PLANNING TECHNIQUE IN MAXILLOFACIAL PLASTY

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We have represented a new method of computer planning in surgical management of posttraumatic and congenital deformities of facial skeleton using individual tetrapolyfluoroethylene implants for contour plasty. There have been developed the technique of preoperative planning enabling to recover the symmetry of a deformed area using a computer 3D-model, and based on the obtained data — to produce individual implants for contour plasty.

There have been received positive results of the technique in clinical use in patients with posttraumatic and congenital facial deformities. Computer planning promotes accurate planning and reliable prognosis of the management results due to an individual implant used for contour facial plasty, which requires correction.

Conclusion. Computer planning and CAD/CAM-production of an individual implant enables to correct deformities and recover facial symmetry and esthetics in patients with posttraumatic and congenital distortions of face.

Key words: contour plastic surgery; maxillofacial operations; digital plastic art in maxillofacial area.

Indications to contour plasty in congenital and acquired deformities of the face are asymmetric bone development of one of the halves of the cranium (e.g. zygomatic bone, mandibular ramus and/or body without malocclusion), incorrectly consolidated fractures of the zygomatic-orbital complex. These operations may also be performed due to esthetic indications in order to change facial contours. Traditionally, autogenous bone grafts or standard silicone implants are used for such interventions. Disadvantages of such autografts are connected with the necessity of additional operations for transplant obtaining, their labor consuming processing to create a congruent surface with the recipient bed, inaccuracy in forming a graft "by eye". Silicone implants are usually made in standard forms and not always allow surgeons to restore the broken symmetry of the face.

Methods of computed tomography: multispiral computed tomography (MSCT) and cone-beam computed tomography (CBCT) play the main role in planning operations of contour plasty. Tomographs, used for investigations, have their own special software for planning and controlling of treatment. Scanning gives a series of sections of the examining area in the form of DICOM-files (Digital Imaging and Communications in Medicine — a medical standard for creating, storing, transferring and visualizing medical images and documents of examined patients), which are transformed in 3D-images of the facial skull. Analysis of the tree-dimensional image obtained enables the surgeon to estimate the amount of deformity, its exact localization and dimensions. Besides, the software of some tomographs makes it possible to perform virtual planning of the operation using function of mirror reflection (a healthy part on the deformed one), segmentation of separate areas of the skeleton and their movement. Visualization of this kind helps the surgeon in making a plan of surgical intervention: evaluation of graft dimensions, definition of the access to the deformed area [1, 2].

A great number of free of charge and commercial programs is available for the analysis of DICOM-images (AMIDE, Synedra View, UniPACS DICOM viewer, Mango, XmedCon, DICOM Viewer, OsiriX, openDICOM.NET, K-PACS, Aesculap-DICOM, a program package 3Dview (Russia), specialized programs for planning surgical interventions on cranium bones: Mimics (Materialise), iPlan 3.0 (Brainlab®, Feldkirchen, Germany), 3D Doctor, Amira, Analise, BioBuild, SliceOmatic (TomoVision, Canada), InVesalius (Brazil). Virtual planning in such programs is based on the broad, but insufficient, to our opinion, set of

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standard functions. Besides, this diagnostic method does not offer the opportunity to transfer accurately the virtual plan to the operative field, which is probably its main drawback. Some specialized programs for maxillofacial surgery give the possibility to make intraoperative models for correct positioning of the bone autografts [3].

