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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

IMPROVING THE EFFICIENCY OF SURGICAL TREATMENT USING VIRTUAL PLANNING IN PATIENTS WITH ORBITAL FRACTURES
Clinical research

Speciality: 3226.01 – Dentistry

Field of science: Medicine

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GENERAL REVIEW OF THE WORK

Relevance of the topic. Surgical treatment of fractures of the orbital complex is one of the most topical issues of modern maxillofacial surgery. This fact is explained by the high incidence of fractures of the bones of facial skeleton, which reaches 40% of the damage to the bone structures of the orbit[1,2]. In addition, the anatomical complexity of the orbit and surrounding structures, the importance of the functions they perform make the surgical treatment of orbital fractures one of the most complex issues in reconstructive surgery[3,4].

Due to the complexity of the anatomical and functional features of the orbital complex, the effectiveness of treatment depends, first of all, on an adequate and comprehensive diagnosis and planning of reconstructive operations. In addition to traditional clinical methods in the diagnosis of this type of fracture, the most important of the effective examinations is the method of radiation diagnosis[5,6,7]. In this

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[1] *Abosadegh, M.M.* Epidemiology of maxillofacial fractures at a Teaching Hospital in Malaysia: a retrospective study / M.M.Abosadegh, N.Saddki, B.Al-Tayar [et al.] // Biomed. Res. Int., – 2019. Feb; 13. – 9024763.

[2] *Balaji, S.M.* Surgical correction of severe enophthalmos caused by bullet injury // Indian J. Dent. Res., – 2016. Jul-Aug. 27 (4), – p. 445-449.

[3] *Baek, W.I.* Comparison of absorbable mesh plate versus titanium-dynamic mesh plate in reconstruction of blow-out fracture: an analysis of long-term outcomes / W.I.Baek, H.K.Kim, W.S.Kim [et al.] / Arch. Plast. Surg., – 2014. Jul. 41 (4), – p. 355-361

[4] *Canzi, G.* Posttraumatic delayed enophthalmos: analogies with silent sinus syndrome? Case report and literature review / G.Canzi, V.Morganti, G.Novelli [et al.] // Craniomaxillofac Trauma Reconstr., – 2015. Sep. 8 (3), – p. 251-256.

[5] *Cha, J.H.* Correlation between the 2-dimensional extent of orbital defects and the 3-dimensional volume of herniated orbital content in patients with isolated orbital wall fractures / J.H.Cha, M.H.Moon, Y.H.Lee [et al.] // Arch. Plast. Surg., – 2017. Jan. 44 (1), – p. 26-33.

[6] *Chang M.* Using the endoscopic transconjunctival and transcaruncular approach to repair combined orbital floor and medial wall blowout fractures / M.Chang, S.W.Yang, J.H.Park [et al.] // J. Craniofac. Surg., – 2017. Jun. 28 (4), – p. 963-966.

[7] *Chen, C.T.* Clinical outcomes for minimally invasive primary and secondary orbital reconstruction using an advanced synergistic combination of navigation

case, the nature and location of lesions to the bone walls of the orbit, the involvement of soft tissue components in the process and its degree; The use of computed tomography and especially 3D reconstruction methods, which allow to assess the relationship of relevant lesions to neighboring anatomical areas, is widespread[8,9,10]. However, despite the high informativeness of these methods, it is not possible to estimate the level of correlation between the severity of lesions to orbital structures and the severity of functional disorders caused by changes in the volume and anatomy of the orbit.

In general, surgical treatment of orbital fractures is based on the restoration of structures and the provision of volume that affects both functional and aesthetic parameters. For this purpose, the use of orbital titanium implants, which replicate the anatomical shape of the orbit, along with autogenous and allogeneic bone grafts, fascia transplants, is widely used. The main criterion for the use of reticular titanium orbital implants is not only the defect of the orbital wall or the adequate reconstruction of the transplanted tissue, but also the restoration of the volume of the orbit by giving the anatomical shape of the reticular plate. This affects both the functional state of the motor apparatus of the eye, as well as the aesthetic performance of the face and especially the midface. Traditionally, the process of plate adaptation is based on intraoperative visual parameters, using the "trial and error" method, which can lead to serious complications in the postoperative period. An alternative to this approach is the application of rapid medical prototyping technology in the preoperative period, the use of intraoperative navigation systems and intraoperative computed

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and endoscopy / C.T.Chen, C.H.Pan, C.H.Chen [et al.] // J. Plast. Reconstr. Aesthet. Surg., – 2018. Jan. 71 (1), – p. 90-100.

[8]*Carrere, J.M., Lewis, K.T.* Complete inferior rectus muscle transection secondary to orbital blowout fracture // Orbit, – 2018. Dec. 37 (6), – p. 444-446.

[9]*Cha, J.H.* Correlation between the 2-dimensional extent of orbital defects and the 3-dimensional volume of herniated orbital content in patients with isolated orbital wall fractures / J.H.Cha, M.H.Moon, Y.H.Lee [et al.] // Arch. Plast. Surg., – 2017. Jan. 44 (1), – p. 26-33.

[10]*Chang M.* Using the endoscopic transconjunctival and transcaruncular approach to repair combined orbital floor and medial wall blowout fractures / M.Chang, S.W.Yang, J.H.Park [et al.] // J. Craniofac. Surg., – 2017. Jun. 28 (4), – p. 963-966.

tomography[11,12]. However, the use of all the listed methods, the application of expensive technology and the need for specially trained highly qualified specialists, the long duration of preoperative training, limits the widespread clinical application of these methods.

