ZIRCONIA HEADS AGAINST ALUMINA INSERTS PRODUCES SEVERE WEAR IN HIP SIMULATOR STUDIES WITH MICROSEPATION

Introduction  Extremely low wear has been reported for Zirconia femoral Heads articulating against Alumina Inserts for hip prostheses under normal simulation conditions and this bearing combination is now in use in vivo (1). Nevertheless, concerns exist due to a potential unfavourable tribological behaviour of this combination observed in vitro and in vivo (2, 3).

Recently, however, it has been shown that for ceramic ceramic bearings the addition of swing phase microseparation into the normal hip joint simulator cycle produces more clinically relevant wear debris, wear mechanisms and wear rates (4). For Alumina on Alumina this has resulted in an increase in the wear rate from &lt; 0.1 mm³/million cycles under normal simulation to 0.2 and 1.84 mm³/million cycles under mild and severe microseparation conditions respectively (5). While Zirconia on Alumina produced low wear under normal simulation it has not been tested under microseparation conditions.

The purpose of this study was, therefore, to evaluate the wear performance of Zirconia heads against HIPed Alumina inserts in a hip joint simulator incorporating mild and severe swing phase microseparation.

Materials and Methods Two commercially available materials were tested: Zirconia ("ZR", ISO 13356) and 3rd Generation Hot Isostatic Pressed (HIPed) Alumina ("AL", ISO 6474). Three components of each material were used for each test and all components were of the same 28mm design. Tests were conducted using a six station hip joint simulator providing a physiological twin peak time dependent loading curve and an elliptical wear path. Inserts were positioned anatomically on top inclined at 45° to the horizontal axis. Heads underwent flexion/extension &plusmn;30° to -15° and the insert internal/external rotation &plusmn;10°. The procedure of microseparation involved applying a small lateral to medial load to the acetabular insert with a spring, which, during the swing phase when the joint load was reduced, produced a medial (200 - 500µm) and superior translation of the insert relative to the head resulting in impact between the head and the superior rim of the insert. Severity of conditions was altered by adjusting the swing phase load in the simulator which, when reduced from 400 N for mild conditions to 50 N for severe conditions, made it easier for the medial separation force to both overcome friction and to produce superior translation between the head and insert. This, in turn, increased the velocity of the insert and upon impact with the head produced an increased momentum and impact energy that resulted in a more severe microseparation condition. The variable swing phase load, therefore, may be representative of varying degrees of joint laxity.

Results  The simulator produced a regular pattern of micro-separation. Under mild microseparation conditions a very faint stripe of wear was formed on two of the three Zirconia heads, which increased the surface roughness Ru from &lt; 0.005 µm to between 0.06 and 0.09 µm. The third femoral head was visibly undamaged. Stripes on the two Zirconia femoral heads under mild conditions were &lt; 0.75 mm wide and &lt; 10 µm deep. Under severe microseparation conditions of prolonged squeaking was observed in the three simulator stations with Zirconia on Alumina bearings. A large stripe of wear was formed on all three of the Zirconia heads, which increased the surface roughness Ru from &lt; 0.005 µm to between 0.09 and 2.1 µm. Stripes on the Zirconia femoral heads under severe conditions were &lt; 5 mm wide and up to 250 µm deep.

Wear volumes are shown in Figure 1. Zirconia on Alumina produced very low wear under mild microseparation conditions for the 5 million cycle test duration with an average wear rate of 0.05 mm³/million cycles. This was significantly lower than previously tested HIPed Alumina under the same mild microseparation test conditions where an average wear rate of 0.2 mm³/million cycles was observed. Under severe microseparation conditions Zirconia on Alumina produced a dramatic increase in wear resulting in a wear rate of 10.6 mm³/million cycles during the initial million cycles. This was significantly greater than previously tested HIPed Alumina on Alumina under the same severe microseparation test conditions where a bedding-in wear rate of 4 mm³/million cycles was observed during this period. With HIPed Alumina on Alumina this wear rate then reduced to a lower steady state level to produce an average wear rate of 1.84 mm³/million cycles over 5 million cycles, however, further testing is required to determine whether this trend will occur with Zirconia on Alumina.

Discussion  Microseparation of Zirconia heads against HIPed Alumina inserts under mild simulation conditions produced very low wear with only faint stripe formation. Under severe microseparation conditions, however, gross stripe wear was observed on the Zirconia heads after 1 million cycles producing a wear rate of 10.6 mm³/million cycles and excessive intergranular fracture. This was three times higher than observed previously with HIPed Alumina ceramic bearings under the same severe conditions which produced a bedding-in wear rate of 4 mm³/million cycles and a steady state wear rate of 1.3 mm³/million cycles. The results suggest that under severe microseparation conditions the wear of Zirconia femoral heads articulating against HIPed Alumina acetabular inserts can escalate to produce excessive wear of the bearing surfaces. While the increased fracture toughness of the Zirconia may resist microseparation wear under mild conditions, the increased hardness of the Alumina may produce elevated wear of the Zirconia under more severe tribological conditions.

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