

Determination of optimal technology for manufacturing dental surgical guides

J N Dementyeva¹, I I Sagitov³, R N Kashapov^{1,2,3}, L N Kashapov¹, G T Saleeva³

¹Kazan Federal University, 18 Kremlyovskayastreet, Kazan, 420008, Russia

²Kazan E.K. Zavoisky Physical-Technical Institute, 420029, Russia

³Kazan State Medical University, Kazan, 420012, Russia

kashramiln@gmail.com

Abstract. This article describes methods of manufacturing surgical guides - their creation in rapid prototyping installations and milling machine grinding. Implantation was carried out using the obtained guides and derating level of installed implants was defined. The work compares existing technologies of surgical guides production and defines a clear advantage of using laser stereolithography technology for product manufacture in quantities greater than one.

Introduction

Dentistry is one of the orthogenics, where the active introduction of new innovative technologies takes place. Individuality inherent in each clinical case, and it has led to active implementation of digital technologies.

One example of the use of digital technologies is the creation of surgical guides. The surgical template is a patch with guide cylinders for precise positioning of implants in the oral cavity in accordance with the planned position on the computer for computed tomography. Most often surgical patterns for implantation are required if the patient does not have a large number of teeth. Using a surgical template can improve the quality of planning and the accuracy of the planned outcome [1, 2]. However, the obtained virtual model must be embodied in a real physical phenomenon. There are two ways of creating surgical templates - CNC mill grinding and usage of additive technologies.

The purpose of this work is to compare existing methods and find the optimal one.

Main part

The computer tomography of patient, namely axial sections in the DICOM format, was used for creation of a surgical guide. Scanning of jaw casts was performed on a 3D scanner. It is very important to have a good quality, because the guides are created according to the pick-up impression. If the patient lacks all the teeth, it is necessary to make a radiopaque guide on the CT scan and the scan itself. With its help you can see the thickness of soft tissues on CT.

Computer tomography and impression scans are loaded into the DDS-Pro software program and combined (Figure 1). The guide is created according to pick up impression, CT is used for endosseous topography. We select the implants and arrange them with the help of the software. We must take into account the precise location of the implant and the anatomical features to achieve the optimal aesthetic result and to prevent complications associated with disruption of the maxillary sinus integrity or damage of the neurovascular bundle, and also we must take into account predicted implant angulation to create an axial load on the implant and achieve a biomechanically



predicted result [3,4 ,5].

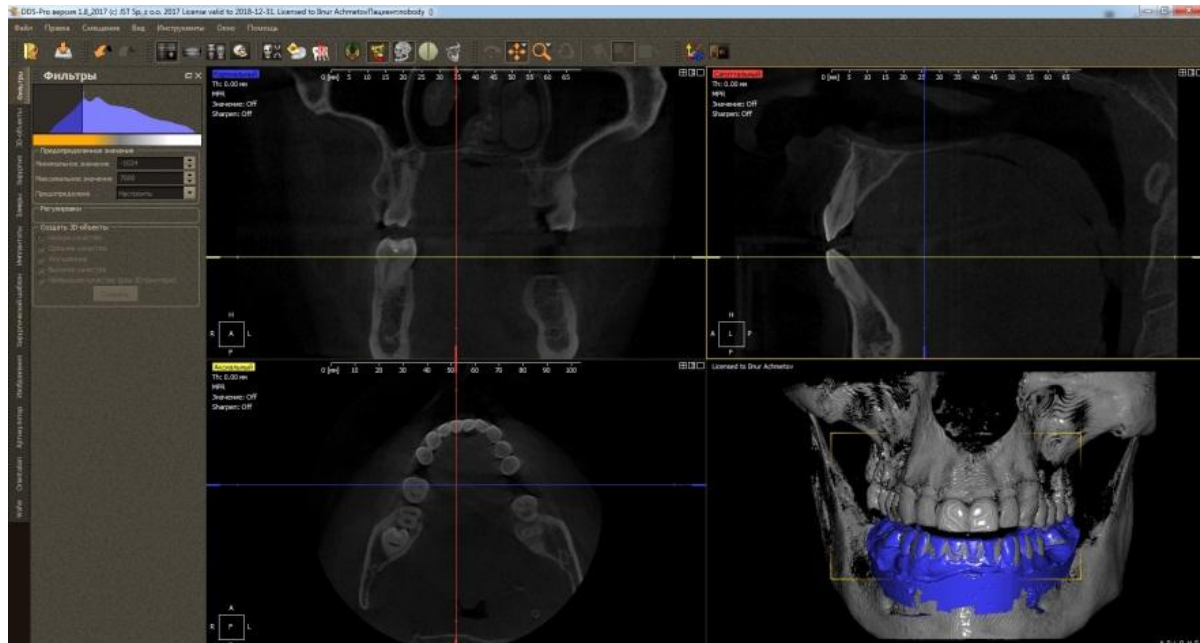


Figure 1 - Superposition of the pick-up impression scans and CT in the DDS-Pro software program

We used a dental 3D-scanner Smart Optics Activity 875 to scan the gypsum models of the jaws. Scanning accuracy is up to 10 microns. The scanning speed of one tooth is approximately 55 seconds, and 90 seconds - of the whole jaw. The test of milling possibility was carried out on a 5-axis CNC mill CORiTEC 450i from IMES-ICORE. This miller allows to conduct dry and wet milling of any materials used in dentistry and to manufacture products with high accuracy. The CNC mill CORiTEC 450i works with the following materials: plastics, zirconia, aluminum oxide, glass ceramics, cobalt-chromium alloy, titanium. Performance specifications: five-axis synchronous processing, servo controller, spindle rotation up to 60,000 rpm, cooling system for wet processing (optional), tools with 3 mm collet, automatic change of 12 cutters, built-in high-precision sensor for measuring the length of the instrument, installed holder for blanks with a diameter of 98.5 mm.

Production by stereolithography (SLA). The technology of laser stereolithography is based on the polymerization of liquid photopolymers. A mesh platform is placed in a container with a liquid photopolymer on which the prototype is created. This method of additive manufacturing is one of the most accurate up to date. For the production of the guides we used installation of rapid prototyping RSPRO 600 created by company Uniontech. The max.build size is 600 x 600 x 400 mm (full bath), the accuracy is ± 0.1 mm (size <100 mm), $\pm 0.1\%$ (size > 100 mm.) The accuracy may vary depending on the model parameters, geometry and dimensions of the part, orientation of the part, and subsequent processing. The installation uses a CO2 laser with a power 1000 mW, a wavelength 354.7 nm, the laser spot size has a nominal diameter 0.12 mm, a maximum diameter 0.20 mm, a scanning speed 12 m / s (max) 6-10 m / s (min). The thickness of the layer is 0.05 mm (min) and 0.25 mm (max).

Manufacture by direct light processing (DLP) method. The method is based on the usage of photocurable resin, which solidifies when irradiated with ultraviolet light. Unlike laser systems that scan the surface of a material with one or more laser heads, DLP printers project an image of the whole layer until the polymer resin solidifies, after what a new layer of material is applied and a new layer of the digital model is projected. To create a guide, we used the ProJet 1200 (3D Systems), USA. The print quality is 0.03 μ m, the layer thickness is 30 μ m, the productivity is 14 mm / hour. The build size is 43x27x150 mm. The installation is used in dentistry, jewelry industry,

design and engineering.

Manufacture by selective laser sintering (SLS) method. Selective laser sintering is a method of additive manufacturing, where a polymer powder is used to create details, which is sintered by an infrared CO₂ laser with a wavelength 10.6 μm .

The surgical guide was made with the help of a selective laser sintering system sPro 60 HD (3DSystems, USA) of polyamide 12. The max.build size is 381x330x437 mm, layer thickness is 0,08 - 0,15T mm, productivity is 1,0 l / h. The laser power is 70 W.

