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A Comparison of the Wear of Two Different Surface Replacement Metal-on-Metal Bearings under Edge Loading Conditions

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Mazen Al-Hajjar, Philippa Clarkson, Sophie Williams, Louise M Jennings, Eileen Ingham, John Fisher+
Institute of Medical and Biological Engineering, School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT
+ j.fisher@leeds.ac.uk

Introduction

- Over the recent years, there have been many reports of failures of metal-on-metal bearings especially with surface replacement bearings and large diameter total hip replacement bearings [1-3].
- High wearing metal-on-metal bearings have been associated with edge loading conditions.
- Edge loading can occur due to either rotational or translational mal-positioning [4]. Both scenarios have been replicated in vitro [5, 6], with edge loading due to translational mal-positioning proving to be the more severe condition [7] and resulting in high wear rates and wear features similar to those seen on some of the high wearing retrieved explants [8].

Aim

The aim of this study was to compare the wear of different design metal-on-metal bearings under edge loading conditions associated with translational mal-positioning.

Materials

Table 1: Surface replacement bearings used:

	Nominal diameter (mm)	Diametrical clearance (μm)	Acetabular cup outer diameter (mm)	Acetabular cup included (coverage) angle (degrees)
ASR (size 55)	54.5	115 (range: 111-121)	62	154
BHR (size 54)	53.8	288 (range: 271-300)	60	163

ASR™, DePuy Synthes (n=5)
BHR™, Smith and Nephew Ltd. (n=4)

Method

ProSim 10-station hip joint simulator
Test conditions:
- standard in vitro gait conditions (4 million cycles)
- edge loading due to translational malpositioning (Figure 1, 4 million cycles)
  - ➢ with fixed 0.5mm dynamic microseparation (2 million cycles)
  - ➢ with fixed 1mm dynamic microseparation (2 million cycles)
- Inclination angle equivalent to 60° in vivo

Lubricant: 25% (v/v) new-born calf serum
Measurements:
Wear volume: gravimetrically using a microbalance (Sartorius CC500)
Wear location and penetration: A coordinate measuring machine (CMM, Legex 322, Mitutoyo)
Statistical analysis: one-way ANOVA (α=0.05).

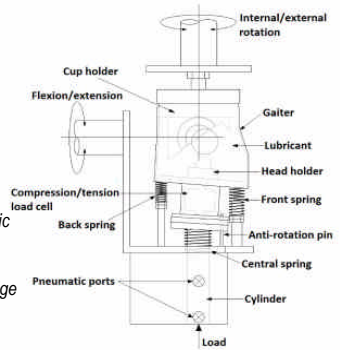

Figure 1: Schematic of simulator set-up on the ProSim hip simulator under edge loading due to translational malpositioning.

Results

- There was no significant difference in the wear rates (Figure 2) between the two designs under these adverse conditions with the same level of dynamic medial/lateral displacement (p=0.7 for 0.5mm condition and p=0.8 for 1mm condition)
- The introduction of edge loading due to translational mal-positioning resulted in significant increase in the wear rates of both of the surface replacement metal-on-metal bearings.

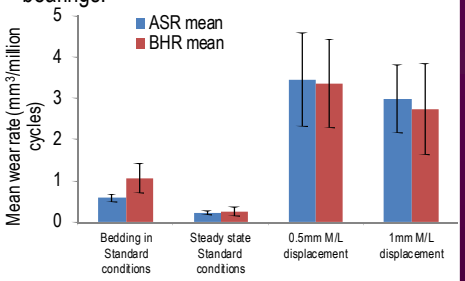

Figure 2: Mean wear rates of ASR and BHR metal-on-metal surface replacement under standard and microseparation conditions. Error bars represent one standard deviation.

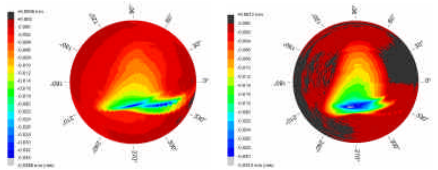

Figure 3: 3D reconstruction of the femoral head surface showing the wear area after testing under edge loading conditions. ASR head (left) and BHR head (right).

Discussion

- This study controlled the medial/lateral displacement as an input and replicated it on every cycle.
- In vivo, the frequency of edge loading and its severity will depend on many factors including, the inclination of the cup and the coverage angle of the bearing surface of acetabular cup. Although both bearings were tested at the same inclination angle, the ASR has a lower bearing coverage angle. It is possible that the frequency and severity of edge loading in vivo in the ASR may be more severe as a result of this design difference.
- Future research will study the combined effect of changes in biomechanics and tribological conditions on the wear of different designs of prostheses under adverse conditions.

Significance

- The wear rates of both metal-on-metal surface replacement bearing designs were similar under edge loading due to translational malpositioning for a fixed level of dynamic microseparation displacement.
- The findings of this study are important for the development of standards for pre-clinical testing of hip prostheses under adverse conditions.

References
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