In-Vitro Wear During Micro-Separation of Zirconia Toughened Alumina for Total Hip Joint Replacements

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Introduction

Wear of the latest generation of zirconia toughened alumina materials for ceramic-ceramic hip replacements have been reported to be very low (less than 0.1mm³/million cycles) in hip simulator studies, supporting their use *in-vivo*. However, it has been recently shown that modified simulator testing, which introduces micro-separation of the head and insert during the swing phase, has been shown to accelerate the wear of alumina on alumina bearings *in-vitro* to approximately 1mm³/million cycles, generating a clinically representative stripe of wear on the femoral head and relevant wear mechanisms and debris.(1)

The purpose of this study was to evaluate two zirconia toughened alumina materials from different suppliers *in-vitro* under micro-separation conditions to compare their wear and resistance to that of previously tested alumina.

Materials and Methods

Two different zirconia toughened alumina (ZTA) materials were tested against themselves (A,B) and compared to the current generation HIPed alumina. The ZTA materials are similar in hardness to alumina, with a 50% improvement in fracture toughness and flexural strength.

Simulator studies were conducted using a physiological hip joint simulator with the acetabular insert superiorly inclined at 30° to the vertical loading axis. All tests were conducted at 1 Hz using a 25% v/v bovine serum lubricant with sodium azide solution as an antibacterial agent. Two separate tests were carried out the first to 3 million cycles under standard simulation conditions and the second to two million cycles with micro-separation. Separation was achieved by applying a small medial to lateral force which separated the head from the insert by up to 400 μm. Upon reapplication of the load the head contacted the rim of the insert before relocating.

Wear was evaluated throughout the study using a Metler A201 micro-balance with a tolerance of ±0.01 μg. Surface analysis was completed using a Form Talysurf 5 surface profilometer. Debris was isolated from the articulating fluid and characterised using techniques previously described (2).

Results

The wear rates under standard and micro-separation conditions are shown in Figure 1. Under standard simulation conditions both ZTA materials produced very low wear rates < 0.1 mm³/million cycles. These values were lower than found in previous studies with alumina on alumina, however, the difference was not statistically significant. The wear rates increased with the introduction of micro-separation with an initially high bedding-in wear (~1 mm³/million cycle) for the first 1 million cycles corresponding to the formation of a wear stripe on the head and a worn area on the insert rim. This damage was less severe on one of the AZTA pairs of materials, however, the average wear rates were not significantly different between the two ZTA materials. The average wear rates reduced to a lower steady-state value of ~0.2 mm³/million cycles for the remaining 1 million cycle period and again there was no significant difference between the materials. This pattern of wear was similar to that observed in previously tested HIPed Alumina.

The surface roughness of the components did not change during standard simulation testing (R*a* <0.01μm). However, under micro-separation inter-granular fracture occurred in the area of the stripe wear and the Ra increased to ~0.05μm for the ZTA heads. This was lower than seen previously with alumina(~0.2 μm). The wear debris analysis reflected the change in surface roughness with very small nanometer size particles under standard conditions and small 10 nanometer size particles mixed with larger >100nm size particles under conditions of micro-separation.

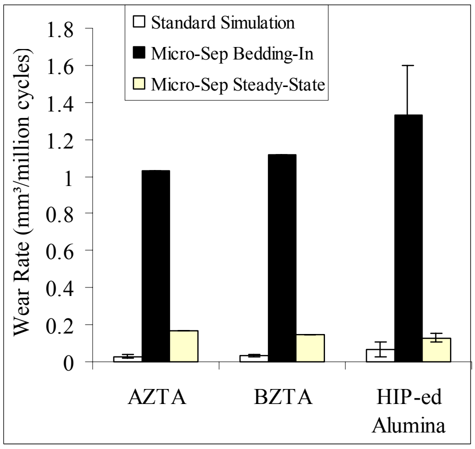

Figure 1. *In-Vitro* Wear Rates of Ceramic Hips

Discussion

Both new ZTA materials produced very low average wear rates (<0.1mm³/million cycles) during standard simulation, which increased (~1mm³/million cycles) under micro-separation conditions similar to previous studies of alumina. Micro-separation introduced an instability between the head and insert which resulted in rim contact and the formation of a stripe of wear on the head. It is hypothesised that the resulting damage reduces this instability and as friction between the head and insert increases the wear rate decreases to a lower steady state value.

There was no significant difference between the average wear rates of the two ZTA materials, and while they produced lower wear rates compared to the alumina components the difference was not significant. Micro-separation produced wear rates, surface mechanisms and debris representative of clinical HIPed alumina retrievals (1).

The study indicates that both new ZTA materials may produce stripe wear with micro-separation *in-vivo*.

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References

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2. Fisher *et al*. Proc 6th World Congress Biomaterials, 2000.