The development of computerized and CAD/CAM techniques (Computer-aided design — an automated system using an information technique for making designs; Computer-aided manufacturing — preparation of technological process of item production using computers) made it possible to obtain accurate 3D models of the skeleton from different plastic and biocompatible materials [4–9]. Such methods as laser stereolitography, modeling by building-up technique, or jet printing are the most suitable for making models of the skull. The main idea behind these methods lies in placing material layer by layer using computer 3D-model. Computer virtual planning and CAD/CAM methods of manufacturing from biocompatible materials are actively implemented into clinical practice. This is due to their relative simplicity in use, availability and, what is the most important, wide opportunities in diagnosing and planning. This opinion is supported by the absolute majority of maxillofacial surgeons and stomatologists. According to the work [10], 99.8% of these specialists links the future of maxillofacial surgery with the development and application of nuclear magnetic resonance imaging, computed tomography (CT) and more intensive use of the latest optical, physical, mechanical, physiological, radiological and other methods of diagnosing pathologies in the maxillofacial area. The main advantage of this kind of manufacturing is the ability to create tiny details, voids and complicated geometry [4]. Skull models, manufactured in such a way, are used for more detailed planning in comparison with the above-mentioned virtual 3D-diagnosis [1, 11]. On the three-dimensional model an implant for contour plasty can be modeled from plastic hardening materials (acrylic clay or plasticine), and a surgical access, pathway of its introduction and site of fixation can also be determined. Once a prototype is made, it should be digitized (3D-scanning) and on the basis of computer 3D-model obtained an implant from biocompatible materials (ceramics, polytetrafluoroethylene, titan) be manufactured. At present, planning of contour plasty using individual grafts from biocompatible xenogenic materials is carried on in five stages:

1. Computed tomography of the head, building computer 3D-model of the skull on the basis of the data obtained.
2. Making a cranium model using CAD/CAM techniques.
3. Modeling of individual graft from plastic materials on the cranium model.
4. 3D-scanning of the graft model.
5. Manufacturing of the graft model from the biocompatible materials.

A new optimized technique of planning plastic operations, which consists only of three stages, is offered by us:

1. Computed tomography of the head, building computer 3D-model of the skull on the basis of the data obtained.
2. Computed modeling of the operation, creation of 3D-model of the individual graft.
3. Manufacturing of the graft model from the biocompatible materials.

This method excludes such labor-consuming and expensive stages as making stereolithographic model of the skull, graft prototype and its scanning.

The new method was successfully approved by treating surgically three patients by contour plasty: a female with a congenital pathology (underdevelopment of the mandible body on the right) and two patients with post-traumatic deformities of the zygomatic-orbital complex. Patients did not have any concurrent somatic pathology, which is a contraindication to the planned surgical treatment.

The main idea of the method is as follows. At the first stage MSCT using tomography Toshiba, Aquilon 32 Tochibaco, Japan, (spiral scanning, layer thickness 0.5 mm, 2.0±0.9 mZv is performed. The data obtained in the form of DICOM-file series are converted into 3D-model of the skull using InVesalius 3.0 software in.obj. format. This format is compatible with the programs for 3D-modeling (Autodesk 3D Studio Max, Autodesk Maya and others). These programs possess extended capabilities of three-dimensional modeling and sculpturing. Then, using standard software a mirror image of the healthy side is reflected on the damaged area, the deformity volume is filled with the volume of the graft, and subtracting the less volume (deformed area) from the larger volume (a mirror copy of the healthy side) a graft prototype is obtained. Next, adaptation of the graft model sites of conformity to the deformity area is performed, and, if necessary, modification of its form and conformity (virtual sculpture) is made. Once 3D-modeling of the graft is completed, its model is stored in stl-format, required for CAD/CAM-manufacturing, and the file is sent for making the graft itself.

Implants made of polytetrafluoroethylene were used in all patients. Operative interventions were performed under endotracheal anesthesia. Grafts were fixed to the underlying structures by titanic mini-screws. Post-operative period was uneventful, all grafts integrated well with the tissues, suppurations and rejections of the grafts were not observed. Sutures were removed on the 7th day. In 2 weeks control CBCT was done to check the conformity of the graft and to assess the symmetry.

A clinical example of the method described is given below.

Patient E., 35 years old. Diagnosis: posttraumatic deformation of zygomatic-orbital complex. Vision and mastication function are not damaged. On the basis of clinical and radiological examination contour plasty with the application of the individually manufactured graft from polytetrafluoroethylene was planned. The stages of planning graft production are shown in figures 1–7.

