LUBRICATION AND WEAR OF ALUMINA-ALUMINA HIP BEARINGS

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ABSTRACT

Since the identification of polyethylene wear debris as a major cause of osteolysis and loosening in total hip arthroplasty, there has been a growing interest in alternative bearing materials such as alumina-on-alumina. Past simulator studies have generally predicted lower wear rates compared with clinical cases [1], for reasons that are not well understood. The current study investigates the lubrication and wear of six alumina-alumina hip implants subjected to Paul-type, cyclic loading in an orbital hip simulator [2]. The implants had small variations (avg. ± std. dev.) in diametral clearance (94 ± 10.3 µm) and combined root mean square roughness (5.06 ± 0.422 nm). The lubricant was bovine serum diluted with distilled, deionised water to form either 30% or 90% by volume solutions. The implants were tested for a total of 3 million cycles (Mc) with pauses every 0.25 ± 0.03 Mc to change serum and measure mass loss. Volumetric wear was determined by converting mass loss using a density of 3.96 mg/mm³.

![Figure 1: Total Volumetric Wear](image1)

The highest average wear rate occurred during the first 0.25 Mc and levelled off to an average steady-state wear rate of 0.036 mm³/Mc (Figure 1). No significant difference in wear rates was observed for the two serum solutions, even though some protein degradation did occur at the 30% level. This demonstrates the high wear-resistance of the alumina-alumina couple. The implant surfaces were analyzed at the end of testing using atomic force microscopy (AFM) (Figure 2), which revealed distinct grain-relief patterns around the apex of the head. The surface damage appeared to follow certain crystallographic planes with occasional pits from grain pull-out. The latter could, in turn, cause damage by third body wear mechanisms.

![Figure 2: a) Unworn Surface; b) Apex Region Wear](image2)

The roughness in the contacting apex region (top 15°) of the head was approximately 66% higher than that of the unworn surfaces, as measured by AFM. The minimum cyclic lambda ratio, which is indicative of the lubrication regime (i.e. fluid film, mixed film, or boundary [3]), was estimated at between 3 and 5. This range suggested predominantly fluid film lubrication with the possibility of mixed film action. Despite the protection that such lubricant films would afford, surface damage did occur during testing at both serum concentrations. Thus, surface fatigue might have been the dominant wear mechanism.

Although the wear rates found in the current study were higher than some other alumina-alumina simulator studies [4], they were still low compared to those found in clinical retrievals [1]. Therefore, studies have been initiated on the effects of third body particles and stop-start motion, which may result in abrasive wear mechanisms with the loss of fluid film protection.

REFERENCES