

Study of the possibility three-dimensional printing DLP-technology for casting individual neck telescopic implants

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Abstract. The work is devoted to manufacturing possibility of individual telescopic cervical implants by the casting method for burned-out models obtained on a DLP printer. The ProJet 1200 using possibility for the burned model production of a telescopic cervical implant was studied. The results of the model material influence on the molding mass are obtained. Experimental samples of cervical implants on the Inducast installation are cast. The ineffectiveness of this technology in the manufacture of reticular collapsible telescopic implants is established. The possibility of its application for thick-walled structures is established.

Introduction

Individual approach to the treatment of patients is becoming increasingly widespread. Starting from individual selection of medicines based on genetic analysis and ending with individual implants and orthoses. The creation of individual products has always been a more expensive procedure in comparison with mass production. However, with the advent of additive production technologies, the creation of individual parts has become more accessible. Therefore, additive technologies began to be widely used in various fields of medicine. In the additive manufacturing of individual implants, there are two methods: creating models for subsequent casting or direct manufacturing of finished individual implants from metal powders. The most correct is the direct production by selective laser melting of metal implants, thereby reducing the number of manufacturing stages. However, from laboriousness view obtaining a certificate-permission to use this method for medical purposes, it can not be used in the short term. Therefore, you can use only the first option - the symbiosis of additive technologies and traditional - casting. Therefore, the task was to study the combined method possibilities of manufacturing individual cervical telescopic implants [1,2,3]. Namely, how many complex designs can be obtained using DLP-technology of three-dimensional printing, and whether it will be possible to cast them out of metal. This is very important, as there is a tendency to manufacture mesh implants that have a low weight and are not inferior in strength to the standard one. Another advantage of reticular implants is the possibility of filling them with



various biomaterials for effective osseointegration. One of the common injuries is spinal injury [4,5]. The greatest danger is a fracture or dislocation of the cervical spine. It is important to replace the damaged vertebra correctly. This is achieved only with the installation of individual telescopic implants, with the possibility of changing the upper platform location in the vertical and horizontal directions [6,7]. Therefore, in work, on the example of this type of implants, the possibility of using a combined casting method and DLP-technology was investigated.

Main part

To create an individual implant, you need to obtain digital data of the fracture site or dislocation. The surgeon decides to install a telescopic cervical implant. Obtaining a three-dimensional model of the fracture site is possible only in installations receiving a object layered structure, such type of equipment include tomographs. Digital data obtained with CT, MRI are needed to create a three-dimensional virtual model. Determine the location of installation and cervical implant attachment. Only after receiving this information will it be possible to begin modeling the geometry and calculating the component dimensions of the telescopic implant. With 3D Slicer software, the CT data was processed and 3D model of the patient cervical spine in STL format was created. In the MeshMagic program, we load the STL file of the fracture site and standard size models-blanks of telescopic cervical implants. We adapt the workpiece model to the fracture site. As a result we have individual three-dimensional virtual implant model in the STL format.

To produce a burned-out model, we used a 3d printer ProJet 1200 equipped by pico projector with a resolution 585 dpi in the X-Y, and Z-step height of 30 μm . This setting applies to the DLP (Digital Light Processing) family of 3d printers. At the heart of the DLP-system is a special device - a DMD-chip (Digital Micromirror Device). This is a complex structure that belongs to the so-called class of microelectronic mechanical systems (MEMS - Micro-Electronic Mechanical System). As a source of light can act as a light bulb (incandescent, luminescent or LED), and lasers. The wavelength extends from the ultraviolet to the infrared range. The device has the form of a micromirror matrix. Each micromirror is 10 microns in size. They are able to reflect both the invisible and visible spectrum of light and reflect light in one of two directions. The direction is determined by the angle of rotation. Direction itself is set by loading the bit "0" or "1" in the memory location. Each cell receives an independent bit stream with a frequency of several kilohertz, as a result of which we have a useful image on one of the outputs, and at the other output there is a light absorber. The GeomagicPrint program splits the printed object into layers with the specified thickness. A photopolymer is poured into the printer's bath with a transparent bottom. At the bottom of the bath the metal substrate is immersed, receding from the bottom to one (first) layer of the product. It turns out in the gap between the substrate and the bathroom is a liquid photopolymer. The projector, located under the bathroom, projects the picture of the first layer onto the bottom of the bath and, thanks to UV radiation, only the plastic that gets the image from the projector freezes. Then the working table rises one more layer and again a new layer is glued, which is attached to the previous one. As a result, a three-dimensional object from the liquid photopolymer grows layer by layer. The material used was the VisiJet FTX Green photopolymer from 3D Systems. It has the following properties: heat resistance - up to 93 °C, dynamic viscosity (mPa s): 100 - 130 (30 °C), burn-out - ash residue 0.01%.

Two types of samples were grown in the ProJet 1200 using pre-modeled models: with and without the net filling of the implant body (Figure 1). For casting on burned models, a gating system was modeled, shown in Figure 1b.