The cranium has a complicated structure from the point of view of anatomy and geometry. Injuries and deformities make its three-dimensional structure still more comprehensive. Therefore, planning of the operations to eliminate defects and deformities in the maxillofacial region is a very difficult task. In our work we applied software tools for 3D-modeling, which are used in making animated or

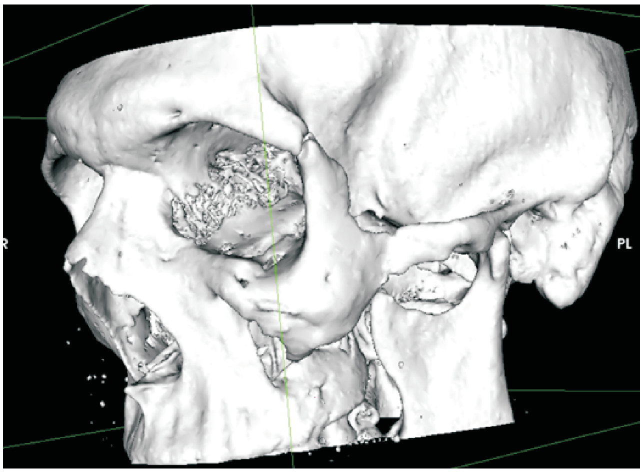

Fig. 1. 3D reconstruction of computed tomography data

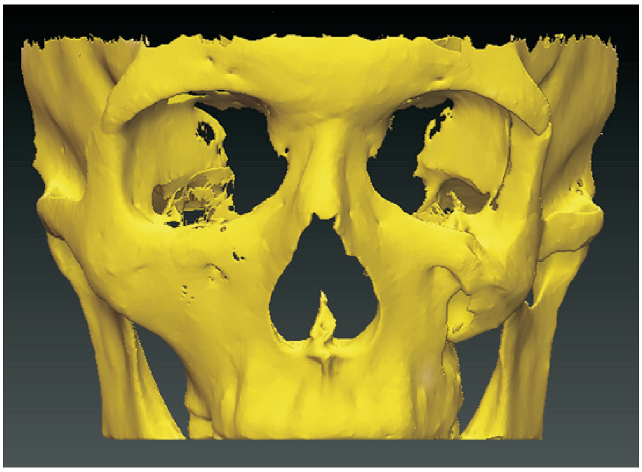

Fig. 2. 3D-model of the skull, prepared for planning and modeling of the graft

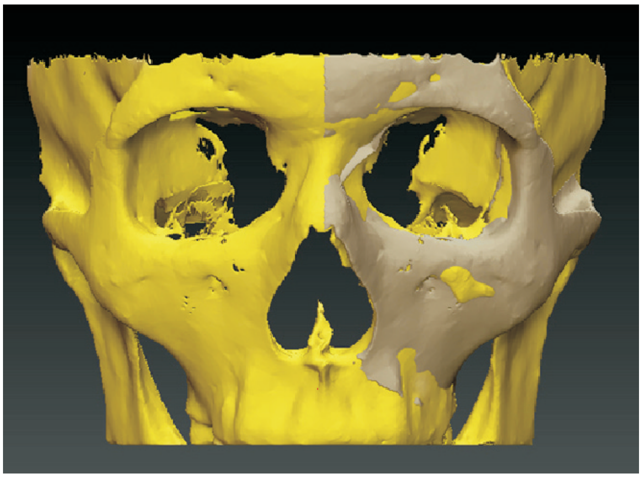

Fig. 3. Virtual planning stage. Segmentation (selection) of sygomatic-orbital complex on the right is performed and its mirror reflection is transferred to the left side on the deformity area

