Institute of Medical & Biological Engineering

Effect of Acetabular Cup Version Angle on the Wear of BIOLOX® Delta Ceramic-on-Ceramic Bearings under standard and Edge Loading Conditions

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Introduction

- Optimum positioning of total hip replacement bearings is difficult to achieve during surgery hence preclinical simulation of hip replacement bearings should include conditions that include mal-positioning of implants in order to assess their safety and reliability under the adverse conditions that might exist in vivo.
- There are two elements to mal-positioning; rotational and translational. Rotational mal-positioning can include steep inclination angle or excessive version/ante-version of the acetabular cup, and translational mal-positioning is a mismatch between the centres of rotations of the femoral head and the acetabular cup [1].

Figure 1: The alumina matrix composite hip replacement (AMC, commercially known as BIOLOX® Delta).

Aim

The aim of this study was to investigate the effect of edge loading due to surgical mal-positioning (rotational and translational), including for the first time the effect of ante-version of the acetabular cup, on the wear of ceramic-on-ceramic bearings.

Method

Materials: 36mm ceramic-on-ceramic bearings (BIOLOX® Delta, CeramTec, Germany, Figure 1)

Machine: Leeds Mark II Physiological Anatomical Hip Joint Simulator.

Test conditions:

- Six cups were mounted with an ante-version angle of 30°; two clinical cup inclination angles were considered, equivalent to in vivo angles of 45° (n=3) and 65° (n=3).
- Standard gait conditions (2 million cycles) with a twin peak load (peak load of 3000N), extension/flexion (-15°/+30°) and internal/external rotation (±10°).
- Edge loading conditions associated with translational mal-positioning by applying 0.5mm dynamic microseparation conditions to the gait cycle [2] (3 million cycles).

Lubricant: 25% (v/v) new-born calf serum

Measurements:

Wear volume: gravimetric analysis every million cycles using a Mettler-Toledo XP205 micobalance (Mettler-Toledo Ltd, UK).

Wear location and penetration: A coordinate measuring machine (CMM, Legex 322, Mitutoyo, UK) was used to reconstruct three dimensional representations of the wear stripes on the femoral heads. SR3D software (Tribosol, UK) was used to visualise the wear areas.

Statistical analysis: one-way ANOVA (α=0.05).

Results

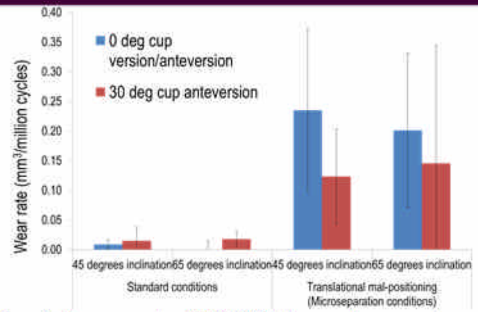
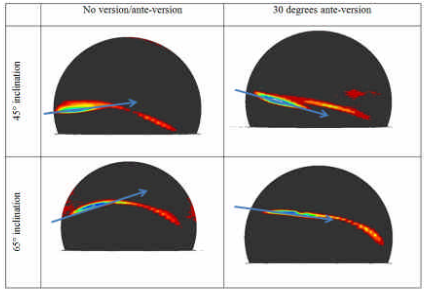


Figure 2: Mean wear rates of BIOLOX® delta ceramic-on-ceramic bearings with no version/ante-version of the cup [3] and 30° cup ante-version angle under standard and edge loading conditions associated with both rotational and translational mal-positioning (mean ± 95% confidence limits, n=3).

Figure 3: Orientation and position of the wear stripe generated on the femoral heads under edge loading conditions associated with translational mal-positioning, with different acetabular cup inclination and version angles. The arrows show how the orientations of the stripe areas change.



Discussion

- In this experimental simulation study, it was found that an increased ante-version angle of 30°, did not increase the wear rate of BIOLOX® delta ceramic-on-ceramic bearings, under standard gait conditions, indicating the resistance of this material combination to rotational mal-positioning.
- Stripe wear and increased wear rates occurred only under edge loading due to microseparation conditions associated with translational malpositioning.

Significance

- Rotational mal-positioning, including both steep cup inclination and increased version/ante-version angles, did not influence the wear rates of BIOLOX® delta ceramic-on-ceramic bearings but changed the position and orientation of the wear stripe formed due to edge loading under fixed 0.5mm dynamic microseparation conditions associated with translational mal-positioning.
- Implant positioning may explain variations in stripe wear orientation reported in different clinical studies of retrieved components.

References

1. Fisher J.BJS-Br 2011; 2. Nevelos J et al. J Arthroplasty 2000; 3. Al-Hajjar M. et al., Proceedings of the institute of Mechanical Engineering- Part H, 2013.

Financial Disclosure

John Fisher is an NIHR senior investigator, a director of Tissue Regenix Ltd and a paid consultant to DePuy Synthes; Sophie Williams is a paid consultant to DePuy Synthes.

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