Chapter 20
Methods of Skull Implants Modeling with Use of CAx and Haptic Systems

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ABSTRACT

This chapter deals with four exemplary methods of virtual skull implants modeling. These methods combine simultaneous usage of three modeling systems: reverse engineering system, surface modeling system, and haptic modeling system, and their characteristic modeling methods and techniques. Using three different modeling systems, the authors obtain a synergy effect of the implant shape and model quality increasing. The target virtual model of the implant is always well suited to the coastline of bone lack in the skull. Additionally, time of the virtual model developed is very short compared to use of only one of the standard engineering CAx systems. The chapter describes four original methods developed by the author.

INTRODUCTION

The need to remove a bone piece in neurosurgical procedures or the occurrence of the loss as a result of mechanical trauma are the causes of a need to restore the natural shape of the skull bone. In the majority of patients who have experienced the loss of cranial bones, proper supplementing the appropriate implants, giving the desired aesthetic effect, so-called cranioplasty surgery (Karbowski, Urbanik, & Wyleżoł, 2010), is an important psychological factor in the recovery and return to normal life in society. Performing trial fit implant constructed should precede the cranial implant implementation. This process can be carried out in two stages: in the virtual world (using 3D models of the skull and of the implant, Figure 1a), and in the real world with the use of physical models of the skull and implant using techniques such as incremental 3D printing, Figure 1b.

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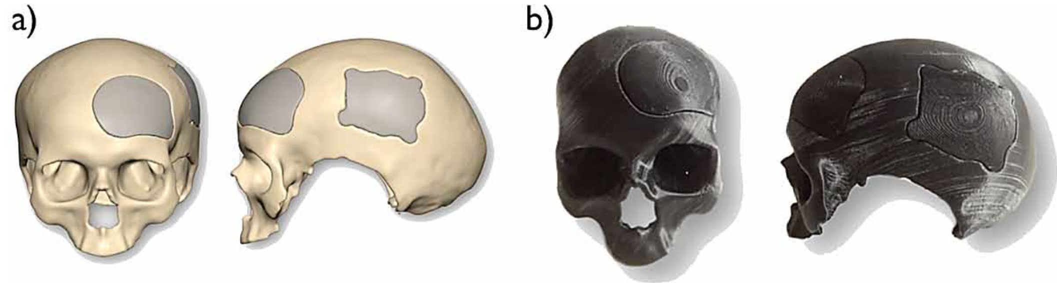
Figure 1. Virtual model of a skull with implants (a) and their physical models made by 3D printing (b)



The selected illustrations of the human skull in the chapter text were derived from real data (courtesy of Jagiellonian University, Medical College at Cracow, Figures 12-15) and serve to illustrate realization process of this method. Other skull models are based on the digitization of their physical models.

BACKGROUND

Modeling objects with forms that contain no standard geometry (i.e.: plane, patch of analytical surface, sphere, cylinder, cone, etc.) is a very difficult process to achieve using conventional surface or solid modeling systems and its tools (Wełyczko, 2009). One of the solutions of this modeling problem is to use the free surface modeling (nonparametric), where the elements allow you to control the shape of the surface patches using e.g. control points of the surface (Kiciak, 2000; Wełyczko, 2009). However, such modeling methods are not suitable to solve problems, which concern the scope of this article, i.e. whether the modeling implants match the difficult skull shape.

In this case (i.e. modeling human skull implants based on a discrete skull bone model with a missing piece), the input element to modeling process of a skull implant is a surface mesh model of the skull obtained from computed tomography (CT) (Eufinger, 1995; Karbowski, Urbanik & Wyleżoł, 2010; Wyleżoł & Otrębska, 2013). Note: the description of computed tomography (CT) or magnetic resonance imaging (MRI) is not the purpose of this chapter. Despite, the author will briefly describe the process of obtaining models based on medical imaging.

Digital images obtained with the type of medical computed tomography and magnetic resonance imaging are stored in the standard DICOM (Digital Imaging and Communications Medicine) images (DICOM, 2013). It is a standard developed by ACR/NEMA (American College of Radiology/National Electrical Manufacturers Association) to harmonize worldwide recording medical data. Images stored in the extension of the DICOM contain not only graphical data i.e. flat images, but also include patient information and parameters of the medical study. Using the mentioned above study we receive flat sections of an organ of the human body. The number, size and quality of these cross-sections depend on the settings selected in the medical study. Ideally, when the sections are spaced apart by about 0.5 mm (or less), because then we are able to correctly reconstruct the three-dimensional model of the human body (Cierniak, 2005; Wyleżoł & Otrębska, 2013).

DICOM images for obtaining and processing three-dimensional models are imported into a specialized program such as Mimics (Materialise, 2013) or Osirix (Osirix, 2014). DICOM images imported to the mentioned program (or some others for DICOM files viewing) are displayed in three planes: