EXPERIMENTAL EVALUATION OF COMBINATIONS OF MATERIALS USED FOR ORTHOPAEDIC IMPLANTS

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Abstract: The abrasion is indispensable parameter for evaluation of the mechanical properties. This article deals with very specific wear resistance testing of the biomaterials used for orthopaedic implants. This type of testing is very important for evaluation of the pertinence of different type of biomaterials. The special wear resistance test is called "Ring On Disc". The experiments were carried out in "Laboratory of Biomechanics" with 5 groups of specimens from different materials. There were 5 tested pairs in each group. The main parameter of the test – the wear volume – was determined.

Introduction

No known surgical implant material has ever been shown to be completely free of adverse reactions in the human body. However, long-time clinical experience of use of the biomaterials has shown that an acceptable level of biological response can be expected, when the material is used in appropriate applications.

This article deals with very specific wear resistance testing of the bio-compatible and bio-stable materials used for surgical implants. The abrasion is indispensable parameter for evaluation of the mechanical properties. This type of testing is very important for appreciation of new directions at the joint replacement design (for example in total knee replacement). The special experiments were carried out in collaboration with company Walter Corporation - developing and producing bone-substitute biomaterials and implants.

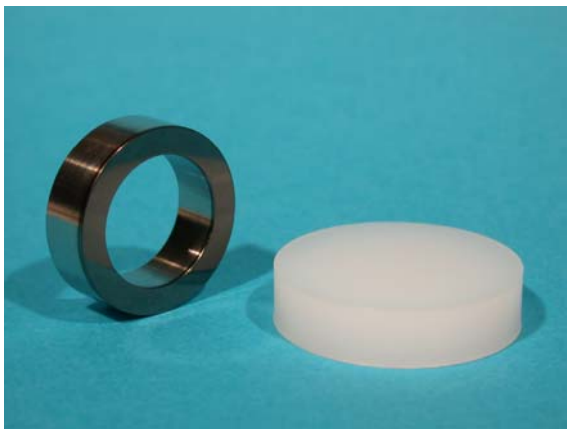

Figure 1: The pair of tested specimens

Materials and Methods

The special wear resistance tests, called "Ring On Disc", were completely carried out with a lot of pairs (Figure 1) of different biomaterials. The experiments were executed according to ISO 6474:1994(E). This International Standard deals with evaluation of properties of biomaterials used for production of bone replacement. The standard requires a long-time mechanical testing at which a complete volume of worn material is evaluated. The test conditions, requirements on the testing system and specimens' preparation are closely determined. For the specimens treatment and their evaluation, a procedure is assessed which ensures the testing objectivity.

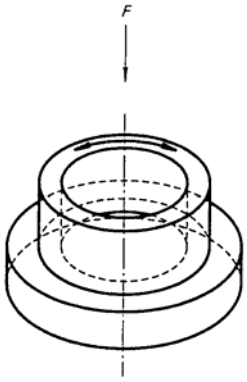

Figure 2: Schematic diagram

The method is based on loading and rotating two pieces from biomaterials. The Figure 2 shows the schematic diagram of the test. A ring is loaded onto a flat plate from different material. The axial load that is applied on the ring is all the time constant and equal 1500±10 N. The ring is rotated through an arc of ±25° at a frequency of (1 ± 0.1) Hz for a given period of time (100 ± 1) hours. There is distilled water using as the surrounding medium.

The outer diameter of the ring is 20 mm, inner diameter is 14 mm. Thickness of the ring is 6 mm. The diameter of the disc is 25 mm and thickness is 6 mm. The Figure 3 shows the geometry of ring and disc test pieces with definition of necessary dimensions.

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The special jigs were used for fixing both specimens during testing. These jigs have to be able to undergo oscillatory rotation of the ring specimen about fixed axis using a sinusoidal or near-sinusoidal rate of change of angle. The disc-holding device is equipped with the especial joint to ensure the plane of the disc surface coincides with the plane of the ring surface at all times during the test.

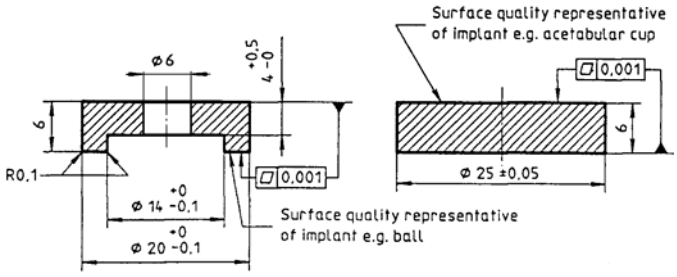

Figure 3: Geometry of ring and disc test pieces with dimensions.

