Individual titanium zygomatic implant

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Abstract. Custom individual implants for the reconstruction of craniofacial defects have gained importance due to better qualitative characteristics over their generic counterparts – plates, which should be bent according to patient needs. The Additive Manufacturing of individual implants allows reducing cost and improving quality of implants. In this paper, the authors describe design of zygomatic implant models based on computed tomography (CT) data. The fabrication of the implants will be carried out with 3D printing by selective laser melting machine SLM 280HL.

1. Introduction
The treatment of skull bony defects in the cranial and facial regions is a common clinical problem. The main aims of skull reconstruction are the protection of soft internal structures as the brain, functional rehabilitation of the masticatory apparatus and aesthetic improvement of a craniofacial appearance following trauma or tumour resection.

The tools used for the reconstruction of defects mentioned above can be divided in view of their handling properties. Some tools, such as titanium plates, have to be modified intraoperatively or, before/during surgery using an individual life-size model. Whereas the other way is to design and manufacture prefabricated patient-specific implants (PSI), made of titanium or polyaryletherketones. Generic implants, such as titanium plates, casts and screws are cheaper to design and faster, easier to manufacture than PSI [1-3]. Today additive technologies are becoming more common, which leads to cheaper production and design costs, which in the near future can lead to a slight difference in value from generic implants implementation [4].

The work aims to describe technology and software instruments, which can be used to design implant models based on CT scan data.

2. Software and methods
Accurate automatic recognition of bones/soft structures threshold is still the subject of scientific research [5]. At the same time, there are many software tools that allow extracting STL surface from CT scan data in an automated semi-manual mode.

At the initial stage of this work, the authors searched the existing software tools, which allow extracting STL-surfaces from CT data. Priority was given to free or open source software with user-friendly convenient interface.
The most suitable and convenient software tools that the authors have found are: InVesalius 3 [6] and 3DSlicer [7]. InVesalius is a free medical software used to generate virtual reconstructions of structures in the human body. 3D Slicer is an open source software platform for medical image informatics, image processing, and three-dimensional visualization. 3D Slicer supports the use of additional plug-ins.

In case if resulting STL-surface needs to be edited, let us recommend using free STL editor Autodesk Meshmixer [8].

This work is part of a larger project, during which the authors plan to use the Statismo library [9] to restore missing parts of bones, or to determine a more appropriate form of existing bones. Fortunately, in this work, the authors had the opportunity to restore the shape of the bone on the basis of the existing healthy symmetrical part.

In this study, the patient had a healthy right side of skull (Figure 1 – a), which was used to obtain the surface model (Figure 1-b) for implant model design (Figure 2).

![Skull STL-surface: a – initial surface, b – skull left side made by mirroring healthy right side.](image)

As can be seen in Figure 1 (a), the patient has a missing zygomatic bone segment. Therefore, the treating surgeon decided to design a suitable implant. Generic implants are not effective for this case, so it was decided to use 3D printed titanium patient-specific implant.
Figure 2. Implant model design - view from the inside and from the outside.

The planned location of the implant on the patient’s skull is shown in Figure 3. The first printed prototypes of the implant are shown in Figure 4.

Figure 3. Titanium implant location.

To facilitate the design and increase the elasticity, to simplify the attachment of the implant to the bone of the skull, to increase therapeutic effect of implant [10], the implant body contains holes.
Figure 4. Titanium implant prototypes.

- DICOM CT data to STL surface conversion (InVesalius or 3D Slicer)
  - STL cropping, modification (Autodesk Meshmixer)
  - Implant NURBS model design (Siemens NX)
  - Implant manufacturing by 3D printing (selective laser melting machine SLM 280HL)

Figure 5. Titanium implant design process block-scheme.

The most suitable tools proposed by the authors according to the design steps are shown in Figure 5.
3. Conclusion
After conducted studies, the authors found the most convenient software tools with which the authors were able to design a first implant prototype. In the future, they plan to add implant mass and strength optimization. As it was already described above, the authors plan to use Statismo to restore the correct shape of the skull or the correct shape of an individual bone of the skull. The authors tested the joint work of the selected instruments and successfully manufactured titanium prototypes of implants.

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