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

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Disclosures:
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Introduction: BIOLOX® delta ceramic-on-ceramic hip replacements have shown reduced wear compared to earlier generations ceramic materials under edge loading conditions¹. These 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 adverse mal-positioning conditions associated with large diameter bearings²,³ are of concern. Edge loading could occur due to rotational and translational mal-positioning⁴. 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.

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.

Methods: The wear of DeltaMotion® ceramic-on-ceramic hip replacements (DePuy Synthes Joint Reconstruction, Leeds, UK) was studied. Bearings were 32mm (n=5) and 48mm (n=5) in diameter and tested on a Prosim 10-station hip simulator (Simsol, UK) for five million cycles under standard simulator conditions (45° in vivo equivalent inclination angle), for two million cycles under steep cup inclination conditions (60° in vivo equivalent inclination angle) representing rotational mal-positioning, and for three million cycles under 0.5mm dynamic microseparation conditions (with 45° in vivo equivalent inclination angle) representing translational mal-positioning. The standard gait cycle composed of 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. Microseparation conditions representing translational malpositioning were given by applying a negative pressure on the femoral head during the swing phase of the gait cycle while springs, placed below the plate holding the femoral head, caused the head to tilt laterally towards the rim of the acetabular cup (Figure 1). This was controlled so that 0.5mm medial-lateral displacement was given between the femoral head and the acetabular cup during the swing phase of the gait cycle. Wear was assessed gravimetrically every one million cycle using a microbalance (Mettler AT201, UK). The means and 95% confidence limits were calculated and statistical analysis was done using one-way ANOVA (significance was taken at 0.05). Three-dimensional reconstructions of the wear area on the femoral heads were obtained using a coordinate measuring machine (Legex 322, Mitutoyo, UK) and SR3D software (Tribosol, UK).

Results: The wear of the 32mm and 48mm ceramic-on-ceramic bearings under standard simulator conditions was very low (<0.05mm³/million cycles). Increasing the inclination angle from 45° to 60° degrees did not affect the wear rates of either bearing sizes. The introduction of translational mal-positioning caused edge loading and the formation of a stripe-like wear area on the femoral head (Figure 2) and increased wear. However, there was no significant difference (p=0.23) in the wear rates between the 32mm (0.10mm³/million cycles) and 48mm bearings (0.08mm³/million cycles) under these conditions. The maximum penetration depth after three million cycles of testing under translational mal-positioning conditions was 5.0±3.5µm for the 32mm bearings and 3.0±1.7µm for the 48mm bearings (mean±95% confidence limit, n=5).

Discussion: Edge loading due to conditions representing clinical translational mal-positioning has increased the wear rate of ceramic-on-ceramic bearings and caused stripe wear⁵. In this study, although the wear rate increased, it was still very low compared to earlier generation ceramic materials¹ (28mm BIOLOX® forte, 1.84mm³/million cycles) and metal-on-metal bearings²,⁶,⁷ (1.8-8.9mm³/million cycles) tested under similar edge loading conditions. Large ceramic-on-ceramic bearings (48mm head diameter) showed similar wear rates compared to the small bearings (32mm head diameter) under these adverse 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 increased under edge-loading conditions due to translational mal-positioning compared to the wear under standard gait conditions with well positioned prosthesis. The wear of
the 48mm ceramic-on-ceramic bearings under these adverse conditions (translational mal-positioning) was similar to that of the 32mm bearings.

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**References:**
Figure 1: Schematic of simulator set-up on the ProSim hip simulator under edge loading due to translational mal-positioning.
Figure 2: Three-dimensional reconstruction of the femoral head showing 6μm-deep wear stripe-like area formed after three million cycles of testing under edge loading due to microseparation conditions representing translational mal-positioning.

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