

WEAR AND WEAR DEBRIS OF ZIRCONIA TOUGHENED ALUMINA AND HIPED ALUMINA BEARINGS IN A HIP JOINT SIMULATOR UNDER STANDARD AND MICROSEPARATION CONDITIONS

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Introduction

There is currently considerable interest in alumina alumina bearings and their potential to reduce wear and wear debris induced osteolysis caused by conventional bearing couples. Alumina / Alumina bearing couples in the hip have shown very low wear rates *in vitro* under standard conditions⁽¹⁾. When microseparation is introduced into the simulator cycle wear rates approaching 1 mm³/million cycles similar to those found clinically have been reproduced⁽²⁾. It is of interest to combine in the same design Alumina qualities from different producers. There remain some concerns over the low fracture toughness and brittleness of Alumina bearings. Recently two manufacturers have developed different Zirconia toughened Aluminas with improved fracture toughness. The aim of this study was to compare the wear and wear debris produced with these Zirconia toughened Alumina bearings to standard Hiped Alumina bearings in a hip joint simulator.

Materials and Methods

Tests were conducted in a physiological hip joint simulator. The acetabular cup and insert was positioned superiorly inclined at 30° to the vertical loading axis. A twin peak Paul type loading curve was applied. Two independently controlled motions were applied, flexion extension to the femoral heads and internal external rotation to the cup. The test was carried out under standard conditions lubricated in 25% bovine serum with the wear measured gravimetrically every million cycles. After three million cycles, microseparation conditions were applied to the simulator by applying a small medial to lateral force which separated the head and cup by up to 400 µm during swing phase. Upon reapplication of the load the head contacted the rim of the cup before relocating⁽²⁾. The test was carried out to 5 million cycles under microseparation conditions.

Six Zirconia toughened Alumina prostheses were tested, three from Manufacturer A (AZTA), and three from Manufacturer B (BZTA) and compared to previous Alumina (CAI; Biolox Forte Ceramtec). An additional test were also carried out on an alternative Alumina (DAI) articulating against (CAI).

Results

The wear rates under standard and microseparation conditions are shown in Table 1. All three bearing couples produced very low wear rates < 0.1 mm³/million cycles under standard conditions. Although the wear rates of the ZTA materials were lower than the Alumina, the difference was not statistically significant. All bearings increased their wear rates by more than 30 fold under conditions of microseparation to between 1 and 2.1 mm³/million

cycles and produced stripe wear on the heads of all materials. This was similar to wear patterns found on retrieved prostheses^(1,2).

Material	Wear Rate mm ³ /million Cycles	
	Standard Condition 0 to 3 million cycles	Microseparation 3 to 5 million
AZTA / AZTA	0.03 ± 0.05	1.6
BZTA / BZTA	0.03 ± 0.06	1
CAI / CAI	0.07 ± 0.04	2.1
DAI / CAI	NA	1.4

Table 1 - Wear rates under standard and microseparation conditions mean ± 95% CL

The surface roughness of the heads did not change under standard testing conditions ($R_a < 0.01 \mu\text{m}$). However, under microseparation, intergranular fracture occurred in the area of stripe wear and the R_a increased to 0.05 µm for the ZTA heads and 0.18 µm for the Alumina heads. The wear debris analysis reflected the change in surface roughness with very small nanometre size particles under standard conditions but small 10 nm and greater than 100 nm size particles under conditions of microseparation.

Discussion

Standard Alumina / Alumina articulation couples produced very low wear < 1 mm³/million cycles under standard conditions and low wear ($\approx 1 \text{ mm}^3/\text{million}$ cycles) under microseparation conditions with wear rates, surface mechanisms and debris representative of clinical retrievals^(2,3). Coupling qualities from different Alumina producers in products of the same design from one implant manufacturer does not change this tribological condition. Zirconia toughened Alumina bearings showed similar changes in wear with very low wear under standard conditions and low wear under conditions of microseparation. Under conditions of microseparation the average ZTA wear rates were slightly lower than the Alumina wear rates and the surface roughness changes less marked, which perhaps reflected the improved material properties. These studies indicate that both the new ZTA Aluminas may also produce stripe wear under conditions of microseparation and rim contact *in vivo*. However even under these severe test conditions the low wear rates remained low at less than 2 mm³ per million cycles.

1. Nevelos et al. Trans 45th ORS, 857, 1999.
 2. Nevelos et al. J. Arthroplasty, 15, 793-795, 2000.
 3. Hatton et al. Proc. 6th World Congress Biomaterials 1188, 2000.
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