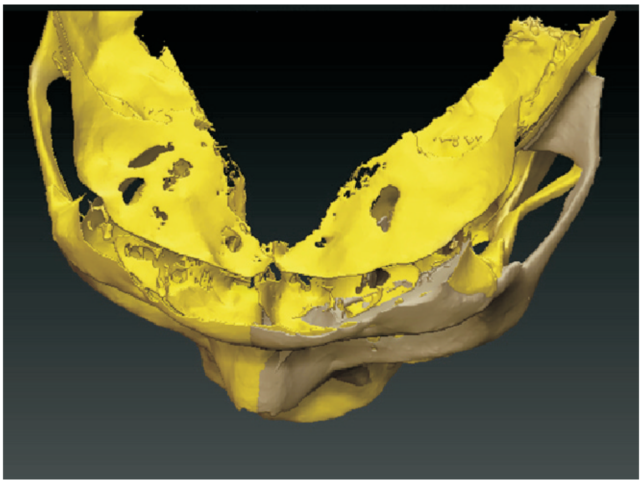

Fig. 4. Top view. A free space is seen between the deformed zygomatic arch (yellow color) and mirror-reflected left zygomatic arch

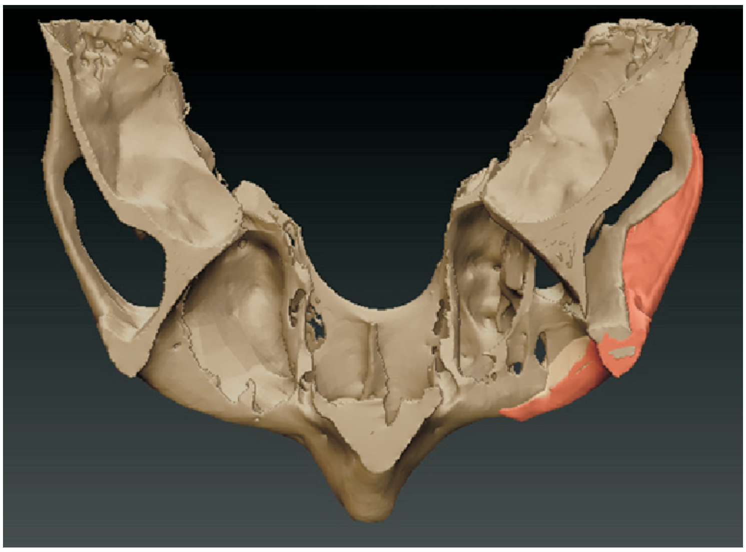

Fig. 5. Top view. Using 3D-modeling tools borders of the graft model are formed and the defect area is filled (shown by the arrow)