Recent literature contains information on unified classification systems for orbital fractures. However, the criteria for these systems are not the three-dimensional configuration of the orbit, but only the localization of the fracture in two-dimensional radiological findings[13,14,15,16]. Thus, the restoration of the volume of the orbit, which is one of the important aspects of the reconstruction operations, is still the subject of urgent examination.

Taking into account the above, the development of more effective preoperative diagnostic and planning methods in the surgical treatment of orbital fractures is considered topical issues.

Object of the research: patients with orbital fractures as a result of maxillofacial trauma.

The purpose of the research was to increase the effectiveness of diagnosis and surgical treatment of orbital fractures using virtual modelling at the planning stage of surgical treatment.

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[11] *Chen C.T.* Clinical outcomes for minimally invasive primary and secondary orbital reconstruction using an advanced synergistic combination of navigation and endoscopy / C.T.Chen, C.H.Pan, C.H.Chen [et al.] // J. Plast. Reconstr. Aesthet. Surg., – 2018. Jan. 71 (1), – p. 90-100.

[12] *Chiang, E.* Etiology of orbital fractures at a level I trauma center in a large metropolitan city / E.Chiang, L.V.Saadat, J.A. Spitz [et al.] // Taiwan J. Ophthalmol., – 2016. Jan-Mar. 6 (1), – p. 26-31.

[13] *Aslan, F., Ozen, O.* Correlation of clinical findings with computed tomography in orbital traumas // J. Craniofac Surg., 2019, Oct. 30 (7), – e586-e590.

[14] *Carrere, J.M., Lewis, K.T.* Complete inferior rectus muscle transection secondary to orbital blowout fracture // Orbit, – 2018. Dec. 37 (6), – p. 444-446.

[15] *Chen, C.T.* Clinical outcomes for minimally invasive primary and secondary orbital reconstruction using an advanced synergistic combination of navigation and endoscopy / C.T.Chen, C.H.Pan, C.H.Chen [et al.] // J. Plast. Reconstr. Aesthet. Surg., – 2018. Jan. 71 (1), – p. 90-100.

[16] *Chiang, E.* Etiology of orbital fractures at a level I trauma center in a large metropolitan city / E.Chiang, L.V.Saadat, J.A. Spitz [et al.] // Taiwan J. Ophthalmol., – 2016. Jan-Mar. 6 (1), – p. 26-31.

Research objectives:

1. Retrospective study of the effectiveness of traditional diagnostic and restorative methods in orbital fractures;
2. Development of diagnostic algorithms and working classification system using virtual planning methods in the diagnosis of orbital fractures;
3. Determining the criteria for selecting the method of surgical reconstruction on the basis of the method of virtual planning;
4. Comparative analysis of diagnostic and treatment data using the method of virtual planning with the effectiveness of traditional diagnostic and surgical methods in patients with orbital fractures.

Research methods: anemnestic, clinical-laboratory and instrumental research methods were used.

Main thesis of dissertation for defense:

1. In traumatic fractures and posttraumatic deformities of the orbital bones, the MRP method is confirmed as a highly effective diagnostic method in preoperative planning.
2. The method of virtual modelling (VM) developed in pre-operational planning and virtual adaptation (VA) of standard orbital implants carried out in a special software environment on a computer allows to use plastic models as an alternative to the implantation of implants and to refuse them in certain clinical cases.

Scientific novelty: For the first time:

- An effective complex diagnostic and preoperative planning method based on rapid medical prototyping (MRP) and VM technologies was used in the treatment of patients with fractures of the zygomatic-orbital complex, and data from MRP and VM technologies were compared.
- An algorithm for the application of MRP and VM methods has been developed, as well as criteria for the application of these methods depending on the specific clinical situation.

Practical significance of the research.

- The use of the MRP method in preoperative planning allows to significantly increase the accuracy of adaptation of standard orbital implants and shorten the time of surgery.

- The method of virtual adaptation of standard orbital implants performed in a computer-specific software environment and VM and developed in pre-operational planning allows using as an alternative method of adaptation (VA) of implants on plastic models and in some cases to give up them. This saves time required for preoperative preparation and reduces operating costs.
- The proposed method can be successfully applied in the planning of treatment of both patients with fractures of the zygomatic-orbital complex and the walls of the orbit, as well as post-traumatic defects of the bones of the midface.
- The diagnostic algorithm developed in the present research allows to determine the selection criteria for the sequence of examinations depending on the severity of the pathology.

Approbation. Materials of the dissertation reported at the scientific-practical conference "Actual problems of Medicine" dedicated to the 100th anniversary of Azerbaijan Democratic Republic (Baku, 2018), at the 11th International Congress of the Turkish Society of Oral and Maxillofacial Surgeons (Antalya, 2017), at the 24th International Congress of the European Association of Skull and Maxillofacial Surgeons (Munich, 2018).

The main provisions of the dissertation were reported and discussed at the meeting of the Department of oral and maxillofacial surgery of Azerbaijan Medical University (21.01.2020, protocol № 05) and at the scientific seminar of the Dissertation Council ED 2.05 operating at Azerbaijan Medical University (20.04.2021, protocol № 03).

