15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

RAPID MANUFACTURING OF MEDICINE IMPLANT

Dr.Sc. Senad Balić
University of Zenica
Faculty of Mechanical Engineering
Fakultetska 1, 72000 Zenica
Bosnia and Herzegovina

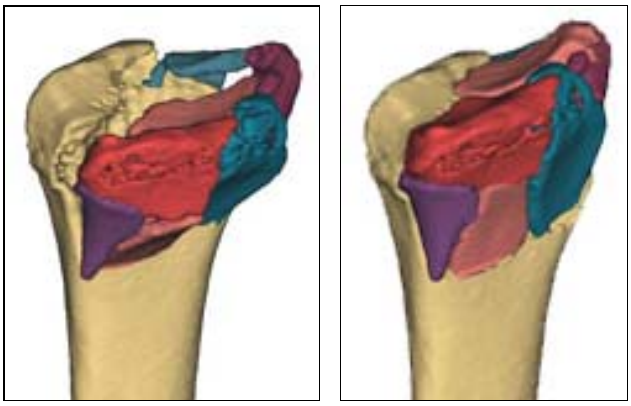
Dr.Sc. Sahib Muminagić
University of Zenica,
Faculty of Health
Crkvice 67, 72000 Zenica
Bosnia and Herzegovina

ABSTRACT
The paper defines the methodology of rapid manufacturing of medical implants for operations in surgery of bone-joint system.
Presented are 3D technologies applied in different stages of the aforementioned methodology, as well as in analysis and preparation for operation procedures in mentioned medical field.
Keywords: medicine implant, rapid manufacturing

1. INTRODUCTION AND OVERVIEW OF PREVIOUS RESEARCHES
The need for rapid manufacturing of implants exists in many areas of surgery. Primarily these are:
1. head surgery,
2. spinal surgery, which involves surgical treatment of diseases, injuries and other disorders of spine, and
3. surgery of bone-joint system in orthopedics and traumatology.

In all these areas, different implants are required, with specific shapes and materials.
In [1] are presented two clinical cases of patients with craniofacial deformities – first a patient with scull bone defect after brain hemorrhage and brain edema as well as a patient with hemifacial microsomia treated by surgery followed by implantation of titanium angular implant produced by means of Computer Tomography (CT) scans, Computer Aided Design (CAD) and Rapid Manufacturing technologies (RM).
Surgical interventions in spinal surgery require some form of spinal instrumentation and use of titanium implants for fusion and stabilization of the same.
With operations in orthopedic surgery and traumatology there is also a requirement to be able to quickly manufacture accurate and quality medical implants. For illustrating can serve figure 1. [4], where under a) shows a bone fracture, with the modeled segments of bone, while under b) given view of 3D model of bone after fusion, or the bringing of all segments in the desired position. In the event that there was too much damage to any of the featured segments of broken bone, it is possible to develop appropriate implants of the same and during operation incorporate them in their place.
In a similar way one can speak of implants needed in surgery of the pelvis, while it may be the implants to replace parts of the pelvis which were destroyed, or an implant that will connect the fractured parts of the pelvis (figure 2.).
Four variants can be distinguished, in respect to situations where you need to apply implant for the patient:
1. use of purchased finished / serial implant,
2. use of customized previously purchased serial implant,
3. manufacturing of a new implant, based on the redesign of existing and
4. manufacturing of a brand new implant.

Implant market is currently covering the area of serial implants and production of biocompatible materials [1]. Serial implants are mainly used in orthopedic surgery, where functionality is the most important. But,in orthopedics and other areas, especially in head surgery, standard implants are insufficient.



a) b)

Figure 1. 3D models of broken bones
a) 3D models of a fractured bone segments,
b) 3D model of the connected segments in preparation for making of implant for surgery

In the paper is defined methodics of rapid manufacturing of medical implants and are shown the main technologies that can be applied in this activity. With this methodology it is realized the unification of resources and technologies in the field of medicine, mechanical engineering and metallurgy.

2. SCANNING OF DAMAGES TO PATIENT AND PREOPERATIVE PLANNING

Manufacture of implants begins with scanning of critical region (skull, face, mandible, pelvis ...) and the transformation of CT or MRI 2D images into 3D digital model using the software for conversion, such as for example software Mimics from company Materialise. Input data for this type of software are usually in the form of DICOM data, while the output is mostly in Standard Tessellation Language (STL) format that can be used directly in most of the RP technology for manufacturing of models. This model is then used as the basis for modeling the defective / missing regions.
3D models of defective regions and the implant can then be used as a means of communication between engineers and doctors, between doctors in preoperative planning and presentation to patients.

