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Wear of Mixed Ceramic-on-Ceramic Hip Replacement Bearings under Adverse Edge Loading Conditions Due to Translational Malpositioning

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Introduction

- Ceramic composites have been developed to further improve the mechanical properties, reduce risk of fracture, and increase the survivorship of ceramic-on-ceramic bearings in total hip replacement[1].
- These composite ceramics have performed very well under adverse edge loading conditions when used in like-on-like configurations, where the femoral head and acetabular cup are of the same material[2].

Figure 1: Composite Ceramics femoral head; Alumina toughened zirconia (Ceramys®, Mathys Orthopädie GmbH).

Aim

The aim of this study was to determine the wear of pure alumina (Al_2O_3), Alumina Toughened Zirconia (ATZ) and Zirconia Toughened Alumina (ZTA) when used in mixed bearing combinations, under edge loading conditions due to translational mal-positioning.

Method

Materials: the head-on-cup couples (n=3):

1. ATZ-on-ZTA
2. ZTA-on-ATZ
3. Al_2O_3-on-ATZ
4. ATZ-on- Al_2O_3
5. Al_2O_3-on-ZTA

Table 1: Constituent of the different materials (supplied by Mathys Orthopädie GmbH, Germany).

Materials	Al_2O_3	ZrO_2
Alumina (Al_2O_3)	100%	-
Alumina toughened zirconia (ATZ)	20%	80%
Zirconia toughened alumina (ZTA)	75%	25%

Leeds Mark II Physiological Anatomical Hip Joint Simulator was used.

Test conditions: four million cycles (MC) under microseparation[3,4] conditions representing translational mal-positioning.

- *gait cycle:* extension/flexion (-15˚/+30˚), internal external rotation (+/-10˚) and a twin peak load with a maximum of 3kN.
- *Microseparation:* 0.5mm dynamic medial/lateral displacement
- *Cup inclination angle:* equivalent to an in vivo cup inclination of 55°.
- *Lubricant*: 25% new-born calf serum.

Measurements:

Wear volume: gravimetrically every one million cycle using a microbalance (Mettler AT201, UK)

Statistical analysis: one-way ANOVA (α=0.5)

Results

- The bedding in and steady state wear rates of ATZ-on-ZTA (1.16mm^3/MC bedding in and 0.18mm^3/MC steady state) and ATZ-on-Al_2O_3 (0.66mm^3/MC bedding in and 0.20mm^3/MC steady state) were lower than that of Al_2O_3-on-Al_2O_3 (1.54mm^3/MC bedding in and 0.55mm^3/MC steady state) bearing combination (no significant difference, p=0.35).
- The wear rates of the other bearing combinations under these adverse microseparation conditions, Al_2O_3-on-ATZ, Al_2O_3-on-ZTA, and ZTA-on-ATZ were very low (<0.14mm^3/MC) with no clear bedding in and steady state phases.

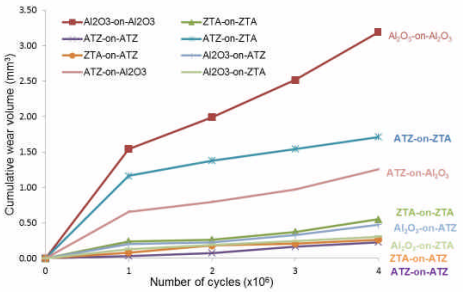

Figure 2: Cumulative wear rates for all bearing combinations tested under adverse microseparation conditions. The wear of Al_2O_3-on-Al_2O_3, ZTA-on-ZTA and ATZ-on-ATZ was taken from Al-Hajjar et al 2013[2] for comparison.

Discussion

The mixed material combinations (ATZ-on-ZTA, ATZ-on-Al_2O_3, Al_2O_3-on-ATZ, Al_2O_3-on-ZTA and ZTA-on-ATZ) tested in this study have shown slightly higher wear rates when compared to ATZ in like-on-like configuration[2], but superior wear resistance when compared to Alumina BIONIT® (Mathys) and BIOLOX® forte (CeramTec) Al_2O_3-on-Al_2O_3 bearings tested under the same adverse microseparation conditions[4].

Significance

- Ceramic-on-ceramic bearings in mixed material combinations where the head and the cup were of different materials showed stripe wear under edge loading conditions due to translational mal-positioning. However, the wear rates obtained were lower than those of Alumina-on-Alumina bearings.
- Therefore, from a wear perspective, these ceramic materials can be used in mixed material combinations.

References

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Financial Disclosure

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