Introduction of outcomes of the research. The results of the research were applied in the clinical practice of the Educational Surgery Clinic of Azerbaijan Medical University, Baku Clinical Medical Center, departments of maxillofacial surgery of the Republican Clinical Hospital named after academician M.Mirgasimov. Algorithm for planning reconstructive-rehabilitation operations in patients with fractures of the zygomatic-orbital complex and post-traumatic deformities of the zygomatic-orbital complex has been applied in the teaching process of the Department of oral and maxillofacial surgery of Azerbaijan Medical University, the Department of dentistry and maxillofacial surgery of Azerbaijan State Advanced Training Institute for Doctors named after A.Aliyev.

The name of the organization where the dissertation has been accomplished. The dissertation was completed at the Department of oral and maxillofacial surgery of Azerbaijan Medical University.

Publications. Based on the materials of the dissertation, 9 scientific works reflecting the main content of the work, including 7 articles and 2 theses were published, of which 2 articles and 1 thesis were published abroad.

Volume and the structure of the dissertation. The dissertation consists of 159 computer pages, (183385 symbols) including an introduction (5 pages, 9291 symbols), a literature review (36 pages, 66956 symbols), research materials and methods (32 pages, 26398 symbols), the results of personal research and their discussion (43 pages, 49629 symbols), conclusion (10 pages, 20311 symbols), findings (1.5 pages, 2752 symbols), practical recommendations (0.5 pages, 982 symbols) and a list of references (25 pages). The dissertation is visualized with 15 tables, 103 figures, 7 graphs, 1 scheme. The list of references covers 260 sources.

RESEARCH MATERIALS AND METHODS

The research was carried out using the clinical-experimental method on the basis of the Department of oral and maxillofacial surgery of Azerbaijan Medical University, the Department of oral and maxillofacial surgery of the Baku Clinical Medical Centre and the Department of oral and maxillofacial surgery of Azerbaijan Medical University in 2007-2018.

The research included 77 patients aged 9-62 years who were treated for facial trauma. According to the treatment, the patients were divided into 2 groups: a) Group I - 42 patients (main - in 2015-2018, preoperative diagnosis and planning were performed and operated by the methods we offered), b) Group II - 35 patients (control - in 2007-2017, preoperative diagnosis and planning were performed and operated by the methods we offered). In group I, 4 patients (3 boys and 1 girl) were under 16years old, and in group II, no patients were found at this age.

Out of the total number of patients, 41 received traumatic injuries due to domestic trauma, 24 to traffic accidents (TA), 7 to industrial injuries and 5 to sports injuries. Out of 77 patients, 32 were diagnosed with “fractures of the orbital walls”, 22 with “fractures of the walls of the eye socket along with fractures of the zygomatic bones and other bones of the facial skeleton”, 15 with “fractures of the zygomatic bones”, 4 with “fractures of the walls of the orbit and fractures of the facial skeleton” and 4 were diagnosed with the “fractures of the zygomatic bones and other bones of the facial skeleton”.

Clinical examination of patients with traumatic injuries of the midface was carried out by traditional methods. This includes the collection of the patient's complaints, the collection of current disease and life history, an objective assessment of the somatic condition, and a clinical examination of the pathology, mainly related to the apple-orbital complex. In addition, depending on the nature of the pathology, dental, neurological, ophthalmological and otorhinolaryngological status were assessed. All patients underwent preoperative laboratory tests that in addition to the general analysis of blood, it includes the determination of a number of biochemical parameters, including the determination of total protein, alkaline phosphatase, creatinine, glucose, urea, residual nitrogen, cholesterol, triglycerides, total bilirubin, amylase, in addition to a general blood test and alanine aminotransferase (ALT). In addition, patients' coagulograms and, in particular, blood clotting time, partial thromboplastin time, fibrinogen, and INR indicators were determined.

Before and after the operation, the patient was photographed with a digital camera "NIKON" (Nikon single-lens, mirrored camera with Sony IMX-038-BQLCOMP matrix with 12.3 megapixels and providing a maximum image of 4288 × 2848 pixels, D5000 model, Minato, Tokyo, Japan) in order to assess the aesthetic features and proportions of the face, to fix the appearance and condition of the eyeballs, as well as to determine the effectiveness of treatment. The photo was taken in front, side and front semi-axial projections at a distance of 0.5-1 meters with the application (Photocavant SB-6090BW) of a special lighting system. In this case, the position of the eyeballs was photographically fixed in four main positions (upper, lower, lateral and inner quadrant). Photon documentation were taken in the preoperative and postoperative periods.

The following examination methods were used in the research:

Two-dimensional radiography. The research used a two-dimensional: 2D-radiography method (Luminos dRF Max, Siemens, Munich, Germany) within the traditional examination algorithms of patients with defects and deformations of the facial skeletal bones. Computed tomography (CT) and 3D reconstruction. All patients underwent spiral computed tomography and subsequent three-dimensional reconstruction within the protocol used in the research. (Toshiba Multi-Slice Computed Tomography, Aquilion CX-18, Tokyo, Japan). The main method of treatment was a surgical method - the reconstruction of the walls of the orbit. The surgery was performed under general anaesthesia using a method of transconjunctival or subciliary.

