WEAR OF ZIRCONIA TOUGHENED ALUMINA HEADS AGAINST HIPED ALUMINA INSERTS IN A HIP SIMULATOR UNDERGOING SWING PHASE MICROSEPARATION

Introduction
Recently Zirconia Toughened Alumina (ZTA) femoral heads have been introduced for hip prostheses as an alternative to the current generation of Hot Isostatic Pressed Alumina. ZTA is reported to offer improved toughness compared to alumina ceramic without a significant reduction in hardness, making it a potentially more flexible for the design of ceramic–ceramic hip prostheses (1). There is, however, no published data on the wear of ZTA on Alumina under microseparation conditions that have been shown for Alumina on Alumina to provide clinically relevant wear rates, wear mechanisms and wear debris (2, 3). The purpose of this study was to evaluate the long-term wear performance of Zirconia Toughened Alumina heads against HIPed Alumina inserts in a hip joint simulator incorporating swing phase microseparation.

Materials and Methods
Two commercially available materials were tested Zirconia Toughened Alumina (ZTA) and 3rd Generation Hot Isostatic Pressed (HIPed) Alumina. The ZTA ceramic was BioLox Delta and the HIPed Alumina ceramic was BioLox Forte, both were manufactured by CeramTec. In the hip simulator three BioLox Delta ZTA heads were tested against BioLox Forte HIPed Alumina inserts (ZTA/AL) and three BioLox Forte HIPed Alumina heads were tested against BioLox Forte Alumina inserts (AL/AL). A six station hip joint 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. Heads underwent flexion/extension +30° to -15° and the insert internal/external rotation ±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 (4). Severity of conditions was altered by adjusting the swing phase load in the simulator which, when reduced from 400N for mild conditions to 50N for severe conditions, made it easier for the medial separation force to both overcame 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 which 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. A stripe of wear was formed on all of the heads of both ZTA on Alumina and HIPed Alumina on Alumina bearings, which increased the surface roughness Ra from < 0.005 µm to between 0.02 and 0.13 µm. Wear volumes are shown in Figure 1. It can be seen that in the microseparation mode the wear of HIPed Alumina on Alumina increased considerably compared to previously tested HIPed Alumina on Alumina under standard conditions with no microseparation. Under severe microseparation conditions the wear rates of the ZTA on Alumina was significantly less than the wear of HIPed Alumina on Alumina. Wear rates under standard and micro-separation conditions are shown in Figure 2. A bedding-in wear rate of 0.99 mm³/million cycles was observed during the initial 1 million cycles corresponding to the formation of stripe of wear on the ZTA femoral heads and a matching area on the rim of the HIPed Alumina acetabular inserts. The wear rate then reduced to a lower steady state level of 0.37 mm³/million cycles for the remainder of the study resulting in an overall average wear rate of 0.49 mm³/million cycles. The wear of ZTA on Alumina was significantly lower than the wear of HIPed Alumina on Alumina where bedding-in, steady state and overall wear rates of 4.0, 1.31, and 1.85 mm³/million cycles were observed respectively.

Discussion
Long term in-vitro microseparation of Zirconia Toughened Alumina heads against HIPed Alumina ceramic inserts produced an overall average wear rate of 0.49 mm³/million cycles under severe conditions. This was three times lower than observed with HIPed Alumina ceramic bearings under the same severe conditions which produced an overall average wear rate of 1.84 mm³/million cycles. A characteristic stripe of wear was observed on all femoral heads with a corresponding area on the rim of the acetabular inserts. Wear was characterised by an initially higher bedding-in period during the initial 1 million cycles which reduced to a lower steady state level for the remaining 4 million cycles with no runaway wear observed.

The results suggest that the Zirconia Toughened Alumina femoral heads articulating against HIPed Alumina acetabular inserts have better resistance to microseparation damage and wear compared to HIPed Alumina on Alumina. This may be due to the improved mechanical properties of the ZTA femoral head.

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References

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