Application of reverse engineering in the production of individual dental abutments.

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Abstract. The purpose of the research is to develop a method of manufacturing individual dental abutments for a variety of dental implants. System of industrial X-ray microtomography Phoenix V'tomeX S 240 has been applied for creation of highly accurate model of the dental abutment. Scanning of dental abutment and the optimization of model was produced. The program of milling the individual abutment with a standard conical neck of hexagon was produced for the five-axis milling machine imes - icore 450i from the materials titanium and zirconium oxide.

Introduction
A beautiful smile is today an integral part of our lives, to realize it is often necessary to resort to the help of dental implants. Implant placement is almost impossible without the abutment.

The abutment is a connecting link between the dental implant and the crown of the tooth. The most convenient and efficient are the individually fabricated abutments, which providing more comfort in their use and with such abutments unable to repeat the tooth shape and to achieve the highest esthetic similarity with the planting of the native teeth.

Functionally, the abutment can be divided into two parts: a conical neck hexagon, which response for fixing the abutment to the implant, and the segment for the individual superstructures, which is fixed on the collet. For install the individual abutment on the standard implant, it is necessary to save a standard conical neck of hexagon, and produce segment for individual superstructures with regard to the shape of the dental crown.

Thus, an individual abutment must have a standard conical neck of hexagon and segment for individual superstructures, which is modeled for each case. Therefore, the aim of this research was to develop a methodology of manufacturing individual dental abutments for various standard implants. To achieve this goal it is necessary to solve the following tasks:
1. Perform an X-ray computed tomography of the abutment and estimate the accuracy of the scanned model.
2. Optimize the model and reduce the file size to simplify the work with the model.
3. Creating a strategy for milling on five axis milling machine.

Main part
To create a fixing of individual abutment to standard implants required to save attaching point of the abutment to the implant.

To achieve the goal, we use a standard metal abutment in two perspectives (Fig. 1). In this abutment we are interested in the upper part, which have the shape of a hexagon because it is the standard and is necessary to preserve its size and shape.

![Fig.1. Abutment.](image)

We refused from manual measurement and design 3d models in software such as KOMPAS-3D and SolidWorks due to the small size of the abutment and the presence on the surface of the channels grooves of small quantities which can’t be measured using calipers. The method of using an optical scanner such Rexcan 450 also had to be abandoned due to the fact that the abutment is made from metal and the surface is glossy; it becomes necessary to apply a special spray that gives a matte surface. Channels with shallow depth on the surface can become clogged by particles of spray, as a result we get the model does not satisfy the accuracy.

Computer tomography method is most suitable for our purposes, it allows getting the most accurate 3D model of the outer surface, and most importantly providing the exact size and shape of the inside of the through hole. A large load on the locking screw arises in case of violation or changing form of inner hole for screw connection, which can lead to premature destruction.

X-ray computed tomography (CT) - the method of non-destructive research of internal structure of the object is based on measuring the attenuation of X-rays by various parts of the object, differing in density, composition, and thickness. A complex computer processing of data for a variety of its two-dimensional projection is used to generate three-dimensional images of the internal structure of the object.

To create a 3D computer model of the abutment used industrial X-ray microtomography system Phoenix V/tome X S 240 is equipped with two X-ray tubes: microfocus with a maximum accelerating voltage of 240kV / 320W power and nanofocus maximum accelerating voltage of 180kV / 15W power.

Creating 3D models takes place on the basis of a large number of radiographs, more than a thousand, taken from different angles due the rotating manipulator. Projections set converted into the 3D model by software datos|x reconstruction. Software VG Studio MAX 2.1 and Avizo Fire 7.1 are used for the data visualization and analysis on the elements of three-dimensional image.

Nanofocus tube was used for obtained samples. Scanning was performed at an accelerating voltage of 110kV and current of 100mA. Picture resolution is 6.5 mkm (volume of one voxel). Voxel is the volumetric pixel, in this case, the model consisted of cubic elements of the size of 6.5 * 6.5 * 6.5 mkm. CT method imprecision is 0.1 microns, which is acceptable for parts of our size. The main advantage of the method of X-ray CT, consists in that it was possible to obtain not only the outer surface of the model, but the exact shape and dimensions of the inside (Fig. 2) without cutting model...
and any other destructive effects. High accuracy of scanning allows creating snug fit the abutment to the implant, thereby to protect from infection in cracks and in the junction. Also to protect from infection penetration which can lead to rejection of the implant.

![Fig.2 Form and scales of 3D model of abutment in a cut after CT.](image)

The resulting model had STL file format and consisted of 472,275 polygons. Model must be optimized for comfortable work in CAD system by reducing the number of polygons, while maintaining the size, without loss of accuracy and functionality of the model. This operation was carried out in the program 3ds Max. Was used the operation ProOptimizer which reduce the number of polygons by replacement of group polygons to one that is closest to the original group by location peaks. Because of this was able to reduce the number of polygons by 50 times, from 472275 to 9444. The model is angular (Fig. 3), it is possible to fix by smoothing model.

![Fig.3. a) The result of reducing the number of polygons by 50 times, angular (rough) surface. b) The final result of the optimization model. c) Exist model.](image)

Smoothing effect works by combining the process of changing the angle between the polygons on a more obtuse angles and increasing the number of polygons, using for example Bezier curves. Was used the operation Smooth. Model becomes smoother with increasing smoothing coefficient, optimal value 13. Model deformation observed with increasing values of smoothing coefficient.

The file size is reduced from 86 MB to 461 KB (Fig. 2 b, c). This will speed up the subsequent process of the work, because most of the CAD softwares, while working with files of the large volume required spending more time to process the model.

All operations to reduce polygons and volume of file, have not affected on the functionality of the abutment model. Comparing of the distance between the control points have been conducted to verify
the accuracy of the size of the abutment after the stage of optimization models. We compared the distance between the two control points on the model before optimization and after optimization. Positioning the control points are indicated in Figure 4 a, b, c, the maximum imprecision was 3 microns.

Fabrication of the abutment from titanium and zirconium oxide occurs by milling on a 5-axis milling machine imes - icore 450i. Preparation milling strategy occurs in the program SUM 3D.

While writing strategies taken into account the features of processing of materials. For titanium necessary to maintain a small contact area by reducing the milling step on the vertical axis because titanium is the low thermal conductivity material. In this metal is only a small part of the heat away with shavings, most of the heat is transmitted to the milling cutter. The important point is cutting an arc, which allows saving the resource of milling cutter. The effect is comparable to a hammer blow to the cutting edge in the direct cutting of milling cutter. For direct plunging of milling cutter was used circular walkways. Due to the small size of the abutment, milling cutter with diameter 0.6 mm was used. Therefore, heat transfer from the workpiece increased by the milling with the milling cutter which does not exceed 70 percent of the groove diameter. With a smaller gap significantly increases the risk of restricting access of coolant to the instrument and retention of the shavings.

When working with zirconium dioxide should take into account the fragility of the material and reduce the milling step in all directions and cutter speed. Of zirconium dioxide feature is to have the effect of shrinkage during baking in the oven, after which attains a high strength. This feature should be considered while writing strategy. During registration of the disc is required to specify the shrinkage factor, which is written on the disc package and is usually from 1.15 to 1.25. Imprecision of five-axis milling machine imes - icore 450i equals 15 microns.

Conclusion

With reverse-engineering was possible to obtain high precision abutment. It is possible to produce customized abutments to install on a standard implant by this developed technique. Abutment is manufactured by milling of titanium and zirconium oxide on the machine-tool imes - icore 450i. The maximum imprecision in the production of the abutment by reverse engineering was 18.1 microns.

References

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