EXPERIMENTÁLNÍ HODNOCENÍ VLIVU SÍŤOVÁNÍ UHMWPE NA ODOLNOST PROTI OTĚRU

EXPERIMENTAL EVALUATION OF THE INFLUENCE OF UHMWPE CROSSLINK ON THE WEAR RESISTANCE

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Abstrakt

Článek se zabývá specifickým testováním odolnosti proti otěru u biokompatibilních a biostabilních materiálů, které se používají k výrobě ortopedických náhrad. Hodnocení otěru je důležité pro posouzení mechanických vlastností materiálu. Cílem této práce bylo zjištění vlivu síťování UHMWPE na jeho odolnost proti otěru – hodnotícím parametrem je opotřebený objem. Testování bylo prováděno s ozářenými a neozářenými vzorky v Laboratoři mechanických zkoušek. Metodika testování byla založena na mezinárodní normě ISO 6474:1994(E).

Klíčová slova: biomechanika, otěr, UHMWPE, implantát.

Abstract

This article deals with very specific wear resistance testing of the bio-compatible and bio-stable materials used for producing orthopedical implants. The abrasion is indispensable parameter for evaluation of the mechanical properties. The research aim of this work was set on finding out the influence of γ-radiation on UHMWPE (crosslink). The evaluating parameter was wear resistance – the volume of worn material. The test was carried out with irradiated and nonradiated disks at the Mechanical Testing Laboratory. The method of testing was based on international standard ISO 6474:1994(E).

Keywords: Biomechanics, Wear, UHMWPE, Implant.

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. This type of testing is very important for appreciation of new directions at the joint replacement design (for example in total knee replacement). The aim of this work is to evaluate the ifnluence of crosslink (γ-radiation) of UHMWPE on the wear resistance. The special experiments were carried out in collaboration with company Walter Medica Corporation - developing and producing bone-substitute biomaterials and implants – and The Academy of Sciences of the Czech Republic.

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MATERIALS AND METHODS

The special wear resistance tests, called "Ring On Disc", were completely carried out with a lot of pairs 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 spacers, bone replacement and components of orthopedic joint prostheses. 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. The testing objectivity is ensured by the procedure for the specimens' treatment and their evaluation.

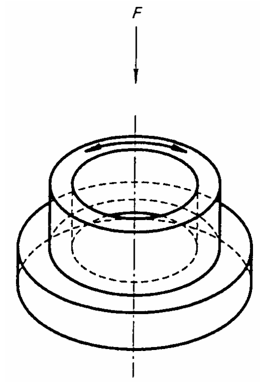

Fig. 1 Schematic diagram

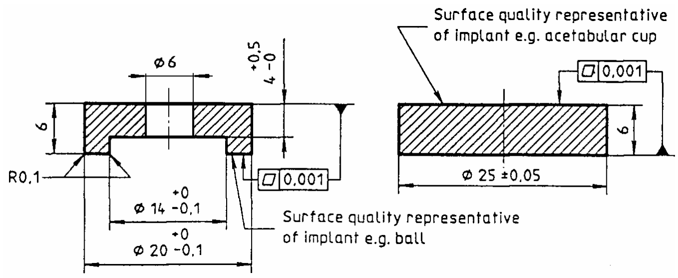

Fig. 2 Geometry of ring and disc test pieces with dimensions

The method is based on loading and rotating two pieces from biomaterials. The Fig.1 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 Fig.2 shows the geometry of ring and disc test pieces with definition of necessary dimensions.

