ORIGINAL ARTICLE

APPLIANCE OF CAD / CAM MODELING IN PROSTHETICS OF BONE DEFECTS OF FACIAL BONES

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Serhii M. Grigorov, Anton K. Khudyk, Iryna S. Sukhina
KHARKIV NATIONAL MEDICAL UNIVERSITY, KHARKIV, UKRAINE

ABSTRACT

The aim: Improving the ability to restore the shape and function of the bones of the maxillofacial area through the use of their own techniques.

Materials and methods: Materials and methods: This research was carry out on the basis of the Department of Surgical Dentistry and Maxillofacial Surgery of Kharkov National Medical University in the Department of Head and Neck Surgery, Kharkov "Regional Clinical Hospital" (2018-2020 years). Examination and treatment of 26 patients, aged from 19 to 55 years, who needed reconstructive surgery to restore the anatomical shape, integrity and function of the maxilla or mandibular jaw.

Results: All patients were treated according to the developed method (utility model patent № 145754 "Method of treating traumatic fractures of the maxillofacial area in adults using bone osteosynthesis 3D modeled titanium mini plates"), which consists in 3D modeling, based on previously performed computed tomography, and exploitation individually modeled titanium mini grids and titanium endoprostheses. The experience of this technique shown the advantage of the proposed method not only in the correction of traumatic defects, but also defects of the jaw bones that occur due to the removal of bulky neoplasms.

Conclusions: Individual 3D simulated mini grids / plates and endoprostheses, according to the study provide maximum adaptation and restoration of anatomical shape, relief of jaws, their integrity and contour, provide prevention of pathological fractures by stabilizing residual bone tissue (titanium mini grids) serves as a carcass , provide prevention of prolapse (germination) of soft tissues in the area of postoperative bone defect (mini grid does not allow soft tissues to germinate in the area of postoperative bone defect on the outside), which improves functional and cosmetic results. Thus, our proposed method of osteosynthesis using 3D simulated titanium miniplates can be recommended for use in clinical practice.

KEY WORDS: jaw defects and deformations, osteosynthesis, CAD / CAM modeling, titanium mini-plate

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INTRODUCTION

Traumatic fractures of the facial skull bones, tumors and cysts of the jaws, according to many authors, occupy a significant place among the pathologies that cause the development of defects and deformations of the facial skull bones [1, 2]. With the development of medicine and dentistry, the emergence of new materials and technologies in the arsenal of the doctor it became possible to develop a large number of different surgical methods to eliminate and stabilize bone defects, the vast majority of which involve the use of auto- and allografts [3]. Starting with historically known methods of treatment of fractures of the jaws such as: bone suture, osteosynthesis with a Kirchner needle, today is used and osteosynthesis from bone structures in the form of mini plates and screws, mainly titanium [4, 5].

However, despite the above, the problem of developing long-term postoperative complications, such as chronic inflammatory processes of soft tissues in the center of trauma, pathological fractures, visible facial deformities and functional disorders remains relevant [6].

According to the authors, bone osteosynthesis using mini plates can reduce the duration of immobilization of the jaws, which in turn restores the function of chewing at an early stage [7, 8] and shortens the rehabilitation of patients.

However, due to the complex anatomical structure of the bones of the facial skull, the presence and displacement of fragments, especially in multifragment injuries, the disadvantage of this method is the inability to achieve an exact complete fit of the plates in the fracture area.

Another disadvantage of this method is the possibility of trauma to the cortical layer of the fixing elements due to the uneven distribution of the load in the incomplete fit of the mini plates, especially in the presence of osteoporosis of the bones.

Also, the method of osteosynthesis of mandibular fractures using a bone plate of a new design with transverse petals is widely used, which provides increased spatial rigidity of fixation of jaw fragments, which is mathematically justified [9, 10].

Many authors suggest the use of CAD / CAM computer modeling, and the creation of a fracture model that is modern and optimal in terms of minimizing surgery and further rehabilitation of the patient.