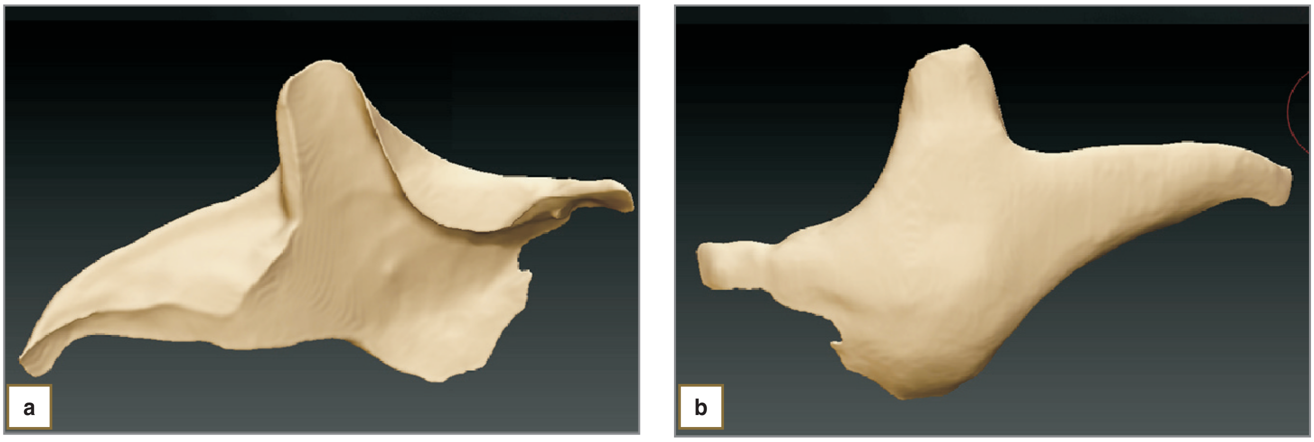

Fig. 6. Graft model: *a* — inner surface matching exactly to the outer surface of the deformed zygomatic bone; *b* — outer surface matching accurately to the contours of the contralateral healthy side

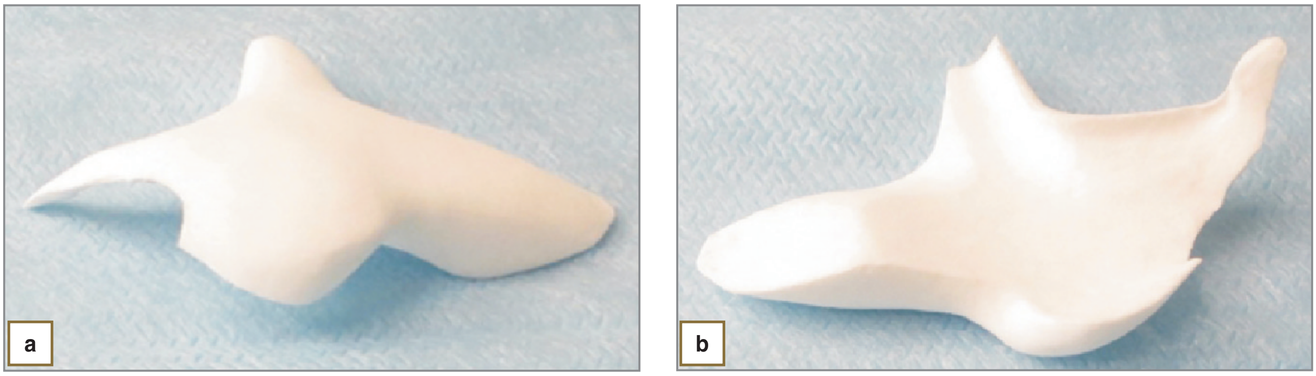

Fig. 7. Individually manufactured graft from polytetrafluoroethylene; *a* — outer surface; *b* — inner surface

feature films. It enables one together with simple functions of segmentation, mirror reflection, Boolean union and subtraction of 3D bodies to create virtual sculpture (digital sculpture). This operation allows to draw in a 3D-space and to reconstruct accurately complicated anatomical cranium structures preserving the sizes of the original.

On the basis of the operations performed we obtained a virtual 3D-model of the graft first, and then made an individual implant, completely congruent with the recipient bed and reconstructing the contours of the face.

Implants from polytetrafluoroethylene, used by us, are convenient in application. They are inert in the tissues, porous, which improves their integration, are hard enough to maintain their form, and at the same time rather plastic, which is important for their passing through the soft tissues when installing and fixing them.

Due to some technological issues we recommend to perform MSCT rather than CBCT to create 3D-models of the skull. MSCT data are more readily processed by the software, are cleared from “noises”, which results in a more accurate 3D-model of the skull. The 3D-image of the skull, graft and soft tissues become more contrast. To control the treatment it is better to use CBCT, which in contrast to MSCT, is radiologically less dangerous for the patient.

Conclusion. Application of computed planning and CAD/CAM manufacturing of individual graft from polytetrafluoroethylene enables surgeons to remove deformities and accurately reconstruct the symmetry and esthetics of the face in patients with posttraumatic and congenital pathologies. The method suggested reduces the time of planning contour plasty operations, increases the accuracy, decreases duration of intervention and its extent, gives the predicted result.

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