Wear of Large Diameter Ceramic-on-Ceramic Bearings in Total Hip Replacements under Edge Loading Conditions

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Introduction

- BIOLOX® delta ceramic-on-ceramic hip replacements have shown reduced wear in vitro compared to earlier generations ceramic materials under edge loading conditions [1]
- Improvements in material properties have allowed the production of thinner acetabular cups, and encouraged the development of larger head sizes to theoretically provide increased range of motion and stability
- However, increased wear rates and frictional torques, under edge loading due to surgical mal-positioning, associated with large diameter bearings [2,3] are of concern
- Edge loading could occur due to rotational and translational mal-positioning [4]
- Rotational mal-positioning represents steep cup inclination angles or excessive version or ante-version of the cup
- Translational mal-positioning is defined as a mismatch is the centres of rotation of the head and the cup and can occur clinically due to head offset deficiency, medialised cup, impingement, subluxation, stem subsidence or laxity of the joint

Aim

The aim of this study was to assess the wear of large diameter BIOLOX® delta ceramic-on-ceramic bearings under edge loading conditions due to rotational and translational mal-positioning.

Method

Materials: DeltaMotion® ceramic-on-ceramic hip bearings (DePuy Synthes, Leeds, UK)
Bearings sizes: 32mm (n=5) and 48mm (n=5)

Figure 1: DeltaMotion® ceramic-on-ceramic hip replacement system

Machine: ProSim 10-station hip simulator (Simulator Solutions, UK)

Measurements:

Wear volume: gravimetrically every one million cycle using a microbalance (Mettler AT201, UK). Statistical analysis : one-way ANOVA (α=0.5)

Wear area & penetration: 3D reconstructions of the wear area on the femoral heads were obtained using CMM (Legex 322, Mitutoyo, UK) and SR3D software (Tribosol, UK)

Test conditions:

- Standard simulator conditions (45° in vivo equivalent inclination angle, 5 million cycles)
- Standard gait cycle: extension/flexion of -15˚/+30˚, internal/external rotation of ±10˚, and a twin peak load with a peak load of 3kN and a swing phase load of 300N.
- Steep cup inclination conditions with standard gait; 60° in vivo equivalent inclination angle representing rotational malpositioning (2 million cycles)
- 0.5mm dynamic microseparation conditions representing translational malpositioning (3 million cycles)

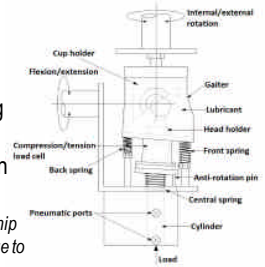
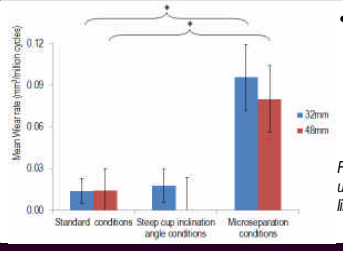


Figure 2: Set-up on the ProSim hip simulator under edge loading due to translational mal-positioning.

Results



- The introduction of translational malpositioning caused edge loading and the formation of a stripe-like wear area on the femoral heads for both bearing sizes.

*Figure 3: Wear of 32mm and 48mm CoC bearings under three testing conditions (mean ±95% confidence limit, n=5). * indicates significant difference*

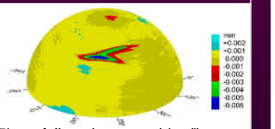


Figure 4: 6µm-deep wear stripe-like area formed after three million cycles of testing under edge loading due to microseparation conditions representing translational malpositioning

Discussion

- Edge loading due to conditions representing clinical translational mal-positioning increased the wear rate of ceramic-on-ceramic bearings and caused stripe wear [5]. However, increasing the inclination angle to 60˚ did not cause an increase in wear rates.
- In this study, although the wear rate increased, it was still very low compared to earlier generation ceramic materials [1] (28mm BIOLOX® forte, 1.84mm³/million cycles) and metal-on-metal bearings [2,6,7] (1.8-8.9mm³/million cycles) tested under similar edge loading conditions.
- Although large diameter BIOLOX® delta ceramic-on-ceramic bearings showed superior wear properties under edge loading conditions compared to other bearing combinations, surgical mal-positioning should be avoided.

Significance

- The wear of the large diameter ceramic-on-ceramic bearings significantly increased under edge-loading conditions due to translational malpositioning
- Large ceramic-on-ceramic bearings (48mm head diameter) showed similar wear rates compared to the smaller bearings (32mm head diameter) under these adverse conditions.

References

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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; Jonathan Thompson, Gemma Kurring and Catherine Hardaker are employees at DePuy Synthes.

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