Thus, taking into account the clinical and radiological features and the variety of defects in bone structures, and

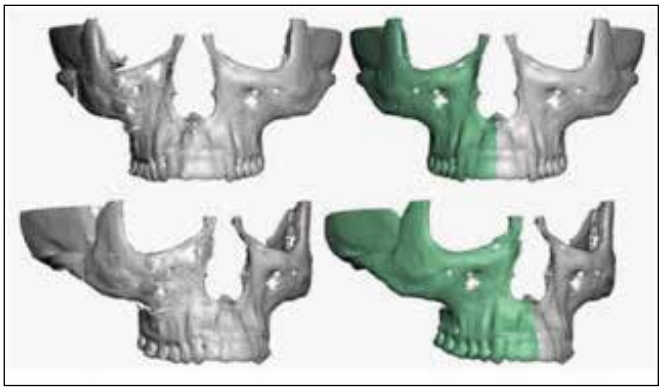

Fig. 1. Example of virtual reposition and comparison of fragments in the fracture zone (fracture of the zygomaticoorbital complex on the right side).

Fig. 3. Individually made 3D mini grid.

the likelihood of postoperative complications, is relevant to further develop methods and techniques of osteosynthesis, taking into account the rational planning of stages of treatment and rehabilitation of patients.

THE AIM

Improving the ability to restore the shape and function of the bones of the maxillofacial area through the use of their own techniques.

MATERIALS AND METHODS

This research was carry out on the basis of the Department of Surgical Dentistry and Maxillofacial Surgery of Kharkov National Medical University in the Department of Head and Neck Surgery, Kharkov "Regional Clinical Hospital"

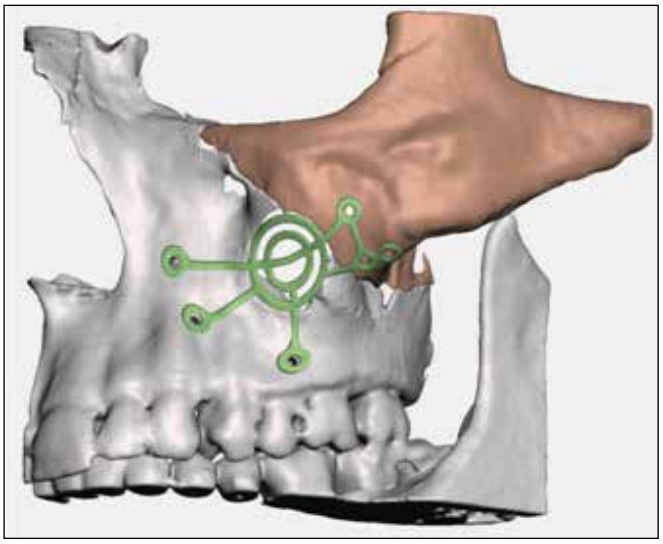

Fig. 2. Example of modeling individual 3-D simulated mini grid / plate with overlapping bone defect of the anterior wall of the maxillary sinus, taking into account the anatomical features of the bone, its shape, relief and fracture location, after a previous virtual reposition and comparison of fragments in the fracture zone.

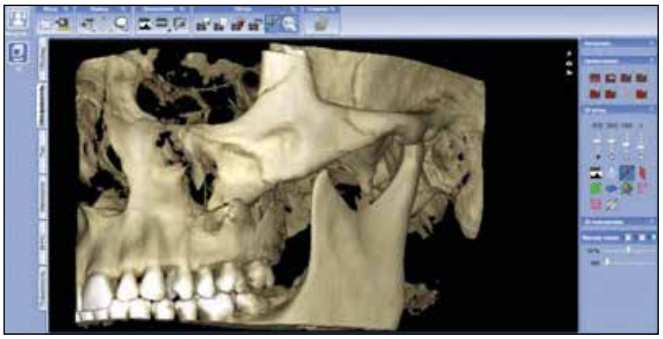

Fig. 4. CPCT patient P., 24 years old, medical history № 4..5789 with a fracture of the left zygomaticoorbital complex.

Fig. 5. Prosthetics of the anterior wall defect of the left maxillary sinus of patient P., 24 years old, medical history № 4..5789, intraoperative photo.

for the period from January 1, 2018 to December 31, 2020. Examination and treatment of 22 patients, aged from 19 to 55 years, who needed reconstructive surgery to restore the anatomical shape, integrity and function of the maxilla

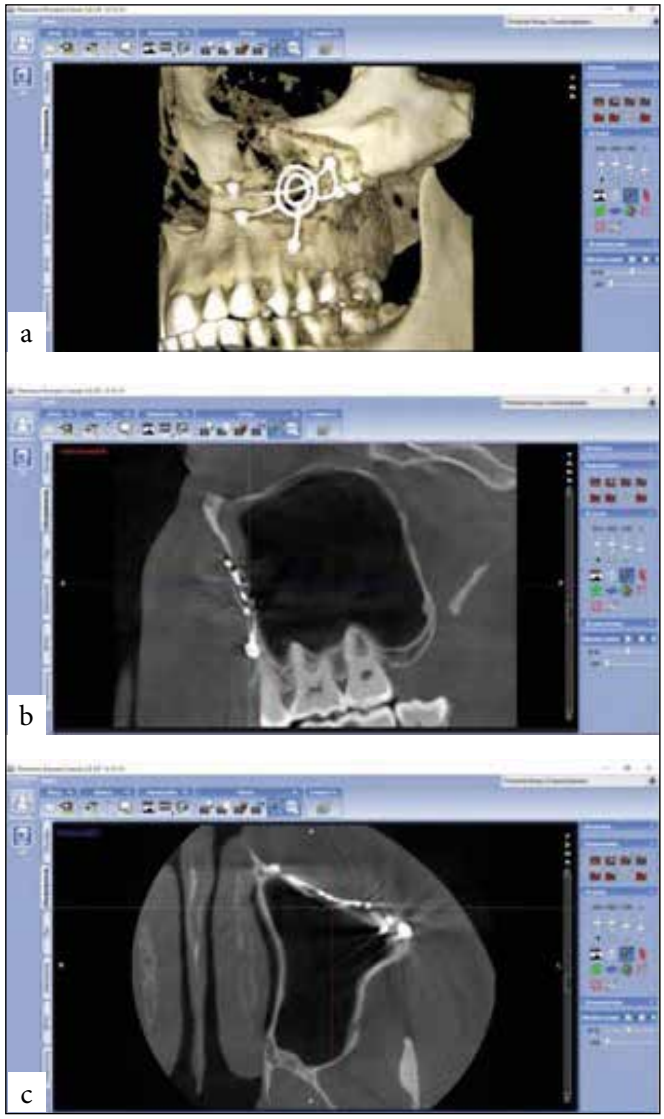

Fig. 6 (a,b,c). Control CT patient P., 24 years old, medical history № 4..5789: 6a – 3D reconstruction; 6b – transversal projection; 6c – axial projection.

or mandibular jaw. Of these, with traumatic injuries of the bones of the facial skeleton with the appearance of bone defects (with fractures of the maxilla jaw - 15 patients; mandibular jaw - 3 patients); with cysts of the jaws of large size, after the removal of which there were significant appreciable anatomical defects of bone tissue or with a high probability of pathological fracture due to the small thickness of the residual bone tissue (5 patients); with neoplasms of the lower jaw that required resection (ameloblastoma - 1 patient, osteoblastoclastoma - 2 patients).

