Institute of Medical & Biological Engineering

Cobalt and Chromium Ion Level Analysis from Metal-on-Metal Hip Replacement Bearings Tested under Adverse In Vitro Conditions

UNIVERSITY OF LEEDS

Mazen Al-Hajjar, Sophie Williams, Joanne L. Tipper, John Fisher, Louise M. Jennings+

Institute of Medical and Biological Engineering, School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT

+ l.m.jennings@leeds.ac.uk

Introduction

- Metal-on-metal (MoM) bearings have shown low wear under standard hip simulator conditions, which simulate standard gait with well-positioned prostheses [1].
- Clinically, high blood cobalt (Co) and chromium (Cr) ion concentrations have been associated with steep cup inclination angles [2].

Figure 1: Total hip replacement

- Edge loading due to rotational or translational mal-positioning has caused significant increase in the wear of MoM bearings *in vitro* [3,4,5].
- Microseparation condition (translational mal-positioning) has been shown to produce clinically relevant wear rates and wear mechanisms in ceramic-on-ceramic bearings [6], replicated fracture of zirconia ceramic femoral heads [7] and increased the wear of surface replacements to levels measured on retrievals [4].

Aim

- The effects of rotational mal-positioning of the acetabular cup and translational mal-positioning of the centre of the cup and head on Co and Cr ion release in MoM total hip replacement bearings were investigated *in vitro*.

Materials and Methods

- 28mm and 36mm heat treated high carbon CoCrMo alloy MoM bearings
- 160º included angle and 40-60µm diametrical clearance

Figure 2: Leeds II Physiological Anatomical Hip Joint Simulator [6].

- Two cup inclination angles were considered, *in vivo* equivalence of 45º and 65º, and standard gait and microseparation conditions [6] were investigated.
- Wear volume was determined gravimetrically every million cycles [5]. Lubricant : 25% (v/v) new-born calf serum.
- At each measurement point, 0-0.33Mc, 0.33-0.66Mc, 0.66-1Mc, 1-2Mc and 2-3Mc, five 3ml-samples were taken from each station which underwent nitric acid digestion and centrifuging processes to eliminate proteins, contaminants and wear debris.
- The resulting solution was analysed using ICP-MS for Co and Cr ions.

Results

- There was a significant increase in Co and Cr concentrations due to rotational mal-positioning only when edge loading occurred.
- Edge loading due to microseparation conditions caused significant increase in the release of Co and Cr ions (Figure 3).
- There was a strong correlation between the Co ion concentration and the wear volume measured gravimetrically (Figure 4).
- Under standard conditions when the wear was relatively low, there was a good correlation (R^2=0.86) between Cr ion release and wear volume. However, the correlation became weaker with increased wear (Figure 4, R^2=0.06)

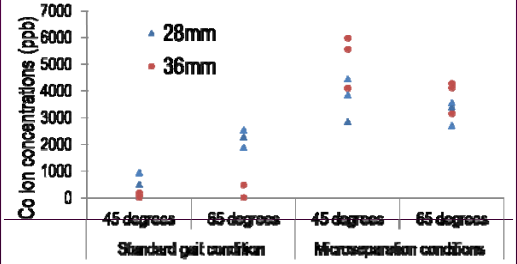

Figure 3: Cobalt ion concentration under different testing conditions at the 3 million cycle measurement point relative to 450ml volume of serum over one million cycles. Each data point is the mean of 5 replicates.

Results

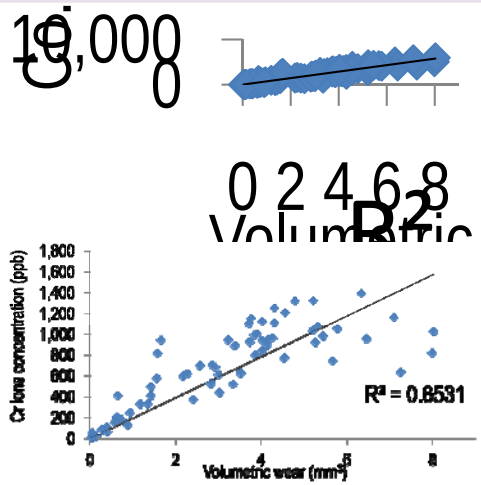

Figure 4: Correlation between Co ion concentration and volumetric wear (top) and Cr ion concentration and volumetric wear (bottom).

Significance

- In vivo, ions released by the prosthesis are naturally diluted and filtered away, so it is difficult to relate values measured from a simulator study to patient blood or serum ion levels.
- However, this study showed the significance of adverse clinically relevant *in vitro* testing conditions on ion release in MoM bearings.

References

1. *Chan et al., Clin Orthop Relat Res, 1999(369): p. 10-24.*
2. *De Haan et al.,JBJS Br, 2008. 90(10): p. 1291-7.*
3. *Angadji et al., Proc Inst Mech Eng [H], 2009. 223(H4): p. 449-457.*
4. *Leslie et al., Clin Orthop Relat Res, 2009. 467(9): p. 2259-2265*
5. *Al-Hajjar et al., Orthopedic Research Society proceedings, 2011.*
6. *Nevelos et al., J Arthroplasty, 2000. 15(6): p. 793-5.*
7. *Stewart el al., J Arthroplasty, 2003. 18: p. 726-34.*

Financial Disclosure

John Fisher is an NIHR senior investigator, a director of BITECIC Ltd and Tissue Regenix Ltd and a paid consultant to DePuy International; Sophie Williams is a paid consultant to DePuy International; Joanne Tipper is an NIHR senior investigator

Acknowledgement

This study was supported by the Orthopaedic Research UK and the National Institute of Health Research (NIHR) as part of a collaboration with the Leeds Musculoskeletal Biomedical Research Unit (LMBRU). Components for this study were specially manufactured by Corin Ltd, UK.