Development of the technology of manufacturing a ceramic tip of a resectoscope

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Abstract. The development of medical technology is strongly correlated with the development of new materials and the technology of their processing. At the moment, the most common type of surgery is resection of the prostate gland, for its use a resectoscope is used. In this work, the problem of increasing the mechanical characteristics of ceramic tips of resectoscopes is solved. The material of yttrium stabilized zirconia has been tested and manufacturing technology based on CAD / CAM and heat treatment has been proposed.

Introduction

Endoscopic operations have become widespread in clinical practice, while gaining increasing recognition in professional medical circles. Treatment with this method covers a wide range of diseases, whose treatment was once possible only by traditional surgical intervention. To ensure the accuracy of surgical manipulations and ensure the effectiveness of the operation, special endoscopic instruments are used. For this, resectoscopes are actively used in urology and gynecology.

In urology, resectoscopes are used for transurethral electroresection of the bladder neck with its sclerosis, resection of the prostate gland with its adenoma and cancer, resection under the control of papilloma vision and tumors of the bladder etc. In gynecology, resectoscopes are used to diagnose and perform various kinds of surgical interventions in the uterine cavity, in which the instrument is inserted through the cervix (cervical canal). At the same time, during the operation, the abdominal opening is not performed and the anatomical integrity of the organism is not disturbed. Directly, resection (removal of tissues) and coagulation of blood vessels is carried out by high-frequency electric current. Resectoscopy is a minimally invasive operation, the postoperative rehabilitation period is significantly reduced.[1],[2],[3]

The use of resectoscopes ensures high accuracy of medical manipulations and controllability of the operation as a whole. The principle of action resectoscope allows you to get a highly effective result, and in addition, significantly reduces the rehabilitation period.[4]

The modular design of the instrument (Figure 1a) consists of an external tube, an internal tube with an insulating ceramic tip for insulation and protection against heating of the cutting element (Fig. 1b), an operating element with a handle and an electrode attachment, an obturator with a smooth distal end, which is inserted into the inner tube for atraumatic injection of the resectoscope into the cavity.
Developers are constantly improving the designs of resectoscopes. New resectoscopes practically exclude the risk of thermal burns of healthy tissues and postoperative complications. Modern models of the device provide a full visualization of endosurgical manipulations, safe excision of damaged tissues and accurate coagulation. [1]

After analyzing the design of the resectoscope, it was established that the ceramic tip for insulation and protection from heating the cutting element is not always reliable - it is brittle enough and in the process of operation it breaks down. During the operation, this can lead to irreversible consequences. In addition, these tips are imported from abroad and have a high cost. To date, these tips are made of aluminum oxide.[1],[2],[5],[6],[7]

The purpose of the research is to increase the life of the tip by replacing it with new material. Thus, it is necessary to solve two main tasks: 1) to choose a material with high dielectric, strength and thermophysical properties; 2) choose technology and processing modes. [1],[8]

Main part

In the studies, two types of tips were used, shown in Figures 2a and 2b.

Both tips are a tube 15.5 mm long and an external diameter of 8 mm.

When choosing the material, certain requirements for the material were taken into account, namely high bending strength (750-1000 MPa), Young’s modulus - 200 GPa, crack resistance - 8 MPa m½, coefficient of thermal expansion - 10 * 10-6 * K-1, high dielectric properties, breakdown voltage - 1000V, and ease of processing.

Such characteristics are possessed by zirconium oxide, namely ceramics based on zirconium dioxide ZrO2 partially stabilized with yttrium oxide (Y2O3).

Zirconium oxide in sintered form is difficult to process, so milling is carried out before heat treatment. Before sintering, zirconium oxide is similar in properties and characteristics to ordinary chalk. The processing of such material is feasible only by using the CAD / CAM system. CAD / CAM technology has a number of advantages: high precision of work, short terms of manufacturing of parts, saving of working place, automatic creation of trajectory of grinding, preliminary account of material shrinkage during sintering, high productivity.

It is also important that zirconium oxide is allowed for medical use, which will greatly simplify the process of launching the product into production.

Due to the fact that the tips have a thin wall, and the material itself is brittle enough (before sintering), a CAM-center was used for manufacturing. Namely, the model developed with the help of CAD-technology was grinded on an automated 5-axis CNC milling machine Coritec 450i.
To work with the CAM system, we need three-dimensional models of tips in the STL format that were created in the CAD system.

Then the 3D models of the tips were imported into the cad system. At this stage, first the necessary zirconium oxide blank is selected in the Sum 3D program, the shrinkage factor is specified (because during sintering, zirconium oxide shrinks and only afterwards acquires the required dimensions), the tips are placed, support is built, the necessary grinding strategy is selected with allowance for the modes of machining (cutter size, feed rate, tool rotation speed, etc.) and machining path, then the g-code is generated. In the same program, using the "Simulation" function, a visual check of the resulting trajectories is performed.

After completing the work in the SUM 3D program, the finished g-code is transferred to the machining center - the 5-axis milling machine Coritec 450i.

When drilling, drills of three sizes were used: 2.5, 1.02 and 0.6 mm. Drills 2.5 and 1.02 mm are required for rough and medium processing, and 0.6 mm for final finishing. As a blank was used a standard disc of zirconia partially stabilized with yttria (Y2O3) G 526 thickness of 12mm and a heat shrinkage factor of 1.256. The processing of the two tips was carried out for 20 minutes. After milling, the tips are extracted from the zirconium oxide blank and sintered.

Sintering was performed on a P 330 Nabertherm controller. For the sintering of parts, a sintering regime for small structures was chosen. In this mode, the temperature rises to 900 °C for 90 minutes. When this temperature is reached, the exposure is held for 30 minutes, then within a hundred minutes the temperature increases to 1550 °C. When the 1550 °C mark is reached, the temperature rise stops and a 2-hour exposure at 1550 °C is carried out. Further, the products cool down to 200 °C for 2 hours.

Obviously, the most optimal and effective technology for processing zirconium oxide is CAM-technology. Its use excludes manual work and settings on the milling machine, allows you to adjust the parameters and machining configuration without loss of time.

Figure 3a shows a photo of a zirconium oxide billet. Figure 3b shows the finished tips after extraction from the preform and subsequent sintering.

![a) zirconium oxide](image-a.png) ![b) ready-made tips](image-b.png)

**Figure 3. Machined parts**

The resulting finished products were tested for dielectric strength and performance. Tests on the samples were carried out using a megawatt F 4102 / 2-1M at a voltage of 1000V. The tests proved the dielectricity of the new ceramic tip. [8]

Thus, the suitability for using a zirconia tip was established.

**Conclusions**

As a result of the carried out researches the technology for manufacturing ceramic tips for resectoscopes was chosen. This led to a simplification of manufacturing technology and increased reliability of the tips.

The tool has become much easier to manufacture and more reliable to use.

The developed technology for the manufacture of ceramic parts makes it possible to manufacture ceramic tips for resectoscopes of «Aleps» firm, which are used in gynecological and urological...
operations. The use of the new technology made it possible to fabricate tips with the necessary spatial configuration and sufficient dimensional accuracy. The material used was more durable than the material in the imported instruments. The use of tips for resectoscopes obtained by the new technology makes it possible to increase the reliability, service life of the product and reduce the cost of the final instrument.

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