CT examinations were carried out for the purpose of diagnosis and planning of preoperative intervention in the care of patients who took the examination. In terms of preoperative planning, patients were divided into 2 groups: The data obtained during the computed tomography in the method of virtual computer modelling CAD / CAM were converted to DICOM-format (Digital and Image Communication in Medicine, Arlington VA, United States of America) and transferred to an optical information carrier. The data in this format was then transferred to a virtual software environment (Materialise Mimics Research 21, Materialise NV, Leuven, Belgium), where it was converted from the DICOM format to a format specific to that program. The Rapid Prototyping Method (RPM) was applied as an additional method in this study, and a 3D Reprap Prusa I3 filament printer was used for this purpose. (RepRap Prusa by Josef Prusa, Czech Republic). A three-level working classification (AOCMF) of posttraumatic defects and deformities of the midface was used to make a correct diagnosis. Then, in the AOCMF Classification Systems (CS), coding of fractures of the cranial-facial skeleton bones was performed.

Surgical intervention: In all cases, surgery was performed under general naso- or orotracheal intubation. In all cases, the patients were in a lumbar position. The approach to the damaged orbit was performed mainly by transconjunctival or subciliary surgery. Orbital dissection and fixation of orbital titanium implants were performed using traditional methods.

Statistical processing of the data obtained during the survey was performed. For this purpose, the mathematical average (M) of quantitative indicators and its standard error (m), the absolute number of quality indicators and the frequency of occurrence (%) were calculated for each group.

Statistical comparisons of quantities by groups and subgroups were made, and non-parametric statistical criteria - Mann-Whitney's U-test and Fischer's accurate test - were used to determine the accuracy of the difference between them. The difference between the indicators in the compared groups was considered statistically accurate at $p<0.05$.

Statistical processing of the obtained results was performed on a personal computer using Microsoft Office Excel 2013 spreadsheet editor and MedCalc 12.7 statistical software package.

RESEARCH RESULTS AND DISCUSSIONS

Treatment of fractures of the walls of the orbit and the zygomatic-orbital complex is one of the most topical areas of modern maxillofacial surgery. In addition to clinical examination methods, traditional diagnostics and planning of such operative interventions are carried out using 2-dimensional technologies, such as traditional 2-dimensional radiography, and various functional tests. However, the accuracy of diagnostics and preoperative planning is somewhat more important. The application of computed tomography and simulated 3D reconstruction to some extent optimizes diagnostic and planning data. In contrast to these methods, medical rapid prototyping (MRP) and virtual computer biomodelling allow to expand the scope of preoperative diagnostics and planning to some extent. Virtual modelling and intervention planning involves the application of these computer software packages for the virtual adaptation of various titanium devices (reconstructive plates, network screens, reticulated orbital plates).

Taking into the account above, we have made efforts to optimize the treatment of patients with facial skeletal bone defects and deformations through the use of MRP technologies and virtual biomodulation. As part of the examinations, we conducted prospective and retrospective examinations of 77 patients treated for fractures of the midface. In this case, patients were conventionally divided into main (42 patients) and control (35 patients) groups. MRP and virtual biomodulation methods were used in the main group, whereas diagnostic and planning methods were traditionally used in the treatment of patients in the control group. In addition, the patients in the main group were also divided into 2 subgroups - those treated using the rapid medical prototyping method and those treated using the virtual modelling method, which in turn allowed for a comparative analysis of both methods.

The age range for all patients treated ranged from 9 to 62 years, with an average age of 32 years. Of them, 61 patients (79%) were men and 16 patients (20.8%) were women. Of the total number of patients, 41 were caused by traumatic injuries, 24 - by traffic accidents, 7 - by industrial injuries and 5 - by sports injuries.

Out of 77 patients, 32 were diagnosed with “fracture of the walls of the eye socket”, 22 with “fracture of the walls of the eye socket together with fractures of the zygomatic bone and other bones of the facial skeleton”, 15 with “fracture of the zygomatic bone”, 4 with “fracture of the eye socket and other bones of the facial skeleton" and 4 were diagnosed with "fractures of the zygomatic bones and other bones of the facial skeleton".

During the clinical examination, the main focus was on the mobility of the eyeball, the presence of binocular diplopia and enophthalmos. The fact of diplopia was noted in a total of 51 patients.

Another parameter assessed in the current research was the period of patient referral after trauma and the likelihood that it would affect the presence of residual diplopia. It was found that patients applied mainly immediately after the trauma (57.1% of cases), some within the next month (31% and 22.9%, respectively), and some more than 1 month after the trauma (11.9% and 20% respectively).

The MRP method was used in 11 of 42 patients in the study. According to the proposed algorithm, the data recorded in the form of an optical carrier after CT examination, processing of data obtained with the help of software was used in the development of a 3-dimensional model. In this case, the preparation time of the model took an average of 1 day, and the time required to work with the model within the preoperative preparation was up to 30 minutes. The time required to sterilize orbital implants was 1 day. Thus, the duration of preoperative preparation using MRP technology took 2 days from the moment of obtaining computed tomography data[17] (Fig. 1).

