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Long-term wear of HIPed alumina on alumina bearings for THR under microseparation conditions

T. STEWART[1], J. TIPPER[2], R. STREICHER[3], E. INGHAM[2], J. FISHER[1]
[1]*School of Mechanical Engineering, University of Leeds, LS2 9JT, UK*
[2]*Division of Microbiology, University of Leeds, LS2 9JT, UK*
[3]*Stryker Howmedica Osteonics, Alte Landstr. 36C, CH-8802 Kilchberg, Switzerland*

The long term wear and wear debris generated in HIPed alumina on alumina bearings for hip prostheses with microseparation *in vitro* is compared to standard simulator conditions and *ex vivo* specimens. Microseparation studies were completed to five million cycles at two severity levels in attempts to rigorously evaluate the long-term tribological performance of the bearings. During the first million cycles (bedding-in) of the microseparation tests characteristic stripe wear was observed on all of the femoral heads with a matching area on the rim of the acetabular inserts. Under mild microseparation conditions an average wear rate of 0.55 mm^3/million cycles was observed during the initial million cycles which reduced to a steady state level of 0.1 mm^3/million cycles. Under more severe conditions an average wear rate of 4.0 mm^3/million cycles was observed during bedding-in which reduced to a steady state level of 1.3 mm^3/million cycles. These compare to a bedding-in wear rate of 0.11 mm^3/million cycles and steady-state wear rate of 0.05 mm^3/million cycles for the same material under normal simulation with no microseparation. Furthermore, under microseparation the wear mechanisms and wear debris were similar to those observed in previous alumina retrieval studies with debris ranging from 10 nm to 1 μm in size.

1. Introduction

Substantial differences have been found between the wear of alumina ceramic on ceramic hip prostheses *in vivo* [1] and the wear found in standard simulator tests [2]. *Ex vivo* specimens have shown wear rates of the order of 1 mm^3/year, stripe wear on the head with surface roughening, intergranular fracture and wear debris from 10 nm up to 1 μm in size [3]. Standard simulator studies have shown wear rates of less than 0.1 mm^3/million cycles, with only relief polishing wear of the alumina ceramic [2]. It has been recently discovered that hip joint separation occurs *in vivo* during normal gait and that introducing microseparation of the femoral head and acetabular insert into the swing phase of the hip joint simulator cycle, produces rim contact on heel-strike and stripe wear of the head similar in quantity and wear mechanism to that found in *ex vivo* specimens [4, 5]. As microseparation testing is still in its infancy there remain questions relating to test variability, conditions and long term performance of the bearings.

The purpose of this study was to evaluate the long-term performance of hot isostatic pressed (HIPed) alumina/alumina hip prostheses under mild and severe microseparation conditions. Wear rate, surface analysis and debris morphology was evaluated and the results compared to standard simulator studies and retrieval specimens.

2. Materials and methods

All components were commercially available and manufactured from HIPed third generation alumina ceramic. The Leeds MKII six station hip simulator was used providing a physiological twin peak time dependant loading curve with an elliptical wear path. Inserts were positioned anatomically "on top" inclined at 45° to the horizontal axis (Fig. 1). Heads underwent flexion/extension + 30° to − 15° and the insert internal/external rotation ± 10°(2).

Under standard conditions the Leeds MKII simulator applies a small positive swing phase load which ensures the head remains located correctly in the insert. To provide microseparation a small lateral to medial load was applied with a spring. Microseparation conditions were varied by altering the swing phase load from 400 N for mild to 50 N for severe separation. The medio-lateral separation load was regularly adjusted in each of the six stations to provide between 200 and 500 μm of medio-lateral motion.

Tests were carried out for five million cycles with 25%