

PERSONALIZED APPROACH TO VISCERAL SKULL REGION CERAMICS OSTEOIMPLANTS MANUFACTURING

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The increase in the life duration and quality, the transition to the provision of reconstructive personalized medical care is one of the main directions of the Russian Federation scientific and technological development.

Oncological diseases are on the second place among of death and disability causes in the Russian Federation [1]. In most cases, timely-rendered medical care implies surgical intervention with a one-time reconstructive stage. In the case of bone tissue tumor lesion, the use of standard and serially produced osteosubstitution implants cannot always satisfy modern principles of reconstructive and plastic surgery, and sometimes involves a high risk of postoperative complications.

When the bones of the skull visceral region are affected, the aesthetic aspect of the prosthesis plays an important role: the anatomical geometry violation of the face leads to social and psychological disadaptation of patients. The solution in this case can be a personalized approach to the design of an osteoimplant based on the construction of a three-dimensional model of a bone tissue region planned for resection and its reproduction in a biologically compatible material by the additive production methods.

The successful osteosubstitution is determined not only by biochemical, but biomechanical compatibility of the prosthesis material with the bone tissue also. It is consisting in accordance strength parameters and structural identity. From the literature it is well known that for the providing of osteointegration processes the most preferable is the connected polymodal pore structure of the osteoimplant. The macropores play the role of niches for the pre-osteoblasts cell clusters proliferation, and the micropores - channels for the vascular system development [2,3]. At the same time, in the area of absence of contact in the implant-bone system, it is necessary to avoid the developed surface structure to prevent excessive development of soft tissue integration processes, which can negatively affect the muscular activity and mimicry.

At present, metal materials are widely used in osteo-prosthetics, but the high risk of metallosis and inflammatory reaction leaves the need for new solutions.

From the point of view of biochemical compatibility with body tissues, the most preferred material is oxide ceramics based on ZrO_2 and Al_2O_3 [4]. They have a similar to inorganic bone matrix type of chemical bonds and do not provide the electrochemical interaction with the body. However, the sintered ceramic material mechanical treatment is a high-tech task, which makes it impossible to fine-tune the serial ceramic osteo-implant for the needs of a particular patient in the clinic conditions.

Thus, the aim of this work is to develop an approach to the personalized osteoimplants based on oxide ceramics production. The personalized approach to the manufacture of osteoimplants allows to take into account the peculiarities of the individual structural state of the patient's prosthetic bone tissue and to minimize the resection area, which satisfies the principle of organ preservation.

The basis for creating a model of osteoimplant is a high resolution three-dimensional computer tomogram. The computer model of the endoprosthesis is constructed using modern CAD / CAM design systems. The main difficulty at this stage is to determine the bone matrix on the tomogram, excluding soft, fatty and cartilaginous tissues, Figure 1.

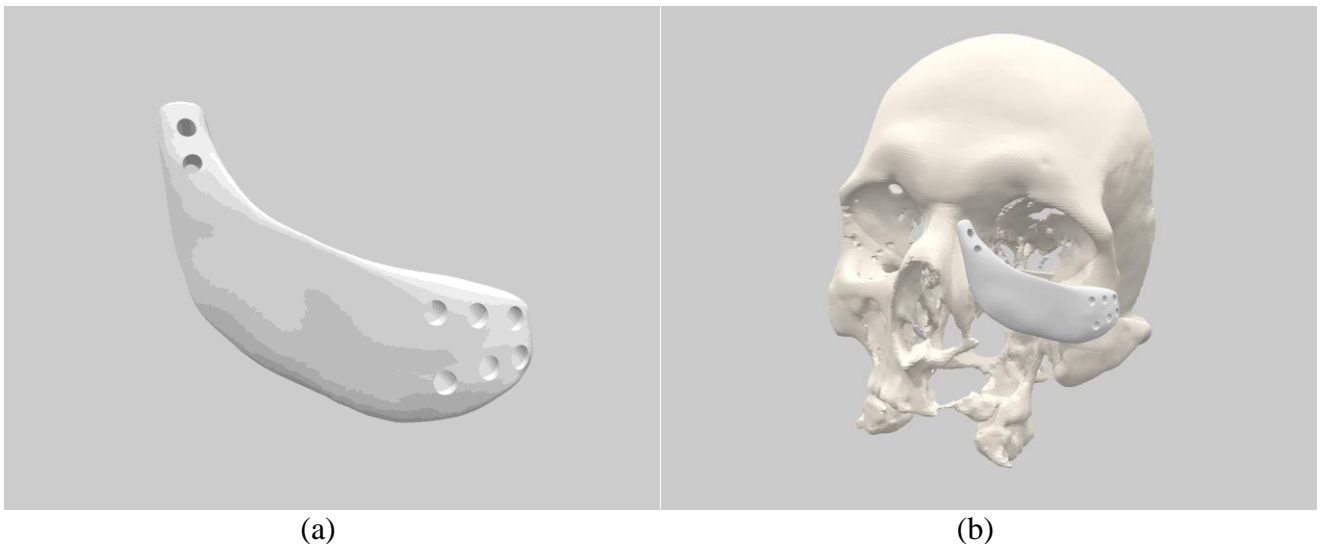


Figure 1. Osteoimplant model (a). Comparison of the osteoimplant model with a three-dimensional computer tomogram of the skull visceral region (b).

The application of additive production technologies for the ceramic, in contrast to the traditional methods of compacting or injection molding, consists of layer-by-layer prototyping, which makes it possible to vary the structural parameters of the implant being created. Reproduction of the osteoimplant model in ceramic material using 3D prototyping technology allows specifying the ceramics pore space volume up to 70%, creating a bimodal pore structure with an average micropores size of 10 μm and a macropores of 100 μm .

By varying the technological parameters, it is possible to control the mechanical characteristics. The compressive strength can be from 20 to 200 MPa, depending on the structure of the prosthetic bone tissue. It will prevent the potential probability of the osteoimplant or bone tissue destruction in the contact area.

References

1. Caprina, A.D. Malignant neoplasms in Russia in 2016 [Morbidity and mortality] / A.D. Caprina, V.V. Starinskogo, G.V. Petrova. - Moscow: Moscow: MNIOI them. P.A. Herzen, 2018. – p. 250.
2. Papastavrou E., Breedon P., Fairhurst D. Low-Temperature Deposition Modeling of β -TCP Scaffolds with Controlled Bimodal Porosity //Biomaterials for Tissue Engineering. – Humana Press, New York, NY, 2018. – pp. 41-54.
3. Tang W. Bioinspired trimodal macro/micro/nano-porous scaffolds loading rhBMP-2 for complete regeneration of critical size bone defect //Acta biomaterialia. – 2016. – T. 32. – pp. 309-323.
4. Hadjicharalambous, C., Prymak, O., Loza, K., Buyakov, A., Kulkov, S., & Chatzinikolaidou, M. Effect of porosity of alumina and zirconia ceramics toward pre-osteoblast response //Frontiers in bioengineering and biotechnology. – 2015. – T. 3. – p. 175.