A NOVEL MULTIAXIAL WEAR TESTER FOR ACCELERATED TESTING OF MATERIALS

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Relevance to Musculoskeletal Conditions: Development of an accelerated wear tester that is clinically relevant will allow rapid evaluation of potential materials to be used in the artificial joint replacement.

Introduction: There is a need for an accelerated wear tester that can evaluate different material pairs in a short time. Current pin-on-disc tester and ASTM F732 test methods produce results that often contradict long term simulator tests. Recent papers[1,2] suggest that multiaxial motions are important in reproducing the surface textures and wear debris morphology. The objective was to design and build a universal wear tester that is capable of multiaxial motion, programmable load history, and able to evaluate various material combinations, including hard on hard bearing material pairs.

Method: Two moving stages, driven by separate motors, are placed orthogonal to each other. For this evaluation, the contact surfaces consist of an ultra-high molecular weight polyethylene (UHMWPE) pin and a Co-Cr alloy disc. One stage holds the pin which glides on an inclined plane. Loading is achieved by geometric interference only with the disc on the second stage. There are actuators placed underneath the stages so that the inclined angles can be adjusted and programmed. Both the stroke lengths and frequencies (velocities) of motions of the two stages are independently controlled. In theory, virtually any pattern of motion can be achieved by adjusting the stroke length and frequency of the two stages. The machine is designed to be rigid and stiff with minimal vibration. The test is controlled by a PC using LabVIEW™ software (National Instruments)[a].

Three known wear-level UHMWPE samples were used. These were samples subjected to three different gamma irradiation conditions: 40 kGy in air, 40 kGy in vacuum, and 80 kGy in vacuum. Wear results of the two 40 kGy materials had been published by Schmidt et al.[3]. These samples were used to calibrate the tester and to develop the test protocol.

The UHMWPE pins were cylindrical in shape and had dimensions of 6.35 mm in diameter and 19.05 mm in length. The Co-Cr alloy discs had dimensions of 50.8 mm in diameter and 5.8 mm in thickness. The discs were polished to have a typical centerline surface roughness Ra=0.05μm.

The wear tests, in bovine serum, were conducted by using the following procedure. The UHMWPE pins were presoaked in bovine serum for a minimum of 14 days prior to testing. They were cleaned and weighed periodically during the test. A minimum of 3 soak control pins were used in each test. For motion control, one stage was set to oscillate at a frequency of 1.8 Hz and a stroke length of 9.5 mm, while the second stage was set at 0.9 Hz and a stroke length of 19.1 mm. By setting the phase difference between the two oscillation directions, the pin traced a figure-8-shaped path on the Co-Cr disc (0.9 Hz, mean linear velocity, ca. 49 mm/s). The load was controlled by the geometric interference. The Co-Cr disc was set at an incline of 2^{o} with the horizontal and the upper stage (UHMWPE pin) has a 0.6^{o} incline angle. This setup resulted in a load history similar to a Paul type loading curve. The peak load attained from the geometric interference was approximately 400 N with a mean contact pressure of ~13 MPa. The peak load was monitored and adjusted to be nearly constant throughout the test to compensate for the wear and creep deformation. A spike load was provided by a set of two actuators underneath the sample holder to provide a computer program driven load increase of 10 % during 20% of the cycles. The pin position was adjusted with respect to the inclined plane so that a 0.2 s relaxation time (no contact) was included in each cycle (20% of the cycle time). During the test, the normal force and the tangential force were continuously measured by a force transducer mounted on the top stage.

Results: Wear (mass loss) of UHMWPE was obtained in 5 days or less. The mass loss data were corrected for fluid uptake by using the average mass gains in the soak control pins. Results are shown in Fig. 1. The ranking of materials is consistent with previously published results for 40 kGy, air and vacuum specimens[3]. Surface texture, as observed by using a scanning electron microscope (SEM), is shown in Fig. 2. It can be seen that 1) separation among the three samples was achieved; 2) the worn surface texture is similar to the *in vivo* case[4]. The wear debris in the serum were also collected and examined by using SEM. The wear debris morphology was similar to those observed in retrieval studies[4,5].

Discussions: A versatile wear tester has been designed and built. The initial study showed that with this tester, test procedures can be developed to achieve clinically relevant simulations in a short time. With the continuously monitored force traces, this tester can be used to study the wear mechanisms of different material pairs. Understanding of the wear mechanisms will aid the rapid development of improved artificial joint materials development.

References: 1) Bragdon et al., Proc. Instn. Mech. Engrs., **210**:157, 1996. 2) Bragdon et al., Trans. 5th World Biomat. Cong., 788, 1995. 3) Schmidt et al., Trans. Soc. for Biomaterials, **21**:415, 1998. 4) McKellop et al., CORR, No. 311, 3, 1995. 5) Schmalzried et al., J Biomed. Mater. Res. (Appl. Biomater), **38**:203, 1997.

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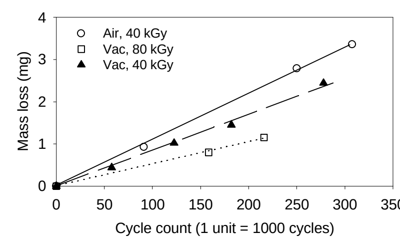

Figure 1: Wear results of the three UHMWPE materials
(Standard deviations < 0.05 mg; not a complete statement of uncertainty)

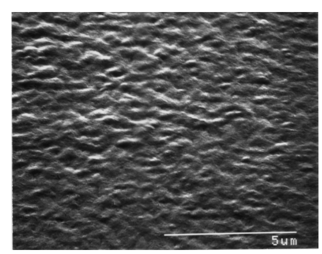

Figure 2: Worn surface of air, 40 kGy pin

[a]Materials and equipment are identified only for describing experimental procedure and do not imply recommendation or endorsement.

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