery. Anophthalmos. Fracture of the lower, medial walls of the orbit, outer and lower edges of the orbit, displacement of the zygomatic bone

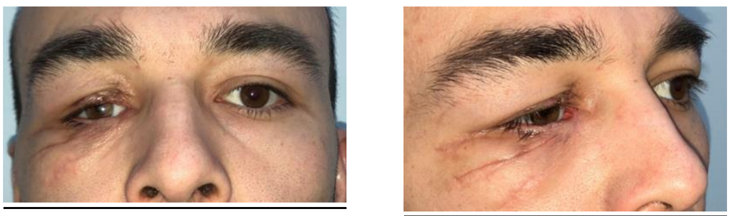

Fig. 12. Patient O., 30 years old. Group 2. Condition after surgery and individual ocular prosthetics. Anophthalmos. Fracture of the lower, medial walls of the orbit, outer and lower edges of the orbit, displacement of the zygomatic bone

When studying the QOL of patients before the start of treatment, low parameters were found in both groups for both mental and physical health indicators. But in comparison, the indicators were slightly lower in the second group.

In the 6-month period after surgical treatment and the production of an individual eye prosthesis, the indicators of physical and mental health components in the first group were 1.2 times higher ($p < 0.05$) (Fig. 13), and in the second group 3 times higher ($p < 0.05$) compared to the indicators before the start of treatment (Fig. 14).

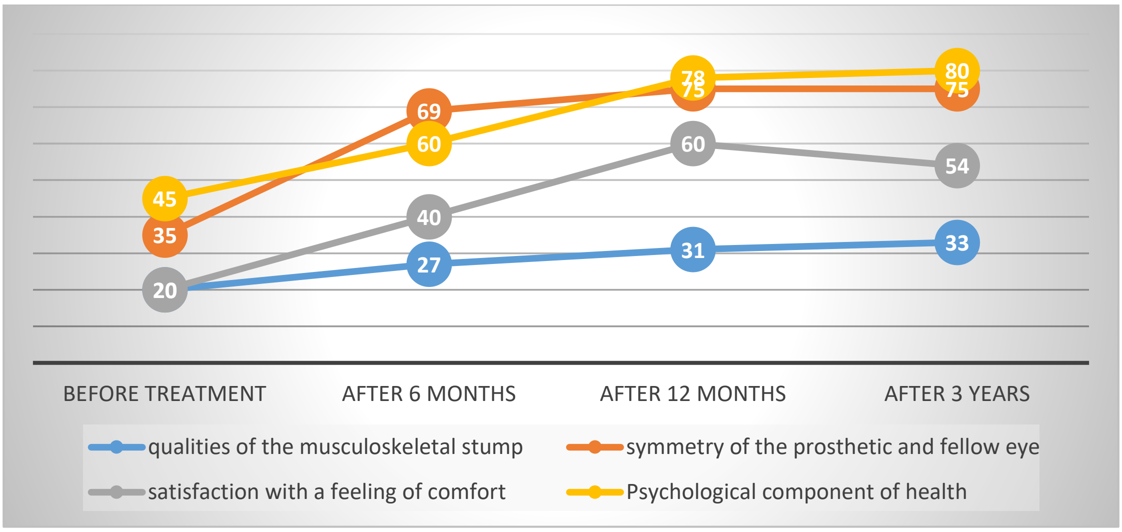

Fig.13. Results of the quality of life study in group 1

When repeating the survey and examination of patients 12 months after the prosthesis was manufactured, an improvement in indicators was observed for all parameters (Figs. 13 and 14).

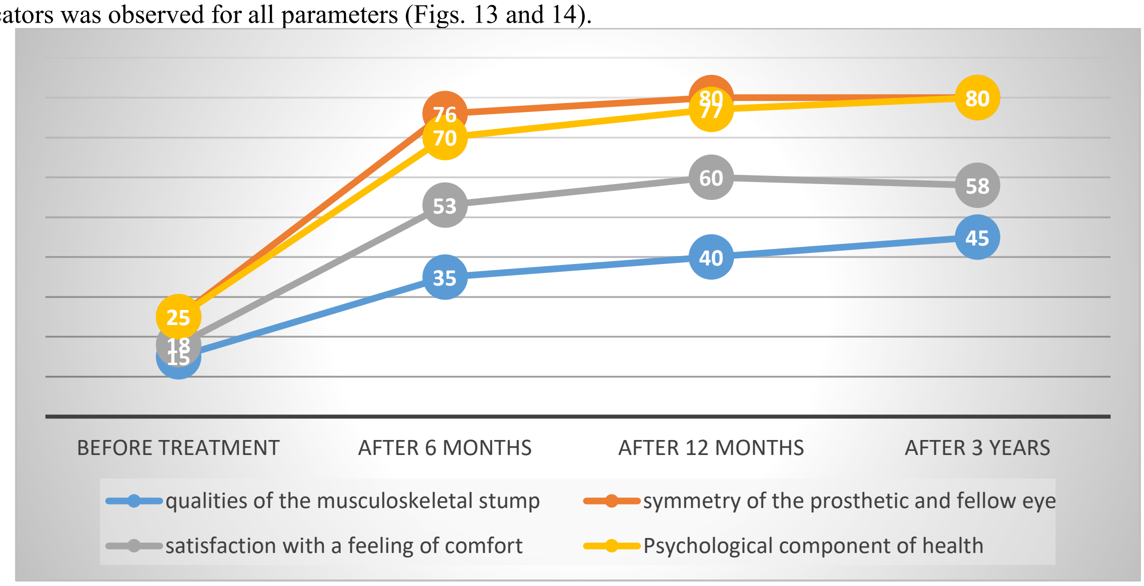

Fig. 14. Results of the study of quality of life in group 2

During the examination 3 years after wearing the eye prosthesis, the SVC values slightly decreased, which was due to the expiration of the acrylic eye prosthesis. This problem was easily solved by replacing the prosthesis with a new one or polishing the surface of the old prosthesis. But the PCS values remained consistently high.

According to the above data, the work studied the effectiveness of using 3D technologies in planning and performing surgical reconstructive interventions, which showed an increase in the quality of life of patients 6 months after surgical treatment and the manufacture of an individual ocular prosthesis. The indicators of physical and mental health components in the first group were 1.2 times higher ($p < 0.05$), and in the second group 3 times higher ($p < 0.05$) compared to the indicators before the start of treatment. Three years after reconstruction and individual prosthetics, the SVC indicators were slightly lower, which was associated with the deterioration of the acrylic ocular prosthesis, while the PCZ indicators remained stably high.

CONCLUSION

Thus, the use of 3D technologies for planning surgery and manufacturing individual implants to eliminate orbital wall defects and replace bone structures allows for effective reconstructive surgeries for patients with complex combined deformities, as well as reducing the time and cost of their rehabilitation.

The correct choice of implantation material and method for reconstructing bone tissues of the orbit and midface, taking into account the volume of deformities to be eliminated, ensures high quality medical and social rehabilitation of patients.

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