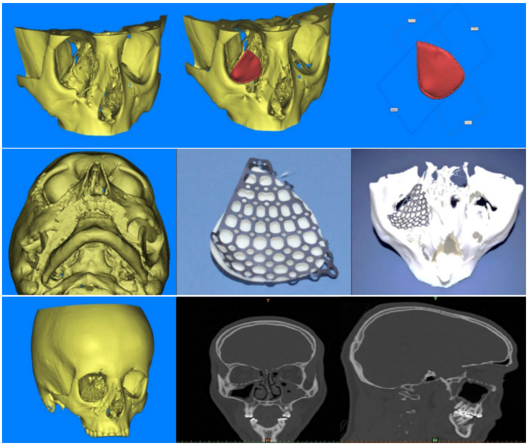

Fig. 1. Virtual planning algorithms. Position of the titanium orbital plate in 2-dimensional and 3-dimensional mode

It should be noted that the obtained models showed a high degree of accuracy and at the same time corresponded to the anatomy of the

[17] *Рагимов, Ч.Р., Фарзалиев, И.М., Ахмедов, С.Г.* Применение метода виртуального биомоделирования для оптимизации хирургического лечения больных с травматическими повреждениями орбиты // – Київ: Сучасна стоматологія (научно-практический журнал), – 2018. № 1, – с. 70-74.

bones of the patient's facial skeleton. The main spectrum of application of MRP-models was the adaptation of orbital implants, in some cases simulated osteotomy was carried out. In this case, the adaptation of orbital implants was approximately observed in 4 cases; For this purpose, additional models of the opposite side were used in 7 cases.

In addition, the material used in the production of plastic models allowed their preoperative sterilization by chemical sterilization with formalin. This, in turn, has allowed such plastic models to be used during direct surgery in order to provide intraoperative navigation and greatly facilitated the work of the surgeon. It is important to note that these 4 patients did not show any significant deviations from the anatomical norm in the postoperative period, but this method cannot be considered completely reliable without a model of the opposite side.

The virtual modelling (VM) method was used in 31 out of 42 patients in the study. In this case, using MRP technology, the main focus was on the use of computer biomodelling techniques. Thus, a method of virtual adaptation of orbital implants has been developed and applied in clinical practice, which has great advantages over traditional methods when using standard titanium orbital implants, as well as when using MRP. In this case, ie in virtual modelling, its advantages are obvious, and above all, it is the reduction of the time of operative intervention, as well as the possibility of inaccurate adaptation of the plates. In addition, without losing the quality of preoperative preparation (POP), the time required for POP is shortened, which is very important in the urgent reconstruction of trauma in surgery.

The virtual planning method is an integral part of the medical rapid prototyping method, and the only difference is that most of the virtual functions are sometimes not used during rapid prototyping. The combination of both methods leads to the accuracy of surgical manipulation and ease of planning. Thus, when using the method of virtual planning, it is possible not only to model the virtual reconstruction of the walls of the orbit and create a virtual model of the orbital implant, but also to print such an implant. When printing the model, it is possible to apply the model of titanium implant as an intraoperative template. This significantly shortens the time of surgery[18].

Within the framework of the research, a 3 precision-level working classification of posttraumatic defects and deformations of the midface (AOCMF) was developed. This system allows to determine the characteristics of the pathology with high accuracy and unify these features in the form of a classification code. This system has been proven to be highly effective and is likely to be applied in practice. Given that the software for the examination of defects and deformations is carried out in a virtual environment, detection and classification of defects and deformations was performed as a routine procedure at this stage[19,20].

The statistical analysis showed that the duration of operative intervention in the main group was 2.23 hours for the treatment of patients diagnosed with "fracture of the zygomatic bone", 1.98 hours in the treatment of patients diagnosed with "fractures of the walls of the orbit" and 3.07 hours in the treatment of patients diagnosed with "fractures of the walls of the orbit and other bones of the facial skeleton". In the control group, these indicators were 3.47; 2.05 and 3.31 hours, respectively.

Thus, it is clear that the application of MRP and VM methods objectively shortens the time spent on surgical reconstruction of not only limited fractures of the walls of the orbit, but also a combination (with damage to both adjacent and distant anatomical structures) of these lesions. This, in turn, indicates that this method is perfect.

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[18] *Рагимов, Ч.Р.* Реконструкция травматических повреждений нижней стенки орбиты с применением метода виртуального бимоделирования / Ч.Р.Рагимов, И.М.Фарзалиев, С.Г.Ахмедов [и др.] // – Баку: Oftalmologiya, – 2018. №1 (26), – s.121-127.

[19] *Rəhimov, Ç.R., Əhmədov, S.Q., Fərzəliyev, İ.M.* Üzün orta hissəsinin travmatik zədələnmələrinin təsnifatlaşdırılması məsələsinə aid. AOCMF-nin 3-cü səviyyə təsnifat sistemi // – Bakı: Azərbaycan Təbabətinin Müasir Nailiyyətləri, – 2018. № 1, – s.141-149.

[20] *Əhmədov S.Q.* Orbital kompleksin travmatik zədələnmələrinin təsnifatlaşdırılması məsələsinə aid. AOCMF-nin 3-cü səviyyə təsnifat sistemi // – Bakı: Azərbaycan Ortopediya və travmatologiya jurnalı, 2018. № 1, – s. 24-29.

Significant differences were also observed in bed-day rates in the main and control groups. It was found that, the average number of bed-days in the main group was 6.9 days in the treatment of patients diagnosed with “fracture of the zygomatic bone”, 7.5 days in the treatment of patients diagnosed with “fracture of the walls of the orbit” and 10.1 days in the treatment of patients diagnosed with "fractures of the zygomatic bones, orbital walls and other bones of the facial skeleton". In the control group, these indicators were 14.2; 8.7 and 16.5 days, respectively. This difference in bed-day indicators in the control and main groups was due to differences in the course of patients' postoperative rehabilitation and this can probably be explained by the use of VM and MRP methods - they, in turn, have led to greater expected outcomes and, consequently, a reduction in the number of postoperative complications that prolong the patient's stay in the hospital and require special treatment.

