ZIRCONIA FEMORAL COMPONENT OF THE TOTAL KNEE REPLACEMENT

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INTRODUCTION: The main disadvantage of the knee endoprosthesis having the metallic femoral component (FC) and UHMWPE tibial plateau is a relatively high formation of toxic debris of polyethylene. This is a major cause of ostheolysis, gradual bone degeneration and subsequent prostheses loosening. The effort to minimize this abrasion has resulted in the application of ceramic materials to be used for FC. This research works were carried out in the following fields: verification of suitability of the cold isostatic pressing method (CIP) of creating intermediate product of the ceramic FC, experimental research, and FEM stress comparison analysis, of both the metallic and ceramic femoral components.

MATERIALS AND METHODS: Although the situation seems to be similar when replacing no-completely bioinert materials of hip joints by ceramics there is a great difference between geometry of the hip joint and the knee joint. For the reason of the shape complication, the injection molding was chosen. A manufacture of the model of the prototype knee mold occurs as another difficult problem. After having coped with the CAD construction of the knee components we aimed at a fast providing of the 3D models for the mould formation. After estimating all parameters, a priority was given to the process of the 3D Rapid Prototyping. Based on the CAD construction, manufactured were models on the base of ABS, according to the 3D RP method (FDM). These models were used for manufacturing sample moulds for the CIP method of ceramic semi-products (Zirconia Y-TZP ceramic). According to the results of previous works, priority was given to the technology of forming ceramic powder by the CIP method. The following thermal operations were carried out in an oxidative atmosphere. Corrections of the dimensions of functional areas were carried out on a CNC milling machine.
On thus obtained component, basic physical and mechanical tests according to ISO 13356, EN 843 and 623, were carried out. There were manufactured testing particles from the zircon, and these testing particles meet the test according to the standards ISO-EN 843-1 and 4 for measuring the bending strength and microhardness. The fracture toughness was determined by calculating from values, which we have obtained at microhardness test. The volume mass stated in accordance with ISO-EN 623-2 reached the value of 6.03-4 g/cm^3 (i.e., 99.6 % of theoretical density). The calculation of Weibull modulus was carried out based on the bending strength measurement. Laboratory confirmation of the increased abrasion resistance at the ceramic combination FC against the tibial component made from UHMWPE, and the cyclic fatigue test may be carried out only on a knee simulator. Therefore such a knee simulator was designed. The necessary biocompatibility tests, according to ISO CSN 30993-1, were carried out on: cytotoxicity and carcinogenity, allergization, genotoxicity (Ames test) and implantation compatibility.
By means of FEM, the contact pressures and stress distributions of two models of the knee replacement were calculated, as well as the stress comparison analysis of these models. The first model had metallic and the second model ceramic FC. Each of the FE models consisted of 15956 elements and 96057 degrees of freedom. The presented non-linear and contact analyses were performed considering the knee joint in full extension under the femoral - tibial force loading, corresponding to the three times BW. The bottom side of tibial plateau was fixed. The maximum contact pressures resulted in 8.2 MPa (the metallic FC) and 8.2 MPa (the ceramics FC). While the maximum Mises stresses were 5.7 MPa (the metallic FC) and 7.4 MPa (the ceramics FC). The maximum Misses stresses in the tibial plateau resulted in 7.0 MPa (the metallic FC) and 7.1 MPa (the ceramics FC).
CONCLUSION: The CIP method showed itself as a progressive production technology of the

ceramic FC, which follows the best mechanical properties of the final components. The CIP method is perspective for a small-scale serial production of the anatomical-shaped FC made of bioceramics. The introductory physical-mechanical properties of the material of the components, produced by the CIP method, reach a demanded level. The first tests executed on the knee simulator are also promising. There are not any significant differences between the stress distributions in the metallic and ceramic FC. The contact pressures were proved to be quantitatively identical in the two types.

REFERENCES:

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