To control the test, a program was developed using the TestWare software, which, according to set limit values, reacts immediately on their reaching, or crossing, by an action selected in advance. The control program stores, in the data files, data concerning the time, the pressing force, the piston vertical position, the rotation angle, the torque, the number of cycles and the distilled water temperature.

Figure 4: The device for profile measurement

During the test, it comes, due to the specimen's friction, to heating and evaporation of water. Therefore, to supply the liquid into the space of the make-up piece, the PCD 21 peristaltic pump, adjusted to a minimum velocity for reaching dosing of about 0.025 ml/min, was used.

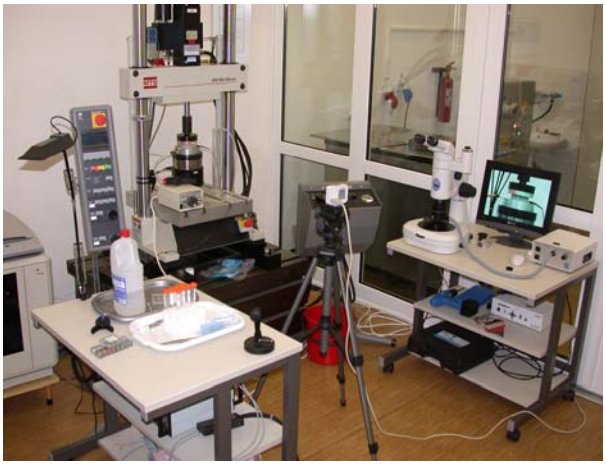

Figure 5: Laboratory of Biomechanics

As a measure of wear resistance is determined and used volume of the wear track on the disc. The wear track cross-sectional area is analyzed from measured profile (see Figure 6) for each disc alone according to (1). The volume is calculated from this area according to (2). After that the average volume is calculated for one group of specimens.

The profile measurements of the tested specimens (see Figure 7) were carried out using a specially adapted assembly. To determine the vertical position of points on the disc was used the digital drift sight MAHR EXTRAMESS 2001, with the sensitivity of 0.2 µm, placed in a sufficiently stiff stand (see Figure 4). A positioning cross-table (ZEISS), containing a make-up piece (in which the disc was inserted), served for the disc shifting. The cross-table is movable in two axes by means of two micrometric screws. The shifting sensitivity is 0.01 mm. Measured data were registered in a table prepared in advance.

$$A = \left(h_o - h_i\right) \cdot \left(r_o - r_i\right) \tag{1}$$

$$V = \pi \left(r_o + r_i\right) A \tag{2}$$

where V [mm^3] is wear volume
A [mm^2] is wear track cross-sectional area,
h_o [mm] is average value of vertical level of measured points outside of the track,
h_i [mm] is average value of vertical level of measured points inside of the track,
r_o [mm] is average value of outer radius,
r_i [mm] is average value of inner radius,

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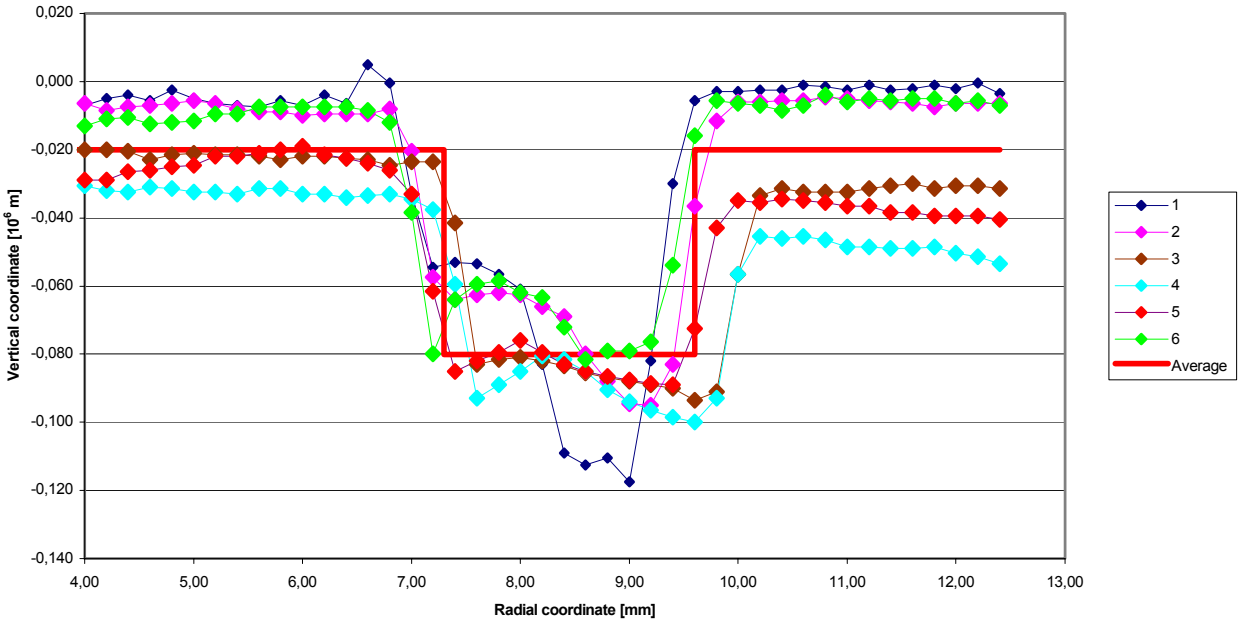