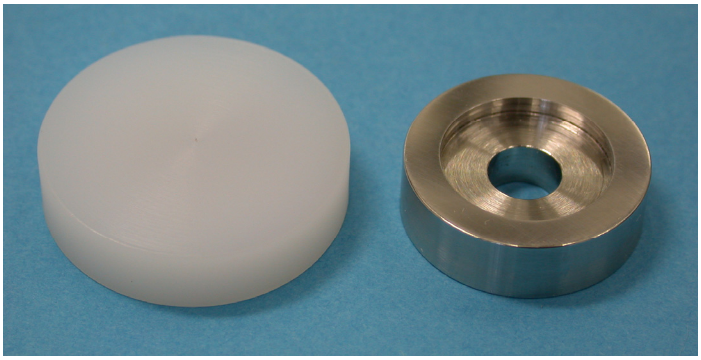

Fig. 3 The pair of tested specimens

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 Fig.4) 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

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

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

where V [mm3] is wear volume
A [mm2] is wear track cross-sectional area,
ho [mm] is average value of vertical level of measured points outside of the track,
hi [mm] is average value of vertical level of measured points inside of the track,
ro [mm] is average value of outer radius,
ri [mm] is average value of inner radius,

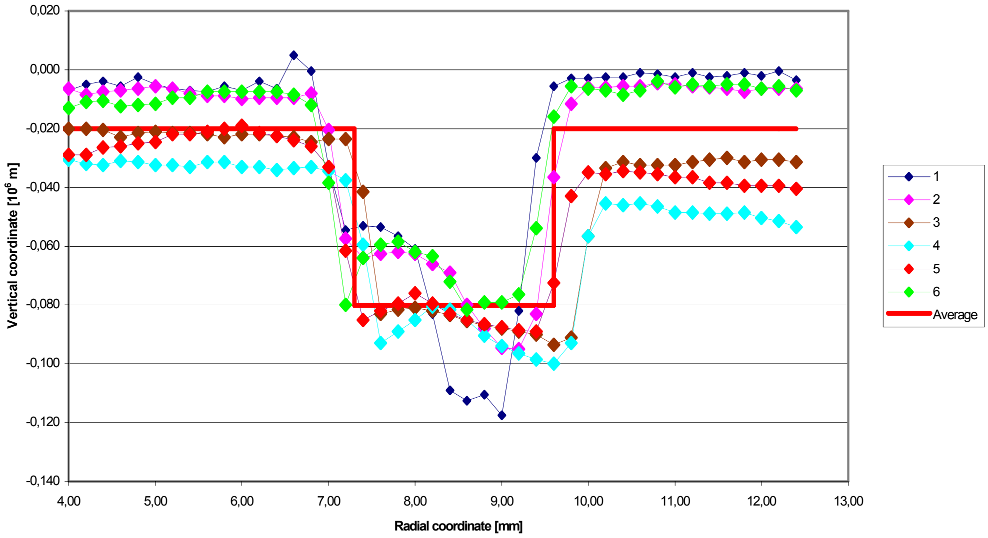

Fig. 4 Track profile measured from the disc No. 1

The profile measurements of the tested specimens 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. 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.

The experiments were carried out on the top quality testing system MTS 858 MINI BIONIX placed in "Laboratory of Biomechanics" at the Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Mechanics, Biomechanics and Mechantronics.

RESULTS AND DISCUSSION

The evaluation was addict on the **influence of γ-radiation (crosslink) of UHMWPE**. The tests were executed with 2 groups of specimens. The first group of UHMWPE disks was without irradiation. The second group of UHMWPE disks was irradiated by 100 kGy. The rate of irradiation was 2.5 kGy per hour. The rings were made from the same material without irradiation for all groups – from Vitalium (Co-Cr-Mo alloy). There were 3 tested pairs in each group (means 2x3x100 hours of testing). The finished parameters obtained in these tests - the wear volumes - were determined (see Table 1).

Final parameters of mechanical testing **Table 1**

Material of RING	**Material of DISC**	**Wear volume [mm^3]**
Vitalium alloy (Co-Cr-Mo)	UHMWPE (no crosslink)	5,51
Vitalium alloy (Co-Cr-Mo)	Irradiated UHMWPE (crosslink) – 100 kGy	4,78

CONCLUSIONS

We obtained information about wear resistance for tested modification of biomaterials. We found out the worn volume on the UHMWPE irradiated by 100 kGy (rate 2,5 kGy/hour) is less than on nonradiated UHMWPE. The wear resistance of irradiated UHMWPE is better by 15 %. 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.

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