3. IMPLANT MODELING

3D models of implants are often particularly demanding in terms of skills of engineers-modelers, who must be fluent in the particular skills of modeling surfaces in some of the CAD engineering software packages. This is especially important because the STL models of the scanned parts of the body almost regularly require additional work in these CAD software. For this purpose the most suitable are mechanical engineers involved in 3D modeling.
The complexity and demanding nature of 3D modeling in manufacturing of implants clearly demonstrates an example of titanium angular implants [1], manufactured based on CT images, 3D modeling and application of rapid manufacturing technology (figure 3.).

4. RAPID MANUFACTURING OF IMPLANTS

In Figure 4 is given a block diagram of the general procedures of rapid manufacturing of medical implants. In the diagram can be seen two major flows. Midle flow implies firstly realization of numerical simulation of implants behavior in conditions that simulate the real conditions in its location in the patient's body. In that, at disposal to doctors and engineers is the base of the acquired knowledge and experiences which among other things, includes the x-ray, CT and MR images, and the types of fractures and defects. There are also appropriate expert systems and application software (in addition to software for numerical simulation, there are different software for the preparation of operations). Based on the results obtained, the procedure may return to the beginning, or the modification of the CAD model. Having successfully implemented the numerical simulations, manufacturing of implants follows.

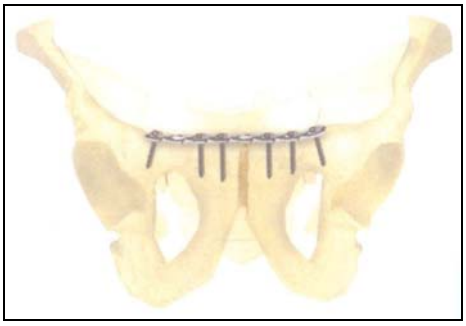


Figure 2. Example of application of pelvic serial implant

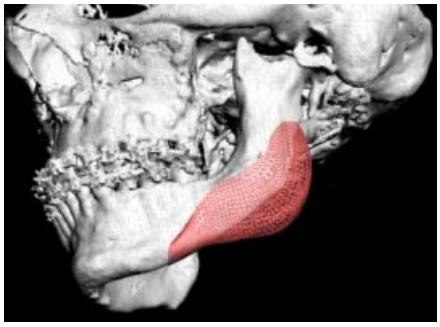


Figure 3. Virtual model of the mandibular implant

In case when doctors do not need, or there is no time for numerical simulations, based on well-designed 3D models of implants, the same can immediately go to its manufacturing.
All the results obtained in suitable formats are stored on hard disks, or the aforementioned database of knowledge and experience.
Rapid manufacturing of new implants is realized based on the application of some of the available technologies and procedures. These can be appropriate procedures for casting, where it is important that the 3D models of implants are used as a "positive" for the development of molds for casting. For this purpose are successfully used 3D printers that print patterns for making molds of relatively inexpensive materials (for example, some models of printer from company Z Corp.). Implants of metal, ceramic, composite, or polymeric biomaterials can be manufactured by casting.
For rapid manufacturing of new metal implants, such as titanium alloys, great possibilities provide specific types of 3D printers. Titanium alloys or cobalt-chromium alloys are currently the only biocompatible materials available for the RM, which can be directly used as an implant [1].
Metal implants can be made on CNC machines, where you need to carry out adequate CNC simulation and generate G code for these machines.
A special category are the implants from degradable composite biomaterial, which after surgery gradually disappear and are replaced by newly formed bone tissue [3]. These implants can be made on above mentioned Z Corp. 3D printers.

5. CONCLUSIONS

Supported by modern computer technology, such as computer aided modeling (CAD) and numerical simulation (CAE), which are based on traditional CT and MRI scanning techniques, in combination with rapid prototyping (RP) and rapid manufacturing (RM) provide practically unlimited possibilities in processes that include visualization, simulation and preparation of operational procedures, and manufacturing of complex implants in clinical medical practice. While these technologies and techniques are not new, research of new possibilities of their applications and opening of new horizons is one of the primary tasks of the surgery and accompanying engineering. By applying these technologies can also improve the overall effects of the medical staff and raises the quality of medical services.
Defined methodics represents unification of resources and technologies in the field of medicine, mechanical engineering and metallurgy. Here is especially pointed out that the challenges in the field of reconstructive surgery require an ever closer cooperation of doctors and engineers with expert knowledge in the area of 3D modeling, engineering simulation and 3D technology in general.