Manufacture by fused deposition modeling (FDM) method. FDM technology means the creation of three-dimensional objects by applying consecutive layers of material that repeat the outline of the digital model. Typically, as materials for printing are thermoplastics, supplied in the form of coils of yarns or rods. For manufacture of a surgical guide of ABS plastic, the Fortus 400mc (Stratasys, USA) was used. The max.build size is 406x355x406 mm, layer thickness is from 127 to 330 μm .

Results and comparison

Grinding of one surgical guide on the milling machine takes approximately 1 hour. Grinding of 20 surgical guides takes about 20 hours. Only one guide can be placed on one blank. Whereas one surgical guide on the rapid prototyping RSPro 600 can be also produced in 1 hour, but the production of 20 guides takes 3,5 hours. This happens due to the fact that the installation has big building platform.

The manufacturing of the guide with the ProJet 1200 takes about 50 min, but it has a small build platform, so only one guide can be placed on the platform. The quality of the obtained guide is as good as the guide obtained on the SLA or CAD / CAM system.



Figure 2 - Process of grinding on the milling machine.



Figure 3 - The finished guide is made of plastic on the CNC mill (left). On the right - a guide, made with RSPro 600 of a photopolymer.

Obtained surgical guide, made of polymer powder, with the help of SLS system is accurate, but flexible, which can be the reason for inaccurate implantation. In addition, the manufacture of a small amount is not rational, since the process chamber must be completely filled with powder. For manufacture of one or 20 surgical guides the same volume of powder is used. The deviation of implants, installed through the guide made with the ABS method, turned out to be higher than deviation of implants installed through the guide, manufactured with the method of SLA, DLP, or on a milling machine.

The research included 16 patients aged from 38 to 60. The bone volume and anatomical features of the patients were studied using CBCT tomography of Planmeca, placed in the dental clinic of the KSMU. All in all, 48 implants of the size from 3,75x10 to 4,2x13 of AB dental were placed. 30 implants were placed through a guide resting on the teeth, 18 implants were placed through a guide

resting on the oral mucosa, mainly to patients with adentia. All implants were placed without separation of the sinus membrane. Comparison of materials for the manufacture of surgical guides was carried out in two groups of patients who had implants placed in size from 3.75x10 to 4.2x13. In the first group, there were 3 patients who had 7 implants, with usage of a surgical guide made from photopolymer resin, and in the second there were 3 patients who had 8 implants placed through a guide made of ABS plastic. To compare the results immediately after the operation, a second CBCT was performed. In the planning program, the postoperative image was superimposed on the preoperative image with the implant models placed.

To measure the deviation of the implant from the planned localization, two points were set on each of them. The first point was established in the center of the coronal part (in the collar region) of the implant, the second one - in the region of the root apex center. Also, the angular deflections of the implants were calculated.

When the guide was produced on the SLA printer, the deviation of the implants placed through the guide resting on the teeth was 0.27 ± 0.24 mm in the collar region and 0.37 ± 0.35 mm in the root apex region. The average angular deviation of the implants, placed through the guide with the support on the teeth, was 1.72 ± 1.67 , through the guide with the support on the mucosa was 2.71 ± 2.58 .

The results of our research testify that surgical guides can improve the functional and aesthetic results of implantation, improve the positioning accuracy, angle and depth of immersion of dental implants. Surgical guide resting on teeth can be more accurate than guide resting on the oral mucosa.

The deviation of the placed implants through a guide made of ABS plastic was 0.45 ± 0.37 mm in the collar region and 0.62 ± 0.56 mm in the root apex region.

When making one guide, it is better to use the CAD / CAM system. When making a large number of guides it is SLA.

Conclusion

The results of our research testify that surgical guides can improve the functional and aesthetic results of implantation, improve the positioning accuracy, angle and depth of immersion of dental implants. Surgical guides resting on teeth can be more accurate than guide resting on the oral mucosa. Surgical guides made of photopolymer plastic are more accurate than surgical guides made of ABS plastic.

It is better to use the rapid prototyping RSPRO 600 for making a large number of guides. For single-piece - CAD / CAM system or DLP.

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