It should be noted that immediately after surgery, diplopia was reported 16 cases (38.1%) in the main group and 12 cases (34.3%) in the control group, which was assessed as similar. However, these figures changed 6 months after the intervention. The number of cases of residual diplopia in the main group was 4 (9,%) cases, while in the control group this figure was 12 cases (34.3%).

The similarity of diplopia immediately after surgery is due to postoperative edema and temporary paralysis of the muscles that move the eye, which is the expected effect of surgery (Fig. 2). However, 6 months after the surgical intervention, Differences in diplopia in the main and control groups indicate that the walls of the orbit and the restored shape of the orbit have more adequate values of the volume of the orbit in the main group than in the control group which is due to the application of more advanced pre-operational planning methods.

The presence of 4 cases of residual diplopia in the main group can be explained by irreversible changes in the muscles that move the eye and a violation of their innervation, which can be considered as a result of traumatic injury. In general, the main group noticed not only a decrease in operation time, but also a qualitative change in the modality of the interventions.

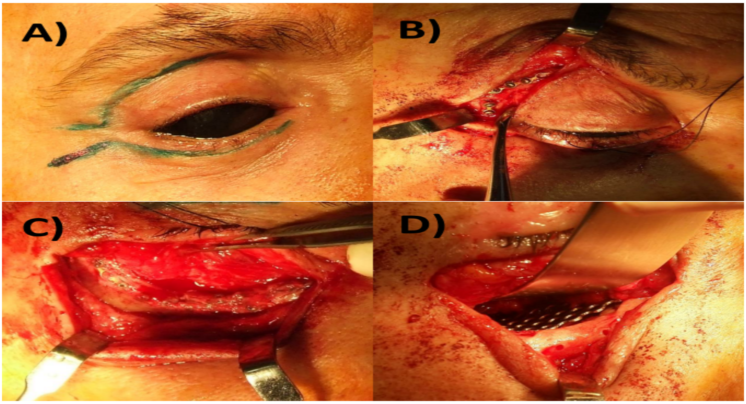

Fig. 2. The course of surgical intervention:
A) marking of dashed lines; B); visualization of the zygomaticofrontal suture; C) visualization of the lower edge of the orbit; D) installation and fixing of titanium plate.

Thus, the VM method, which is an integral part of MRP technology, can be used as an independent method in clinical practice. Also, the development and application of the method of virtual adaptation of the orbital implant makes this technology a more widely used independent method in clinical practice.

However, neither the MRP method nor the VM technology is able to solve the all spectra of problems facing the clinician in the treatment of fractures of the walls of the eye socket and the bones of the zygomatic-orbital complex and this makes the further improvement of the studied methodologies a topical issue.

Improvements to these methods are possible through the improvement of software packages, the creation of additional modules and the reduction of the number of technological stages of prototyping, and the interpretation of 3-dimensional modelling data. Given that the use of both technologies is mainly based on computed tomography data, this expands the scope of application of this method. The future development of 3-dimensional modelling based on MRP data will significantly expand the spectrum of application of this technology.

Clinical case. Patient A.M. He is 57 years old and was admitted to the clinic with a diagnosis of posttraumatic deformity of the right orbit. The main complaints of the patient were diplopia and limited movement of the right eyeball, as well as sinking of the right eyeball and deformation of the middle part of the face. According to the patient, this pathology is the result of trauma he got at home 2 months ago. The patient notes that to date no appropriate diagnostic and therapeutic measures have been taken. Visual examination revealed a significant enophthalmos in the patient and a slight restriction of movement, mainly in the upper and inner squares of the eyeball[21]. According to the patient, subjectively, diplopia was recorded in the upper quadrant (Fig. 3).

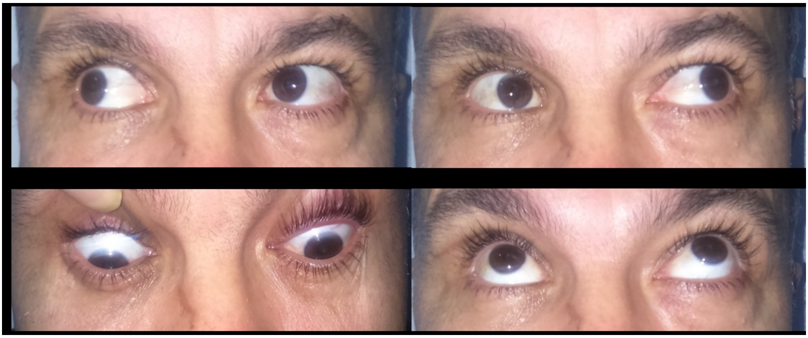

Fig. 3. Movement of the patient's eyes (Restriction is noticeable in the upper and side quadrants)

In addition, subjective signs of paraesthesia were noted in the lower area of the right eye socket and on the right side of the upper lip, on the right nasal alar (wing of nose), and on the right upper teeth.

Computed tomography examination revealed partial defect and deformation of the lower wall of the right orbit, dislocation of the

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[21] *Rahimov, Ch.R.* Significant clinical signs and three-dimensional diagnosis in orbital reconstructive surgery: a retrospective analysis and case presentation / Ch.R.Rahimov, S.G.Ahmedov, M.Ch.Rahimli [et al.] // Annals of Maxillofacial Surgery, – 2020. – p. 3-9.

right orbital components and the associated increase in the volume of the right orbit (Fig. 4).