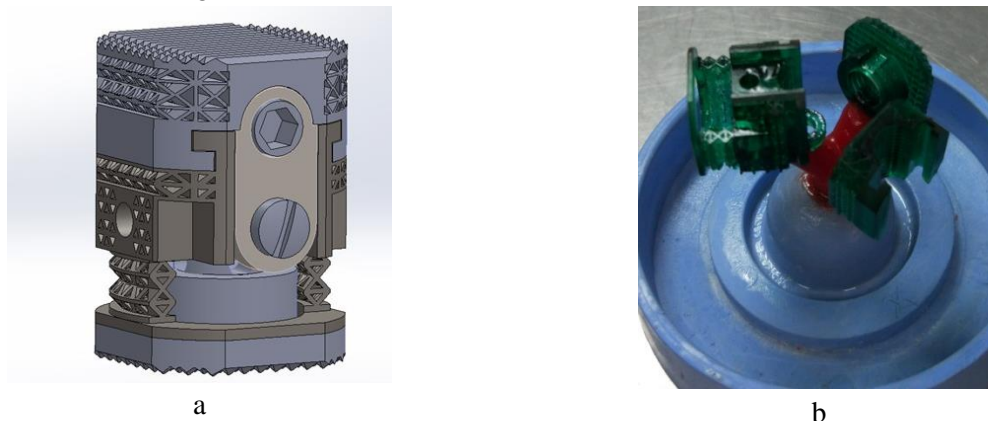


Figure 1 - a - mesh virtual model of the cervical implant assembly, b – gating system.

The construction of the gating system begins with the establishment of each unit according to the feeder. Elements of the implant are supplied with sprue channels with a diameter of 5 mm. The channels number depends on the number of units cast. After building a gating system, it must be weighed. Based on the known mass of wax, the required amount of metal is determined. The calculation is made by the following formula: $M_{Me} = m_{wax} * 10 + 5 \text{ g}$. Starbond CoS dental metal was used in the experiments, the following composition of Co - 59%, Cr - 25%, W - 9%, Mo - 3.5%, Si - 1%, other components (C, Fe, Mn, N) - maximum 1.5%. Ultimate tensile strength (Rp0.2) 650 MPa. The tensile strength is 910 MPa. The maximum elongation is 8%. The modulus of elasticity is 200 GPa. Vickers hardness 280 HV 10. Density 8,8 g / cm³. Solidus-liquidus interval is 1305 - 1400 ° C. The casting temperature is 1500-1550 ° C. The thermal expansion coefficient is 14.0 μm / m. ° C.

In the second stage, the Yeti Expansion refractory molding (90 g) is prepared and kneaded with Yeti Liquid (22/20 ml) + distilled water (0/2 ml). To avoid the formation of air bubbles, a vacuum mixer Fox 88 from OMEC (Italy) was used. The kneading time was 30 seconds, the blade rotation speed was 400 rpm, and the pressure in the bowl was 0.8 Bar. The casting of the gate was made on a vibration table VB 1.1 with 2 vibration frequencies of 3000/6000 min⁻¹. After the molding mass has been filled in, wait 30 minutes before the molding material solidifies completely. The resultant hardening of the molding mass should be heated in the muffle furnace. In the experiments, the method of shock heating of the flask was used. In particular, the Programix 50 Ugin oven was preheated to a temperature of 900 ° C. A mold was used with an X6 size, the minimum warm-up time was 60 minutes. To effectively cast the metal, the crucible with the metal is also heated in a muffle furnace. In the next step, the heated crucible is placed in a casting chamber. The metal is heated by means of high frequency currents. Further, from the muffle furnace, a heated flask is extracted and vertically fixed to the crucible cover and pressed down from above with a clamping mechanism. After that, the vacuum chamber cover is closed, and the evacuation process of air begins with simultaneous high-frequency metal heating. During the heating process, the metal melts, resulting in the formation of a molten metal in the crucible, which is covered with an oxide film on top. At the rupture moment of the oxide film, the caster performs a casting process, namely,

a vacuum-casting chamber is rotated, and compressed air is pumped at a rate of 3 bar/s to a pressure of 3.6 bar. As a result of the overturn, the metal from the crucible is poured into the flask and pressurized by excess pressure. The pressure provides the possibility of spilling metal into channels with a thickness more than 0.1 mm. In the experiments, a fore-casting installation was used. The vacuum-casting chamber is in an inverted state for 30 seconds, during which time the metal cools and crystallizes. Molding box must be cooled at room temperature, and mechanically clean the metal frame from the molding mass. A sandblasting unit was used, in which sand particles stream with a grain size of 250-300 μm , bombarded the surface of the sprue system and cleared the molding mass.

Figure 2 shows cast specimens of individual telescopic cervical implants.



Figure 2 - Samples of castings of individual telescopic cervical implants.

As a result of the research, it has been established that implant molding without a mesh structure in the volume is successful. After additional machining, a ready-made disassembly implant can be obtained. At casting wire mesh there are two problems: the difficulty of molding associated with the air extraction from mesh volume and the difficulty of cleaning the molding mass is a mesh space in the implant volume.

Conclusion

The possibility of using the ProJet 1200 system for producing a burned model of a telescopic neck implant with a mesh structure was studied. The results of the model material influence on the molding mass are obtained. Inducast installation cast prototypes of cervical implants. The technology ineffectiveness in manufacture of reticular telescopic implants is established. The possibility of its application for thick-walled structures is determined.

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