All patients were treated according to the developed method (utility model patent № 145754 "Method of treating traumatic fractures of the maxillofacial area in adults using bone osteosynthesis 3D modeled titanium miniplates"), which consists in 3D modeling, based on previously performed computed tomography, and exploitation individually modeled titanium mini grids, as well as individually modeled titanium endoprostheses.

At hospitalization, all patients underwent screening, which included: a general clinical blood test, a general clinical urine test, a biochemical blood test, an electrocardiogram (ECG), and cone-beam computed tomography (CT).

RESULTS

In order to determine the nature of injuries, the type of fracture (multi fragment, small fragment, linear), the size and direction of displacement of bone fragments, cone-beam computed tomography (CT) was assigned to all patients to select and justify the optimal method of surgery intervention.

With the help of CT, we obtained comprehensive data on the location of fractures and their characteristics, as well as data on the location, spread, volume of benign bone tumors.

After receiving the digital data, STL-files were imported, followed by computer processing and creation of a 3D-model of the pathologically altered area - in the case of a jaw fracture - virtual repositioning and comparison of fragments in the fracture area was performed (fig.1).

Taking into account the type of fracture, its nature (fragmentary, linear and others), localization (upper jaw, lower jaw), anatomical features of the damaged bone surface, its individual relief, the next step was to model individual 3D mini grids and endoprostheses (fig.2).

Next, individual 3D mini-grids or endoprostheses were printed on a SLM 280 HL 3D according to the method SLM (Selective Laser Melting) from titanium powder.

The technique of 3D-modeling using CAD and mathematical modeling (CAD / CAM-systems) gave us the opportunity to make mini grids and endoprostheses of any shape and size for individualization of treatment (fig.3).

In the case of tumors and tumor-like lesions of the jaws, a similar modeling of 3-D mini grids was performed, except that it was not necessary to carry out the stage of virtual reposition and comparison of fragments in the fracture area.

After making individual 3D mini grids, they were sterilized. Intraoperatively, after open repositioning of fragments or removal of a benign neoplasm, immobilization / prosthetics of defects was performed according to a virtually developed model. The 3D mini grid was fixed with microscrews.

Upon contact with the bone-mucous flap, the mini grid was covered with collagen membranes of appropriate size. Then the wound was sutured with latex drainage according to the indications.

In the postoperative period, in order to prevent purulent-inflammatory complications, all patients were prescribed antibacterial therapy.

As an illustration, we give the following clinical examples:

Clinical case № 1: Patient P., 24 years old, medical history № 4..5789 was hospitalized with a diagnosis of traumatic fracture of the left zygomaticoorbital complex with displacement of fragments. The diagnosis was confirmed clinically and radiologically (CT) (fig.4).

The presence of displacement of fragments and bone defect of the anterior wall of the left maxillary sinus (due to a small fragmentary fracture), reaching 4 cm, the probability of prolapse of the soft tissues of the infraorbital, buccal

Fig. 7. Orthopantomogram of patient L., 42 years old, medical history № 4..2539 with a radicular cyst in the frontal part of the mandible.

Fig. 8. Prosthetics of a bone defect with a 3D-modeled titanium mini grid of patient L., 42 years old, medical history № 4..2539.

Fig. 9. Control orthopantomogram of patient L., 42 years old, medical history № 4..2539. In the long-term follow-up of the patient for two years after surgery, no complications were identified.

areas in the left maxillary sinus. Given the need to restore the anatomical integrity of the wall of the left maxillary sinus, bone defect prosthetics were performed with an individual 3D-simulated mini grid after repositioning of displaced fragments and removal of fragments not suitable for repositioning (fig.5).

The course of the postoperative period is uncomplicated. Anesthesia on demand was performed on the first day after surgery. Soft tissue edema. Sutures were removed on the 11th day. When performing control CT on the third day after surgery, satisfactory standing of bone fragments was determined, posttraumatic defect of the anterior wall of the left maxillary sinus was blocked by titanium mini grid, restoration of anatomical shape and size of the damaged area (anterior wall of the left maxillary sinus) zygomaticoorbital complex (fig.6).

In the long-term follow-up of the patient during the year after surgery, no complications were observed.

Clinical case № 2: Patient L., 42 years old, medical history № 4..2539, was hospitalized with a diagnosis radicular cyst in the frontal part of the mandible, the diagnosis was confirmed clinically and morphologically. At hospitalization, the patient provided an orthopantomogram (fig.7).

Indications for bone defect prosthetics with an individually modeled 3D mini grid were the presence of a defect of up to 7 cm and a high risk of distant complications in the form of facial soft tissue deformity and pathological fracture.

After the cystectomy, the bone defect was prosthetized with a 3D-simulated titanium mini grid (fig.8).

The course of the postoperative period was without complications. Sutures were removed on the 10th day. When performing a control orthopantomogram on the second day after surgery, a satisfactory closure of the bone defect was determined (fig.9).

Example № 3: Patient U., 23 years old, case history № 4..5913, who was hospitalized with a diagnosis of osteoblastoclastoma of the mandible in the body, corner and branch on the left. The diagnosis was confirmed clinically, radiologically and morphologically (fig.10).

After examination of the patient, according to the clinical protocol, was performed resection of half of the mandible from the left in area of the tumor with a single endoprosthesis of the resulting bone defect with an individual 3D-simulated endoprosthesis (fig.11).

The postoperative period of the patient passed without complications. The sutures were removed on the 10th day.

On the control orthopantomogram of the patient on the 3rd day after operation satisfactory fixation of an endoprosthesis is noted, the anatomic form of a mandible in a site of postoperative defect is restored (fig.12).

Observation of the patient for two years after surgery revealed no complications, the cosmetic result is satisfactory (fig.13).

DISCUSSION

The experience of using individual 3D modeled mini plates and grids has shown the advantage of the proposed method not only in the correction of traumatic defects, but also defects of the jaw bones that occur due to the removal of bulky tumors.

Individual 3D simulated mini grids / plates and endoprostheses, according to the study provide maximum adaptation and restoration of anatomical shape, relief of jaws, their integrity and contour, provide prevention of

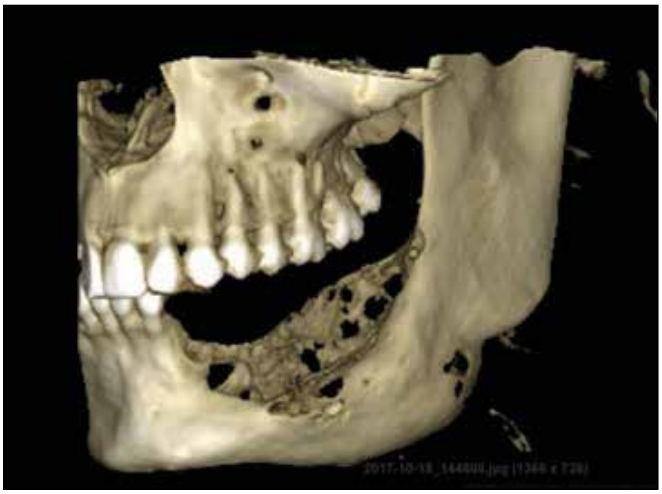

Fig. 10. CPKT of patient U., 23 years old, medical history № 4..5913 in 3D reconstruction of the patient.

