Institute of Medical & Biological Engineering

Geometric Wear Measurement of Metal-on-Metal Hip Replacements Tested Under Adverse In Vitro Simulator Conditions

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Introduction

- Wear is usually measured gravimetrically by weighing the components before and after the test, determining the weight loss and hence volumetric wear when assessed during preclinical testing.
- When studying retrievals, the initial weights are not known, so geometric measurement methods are a useful tool to determine the wear volume.
- Wear of current hip replacement bearings under standard conditions is relatively low when compared to older generations especially in regards to metal-on-metal (MoM) and ceramic-on-ceramic (CoC) bearings (<0.1mm^3/million cycles), which makes measurements using gravimetric or geometric techniques challenging.
- With advances in the technology of coordinate measuring machines (CMM, Fig1), these are now capable of detecting changes on the hip bearing surface in the order of microns.

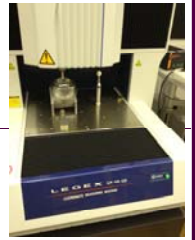

Figure 1: Legex 322 coordinate measuring machine (Mitutoyo, USA)

Aim

- The aim of this study was to validate a geometric measurement technique against gravimetric analysis to determine the volume, location and orientation of wear on the femoral head and the acetabular cup of metal-on-metal hip bearings.

Method

- Six 36mm MoM bearings were tested under microseparation [1] conditions in a six station hip simulator which resulted in stripe wear on the head and rim wear on the cup [2].
- Gravimetric analysis was performed using Mettler AT 201 balance (Mettler-Toledo Ltd, UK, 0.01mg resolution).
- Geometric measurement was performed using a Legex 322 CMM (Mitutoyo, USA, 0.8µm resolution).
- For both heads and cups, 36 traces starting at the pole were taken at 10^o intervals. Each trace consisted of measurement points 0.5mm apart resulting in a total of 2844 points for the heads (Fig2)and 2052 for the cups (Fig3).
- The surface was constructed and analysed using Tribosol SR3D v4.6.3 software (Tribology solutions, UK).

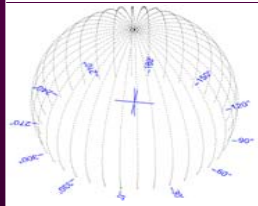

Figure 2: Data points taken using the CMM on the surface of a femoral head.

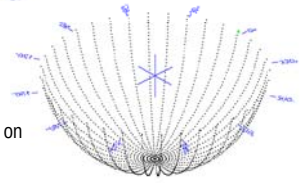

Figure 3: Data points taken using the CMM on the surface of an acetabular cup.

Results

- CMM measurements allowed the assessment of the wear volume and the 3D reconstruction of the wear patch by showing the shape, location, orientation and depth of the wear scar (Figs4&6).
- The accuracy of this geometric technique was +/- 4µm. This accuracy is specific to the components measured in this study.
- Good correlation between gravimetric and geometric techniques (R^2=0.9, Figs5&7).

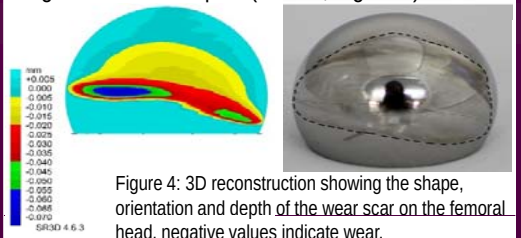

Figure 4: 3D reconstruction showing the shape, orientation and depth of the wear scar on the femoral head, negative values indicate wear.

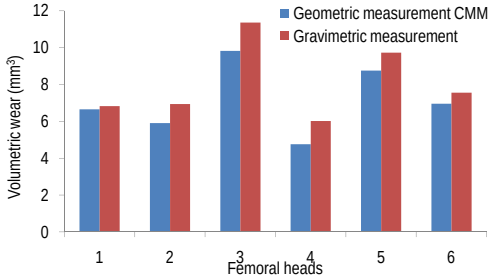

Figure 5: Wear volumes of femoral heads measured using gravimetric and geometric techniques.

Results

Figure 6: 3D reconstruction showing the shape, orientation and depth of the wear scar on the acetabular cup, positive values indicate wear.

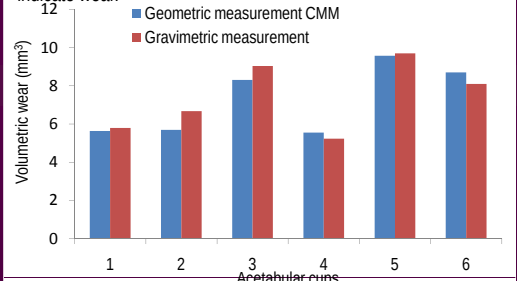

Figure 7: Wear volumes of acetabular cup measured using gravimetric and geometric techniques.

Significance

- This geometric measurement technique allowed accurate assessment of wear in MoM bearings, which could be applied to *in vitro* tested or retrieved components.
- Further work is in progress in order to determine very low wear on CoC bearings.

References

1. *Nevelos et al., J Arthroplasty, 2000. 15(6): p. 793-5.*
2. *Al-Hajjar et al., Orthopedic Research Society proceedings, 2011.*

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

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