Figure 6: Track profile measured from the disc

The Experiments were carried out on the top quality testing system MTS 858 MINI BIONIX placed in "Laboratory of Biomechanics" (see Figure 5) at the Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Mechanics.

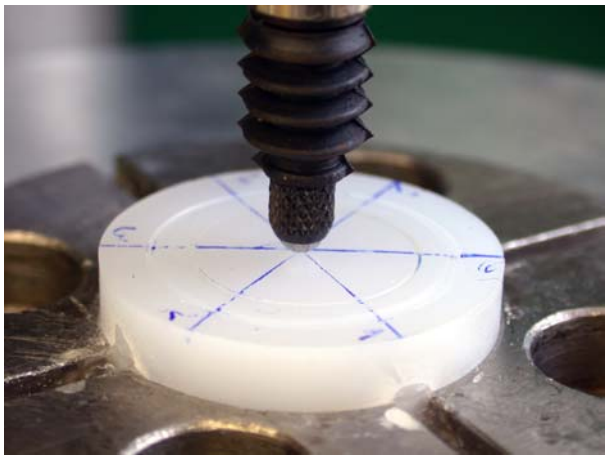

Figure 7: The disc after finishing the test

Results

The tests were executed with 5 groups of specimens from different materials. There were 5 tested pairs in each group (as it is required in international standard). That means 5x5x100 hours of testing. The final parameters obtained in these tests - the wear volumes - were calculated (see Table 1).

Table 1: Final parameters of mechanical testing.

Material of RING	Material of DISC	Wear volume [mm^3]
Zirconia ceramics (Y-TZP)	Alumina ceramics	0,16
Zirconia ceramics (Y-TZP)	Pressed UHMWPE	2,95
Zirconia ceramics (Y-TZP)	UHMWPE	4,64
Titanium alloy (Ti_6Al_4V) with DLC	UHMWPE	6,61
Zirconia ceramics (Y-TZP)	PEEK (PolyEtherEtherKetone)	7,59

Conclusion

We obtained the objective information about wear resistance for these combinations of materials. The resulting wear volume indicates the amount of elements that are loosening during loading of the bone substitute implant in human body and describes one from the mechanical properties.

The comparison of different combination of biomaterials used for implants can be implemented from this analysis.

For next development it is purposeful to finish tests with other bone-substitute materials and increase the database with wear resistance evaluation.

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References

[1] SEDLACEK, R. - ROSENKRANCOVA, J.: *Experimental Analysis of Tribological Properties of Biomaterials Used for Orthopedical Implants*. In 13th Biennial Conference for the Canadian Society for Biomechanics, Canadian Society for Biomechanics, Halifax, Nova Scotia, Canada, 2004, p. 178 - 182

[2] SEDLACEK, R. – ROSENKRANCOVA, J.: *The Wear Resistance Testing of Biomaterials Used for Implants*. In Bioceramics - 16, International Society for Ceramics in Medicine (ISCM), Porto, Portugal, 2003, p. 703 - 706

[3] SEDLACEK, R. – ROSENKRANCOVA, J.: *Experimental Evaluation of Biomaterials – PEEK*. In 20th DANUBIA-ADRIA SYMPOSIUM, Scientific Society of Mechanical Engineering, Györ, Hungary, 2003, p. 164 - 165

[4] SEDLACEK R. - ROSENKRANCOVA J.: *Mechanical Properties of the Biomaterials Used for Surgical Implants*. In 17th European Conference on Biomaterials, Technical University of Catalonia, Barcelona, Spain, 2002, P117

ISSN: 1727-1983