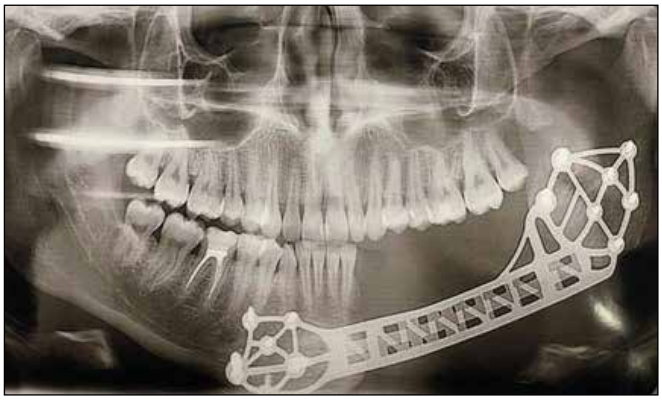

Fig. 12. Control orthopantomogram of patient U., 23 years old, medical history № 4..5913.

pathological fractures by stabilizing residual bone tissue (titanium mini grid) serves as a carcass , provide prevention of prolapse (germination) of soft tissues in the area of postoperative bone defect (mini grid does not allow soft tissues to germinate in the area of postoperative bone defect on the outside), which improves functional and cosmetic results.

Also, the advantage of using individual 3D simulated titanium mini grids is the reduction of the operation duration. No time is spent on their fitting, unlike standard mini plates and grids.

Patients in the postoperative period had less pronounced soft tissue edema and less severe pain, in contrast to patients who used standard mini plates and grids, which reduced the terms of stay in the hospital.

CONCLUSIONS

Our research and treatment of patients with traumatic injuries, cysts and tumors of the jaws show that due to the fact that the individual 3D - simulated mini grid or plate clearly repeats the anatomical contours of the damaged jaw, there is no need to fit it intraoperatively. Due to this, we

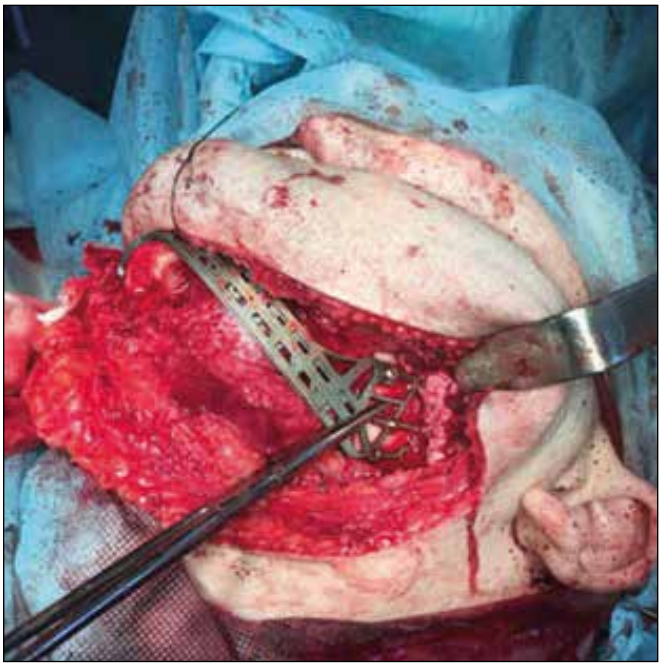

Fig. 11. Stages of mandibular endoprosthesis of patient U., 23 years old, medical history № 4..5913.

Fig. 13. Photo of patient U., 23 years old, medical history № 4..5913 two years after surgery.

have reduced the time of surgery, and minimized trauma to the surrounding tissues.

Also, an individual 3D-simulated mini grid or plate provides better precision to the bone in contrast to standard mini plates or grids and in turn reduces the rehabilitation period of the patient.

Thus, our proposed method of osteosynthesis using 3D simulated titanium mini plates can be recommended for use in clinical practice.

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ORCID and contributionship:
Serhii M. Grigorov: 0000-0001-9527-8408 [E]
Anton K. Khudyk: 0000-0002-9015-2301 [A, B, D, F]
Iryna S. Sukhina: 0000-0003-0572-9047 [C]

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CORRESPONDING AUTHOR
Anton K. Khudyk
Kharkiv National Medical University
4 Nauki Avenue, 61000 Kharkiv, Ukraine
tel:+380507344347
e-mail: vodoo999@gmail.com

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