6. REFERENCES

[1] Drstvensek I., Ihan Hren N., Strojnik T. and other: Layered Additive Manufacturing in Clinical Medicine, Serbian Dental J, 2008, 55, ISSN 0039-1743,
[2] Klapan I., Vranjes Z. and Risavi R.: Računalom podrzana 3D-kirurgija i tele-3D-kirurgija: medicina novog doba, Medix, svibanj 2004., god. X, broj 53,
[3] Ignjatovic N., Ninkov P., Ajdukovic Z. I dr.: Biphasic Calcium Phosphate/Poly-Dl-Lactide-Co-Glycolide Composite Biomaterial as Bone Substitute, Journal of the European Ceramic Society 27 (2007) 1589–1594,
[4] http://www.materialise.com/materialise/view/en/1433801-SurgiCase+Orthopaedics.html.

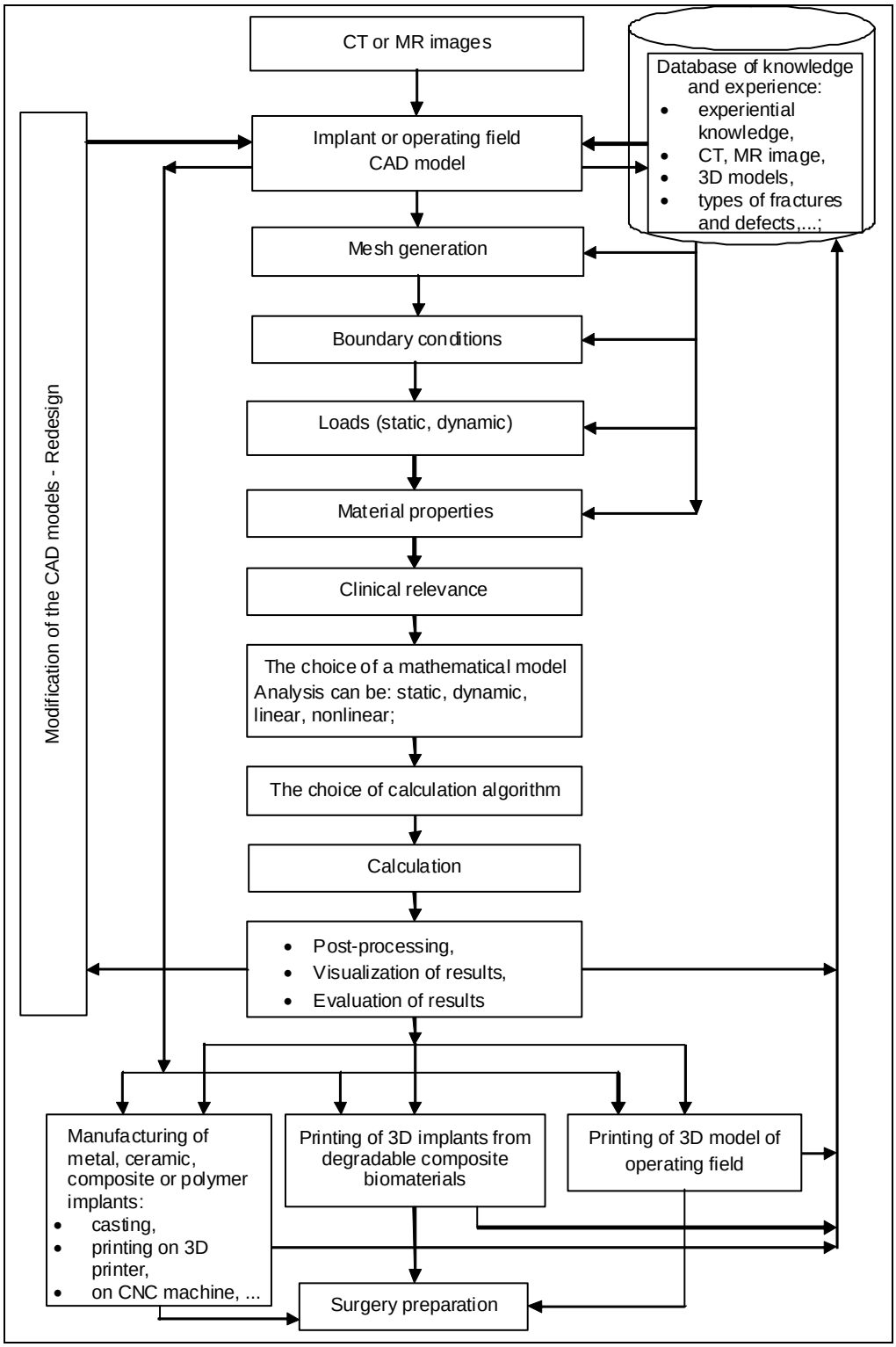


Figure 4. General procedures of rapid manufacturing of medical implants and 3D models