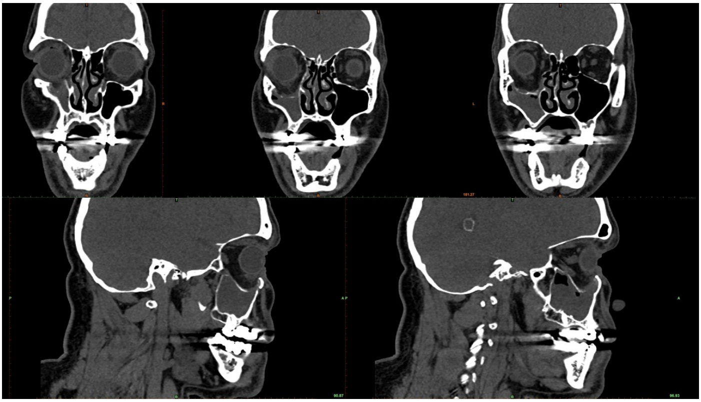

Fig. 4. CT examination of the patient: fracture of the lower wall of the right orbit, as well as displacement of the right zygomatic bone, accompanied by protrusion of the periorbital tissue and the defective side of the lower rectus muscle

It was decided to remove the soft tissue prolapse around the patient's right orbit and reconstruct the lower wall of the right orbit area with a mesh titanium plate. As part of pre-operational planning, the above-mentioned planning algorithm was used, which allowed the titanium orbital plate to bend and adapt preoperatively. The individual stages of planning are described below (Fig. 5).

It should be noted that the virtual template for the reconstruction of the obtained right orbit was evaluated in relation to the facial skeletal bones in both 3-dimensional and 2-dimensional modes (Fig. 6).

Thus, the previously obtained bent titanium orbital plate was used internally without additional adjustments. The orbital plate was sterilized the day before surgery[22].

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[22] *Əhmədov, S.Q.* Orbitanın aşağı divarının sınıqlarının rekonstruksiyası: kompyuter modelləşdirməsi və öncədən əyilmiş implantatların istifadəsi // – Bakı: Sağlamlıq, – 2018. № 1, – s. 161-167.

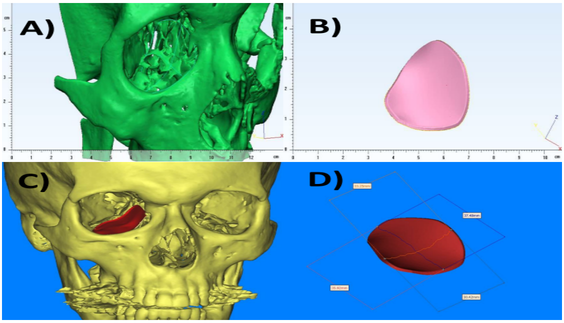

Fig. 5. Virtual planning algorithm:
A) obtaining perimeter lines and guide lines; B) creating a virtual template using these lines; C) 3-dimensional assessment of the condition of the virtual template relative to the bones of the facial skeleton; D) calculation of the longitudinal and transverse dimensions of the virtual template, taking into account the bending of the titanium plate.

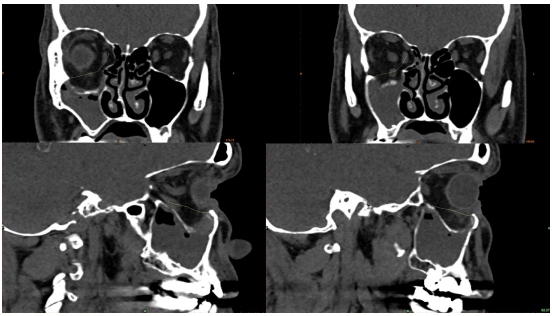

Fig. 6. 2-dimensional assessment of the condition of the virtual template relative to the bones of the facial skeleton

Surgical intervention was performed using a transconjunctival route under general anaesthesia with nasotracheal intubation. After dissection of the tissues around the right eye and visualization of the lower edge of the eye socket, dissection of soft tissues under the periosteum in the area of the lower wall of the orbit and evacuation of displaced tissues from the area of the defect in the lower wall of the orbit was carried out. At this stage, the vitality of the prolapsed soft tissues and especially the lower rectus was assessed. The titanium orbital plate was then applied to the defect area according to the reference points specified in the pre-operational planning and fixed with a titanium screw. In general, 2 screws were used according to the standard protocol for fixing the full titanium orbital plate.

The patient did not have any serious complications in the postoperative period. Primary healing was observed in the wounds. Immediately after surgical intervention, the patient showed signs of double vision in the background of postoperative edema, but the movements of the right eyeball were more physiological. No symptoms of enophthalmos and diplopia were observed clinically 1 month after the intervention. The movements of both eyeballs were physiological.

It should be noted that decompression of the right periorbital nerve was achieved as a result of the intervention, and especially due to the elimination of prolapse in the right orbit. This, in turn, led to a subjective decrease in paraesthesia in the postoperative period (Fig. 7).

