**INTRODUCTION**

Large diameter metal-on-metal (me-me) hip replacement bearings were introduced to minimise wear and to increase resistance to dislocation. Their hard, smooth surfaces, large diameters and small clearances were found, in the laboratory, to promote hydrodynamic lubrication, whereby joint fluid separates the bearing surfaces and wear is dramatically reduced. However, much higher current revision rates for this type of bearing than for any other are blamed primarily on metal wear [1]. This demonstrates that lubrication conditions in vivo are inferior to those in pre-clinical tests in hip simulators.

Compromised lubrication clinically has been related to malpositioning of the components, which leads to load transfer at the edge of the cup and “edge wear” due to the high contact stresses. Poor lubrication also leads to increased friction moments. These must be transferred through the implant system and may overload press-fit interfaces. For example, the metal taper lock between head and stem has demonstrated wear in large diameter me-me systems [1].

Other hard-hard bearing variations have also been introduced, with increasing bearing diameters. In simulator studies ceramic-ceramic (ce-ce) and ceramic-metal (ce-me) implants have shown much lower wear than me-me bearings. However, they have only been measured in ideal conditions, using serum as a lubricant. Although wear in me-me bearings has been shown to increase dramatically with cup inclination angle, the influence of suboptimal lubrication conditions on friction has so far only been measured in 36mm diameter ce-ce bearings contaminated with ceramic debris [2].

In this study friction was compared for large diameter hard-hard bearings in lubricated and unlubricated conditions. Me-me, ce-me and ce-ce bearings with varying diameters were compared. It was hypothesised that, for compromised lubrication conditions, friction moments for ce-me and ce-ce material combinations would be similar to those for me-me bearings, and could therefore lead to similar clinical problems of interface overload.

**METHODS**

Metal-metal (240/50/58mm, Adept, Depuy), ceramic-metal (232/48mm, Depuy) and ceramic-ceramic (240/58mm Delta motion, Depuy) bearings were tested in a hip simulator described elsewhere [3]. Sample numbers are given in Figure 1.

The cup was oriented with its axis at 33° to the vertical joint load and rotated sinusoidally around a horizontal axis at a frequency of 1Hz and an amplitude of ±20°. Joint loading consisted of a sequence of static and dynamic joint force and motion combinations, lasting a total of 380s. Peak friction moments were measured around the cup rotation axis during a constant joint force period of 1700N between 115-125s, sampled at 100Hz. This represents the stance phase of gait.

Bearings were tested first in serum and then dry. Note that the ceramic-metal bearings and the 58mm diameter metal-metal bearings were each tested in water after serum and prior to dry testing. Furthermore, the ce-ce and two smaller me-me bearings were tested at other bearing angles in serum. No effect of repeated testing was observed. This data is not shown. As lubricant 25% foetal bovine serum (“Gold” Kraeber GmbH & Co., Germany) was used at room temperature. Prior to each test, bearings were thoroughly washed in water, followed by wiping with 96% ethanol, and then rinsed again in water and dried in tissue paper.

Maximum moments were sampled for 10 consecutive cycles and the mean moment M was calculated. This value was either used directly as an output variable, or normalised by joint force F and radius R to give a friction factor μ, according to μ=M/(RxF). Friction factors were compared for bearing material combination and lubrication condition by ANOVA with α=0.05.

**RESULTS**

For all bearings dry conditions resulted in significantly higher moments than serum lubrication (Figure 1). In serum, me-me bearings demonstrated significantly higher friction factors than for ce-me or ce-ce bearings. However, in dry conditions, friction factors for all bearings were higher than those measured in serum. Although there was no significant difference between friction factors for ce-me and me-me bearings in dry conditions, friction factors for ce-ce bearings in dry conditions were significantly higher than for any other bearing. Squeaking was observed for unlubricated ceramic bearings.

**DISCUSSION**

Friction moments for unlubricated me-me bearings were roughly two times higher than those in serum-lubricated conditions. The related higher friction moments in compromised lubrication conditions might explain the wear debris observed at the modular head-neck taper junction in clinical revisions of large diameter me-me bearing implantations [1]. Moments of over 10Nm were measured in dry me-me bearings for all diameters, which is within the range of measured taper capacities [4].

Although the ce-me and ce-ce bearings demonstrated lower friction than the me-me bearings, in lubricated conditions, the reverse was observed in unlubricated conditions. Peak friction factors in dry conditions were less than 0.4 for me-me bearings, but were over 0.4 for ce-me bearings and well over 0.5 for ce-ce bearings. This suggests that any problems currently related to high friction of me-me in poorly lubricated conditions, will be repeated in large diameter bearings incorporating a ceramic component.

Although the dry condition is rather extreme, it may indeed represent clinical conditions, suggested by the observation that ceramic bearings in the laboratory can only be made to squeak similarly to clinical cases in completely dry conditions.

**SIGNIFICANCE**

The poor current clinical results of large diameter metal-metal bearings may be reproduced in large diameter ceramic bearings.

**REFERENCES**


**ACKNOWLEDGEMENTS**

This study was supported by Depuy, UK.