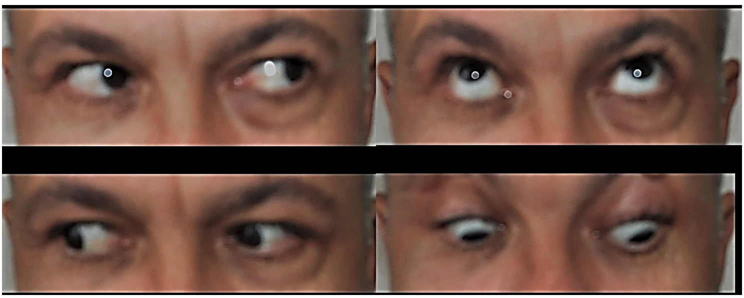

Fig. 7. Movements of the patient's eye
(Restriction is noted in the upper and side quadrants)

Postoperative CT examination showed that the placement of the titanium orbital plate in both 2-dimensional and 3-dimensional modes was adequate. Although no protrusion of the orbital components toward the right Hymor cavity was reported, local hypertrophy of the mucous membrane of the maxillary sinus was noted in the lower aspect of the titanium orbital implant. This was considered to be a scar after surgery and traumatic injury (Fig. 8, 9).

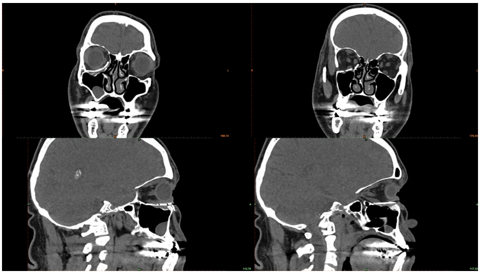

Fig. 8. The state of the titanium orbital plate in 2-dimensional mode

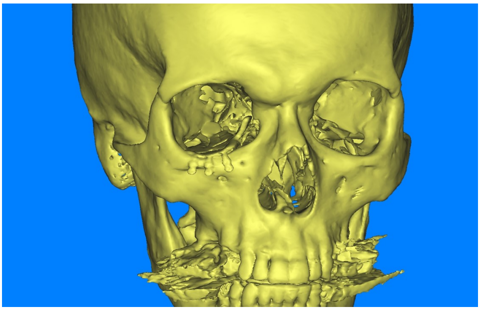

Fig. 9. Status of the titanium orbital plate in 3-dimensional mode

It should be noted that one of the main aspects of virtual planning in this clinical case was the assessment of the condition of the virtual titanium implant in relation to the bones of the facial skeleton, not only in 3D, but also in 2-dimensional mode. In this case, if during the study of the condition of the virtual implant in 3D, it is possible to assess its spatial position in relation to neighbouring structures, then during the examination in 2-dimensional mode, information is obtained about the restored volume of the orbit and, consequently, the adequacy of the reconstruction.

CONCLUSIONS

1. The use of three-dimensional technologies in the radiological diagnosis of fractures of facial skeleton is more advanced than traditional two-dimensional methods in the measurement of the pathological lesion and allows to choose a more effective reconstruction method for adequate repair of orbital complex damage [3].
2. Precise bending of standard orbital plates by means of virtual modeling carried out by three-dimensional technologies to eliminate the defect in the fractures of the orbital complex allows the preparation of individualized implants, which are considered more efficient. This reduces the cost of surgery by refusing to order expensive anatomic orbital implants [1, 4].
3. Preoperative bending of standard orbital plates reduces the operating time by an average of 30%. Thus, the time spent on surgery performed by the method of virtual modelling was an average of 2.23 hours in " the fractures of the zygomatic bone leading to deformation of the orbit", 1.98 hours in "fractures of the lower wall of the orbit" and 3.07 hours in "fractures of the zygomatic bones, orbital walls and other bones of the facial skeleton." In the traditional group of surgical interventions performed in the control group, these values were 3.03; 2.05 and 3.47 hours, respectively [7].
4. The developed pre-operative virtual planning and treatment algorithm also reduces the length of hospital stay of patients. Thus, in the main group, the average bed-day was 7.5 days in the "fractures of the zygomatic bone leading to deformation of the orbit"; 4.9 days in "the fractures of the lower wall of the orbit"; 10.1 days in the “fractures of the zygomatic bone, orbital walls and other bones of the facial skeleton". In the control group, these indicators were 14.2; 8.7 and 16.5 days, respectively [7, 8].
5. The duration of recovery of symptoms of binocular diplopia, one of the main clinical indicators of fractures of the orbital complex, depended on the time of treatment of patients. In the same cases at the time of application, diplopia remained immediately

after surgery in 16 patients (38.1%) in the main group and 12 patients (34.3%) in the control group. There is no statistical difference. However, after 6 months, a clear difference was observed in these groups, and diplopia was found in only 4 patients (9.5%) in the main group and 12 patients (34.3%) in the control group [7].

6. The developed preoperative planning and diagnostic algorithm allows for a comprehensive assessment of existing pathology and adequate reconstruction of orbital fractures to minimize the stages of reconstruction, which meets the basic requirements of reconstructive operations [8].

PRACTICAL RECOMMENDATIONS

1. The application of a classification system based on 3-dimensional examination methods in the diagnosis of fractures of the orbital complex allows a comprehensive assessment of the pathological focus.
2. In the treatment of fractures of the orbital complex, the preparation and proper placement of individual implants from standard orbital plates allows to achieve higher aesthetic and functional performance, and this method can be included in effective treatment protocols.
3. The application of virtual modelling methods in the treatment of fractures of the orbital complex allows to reduce the operating time to some extent, improve the results of surgical reconstruction, as well as reduce operating costs.
4. Virtual modelling of surgery performed with three-dimensional technologies can be included in the treatment algorithm as it is confirmed by high aesthetic and functional indicators in the treatment of orbital fractures.

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