•Friction testing in metal-metal bearings with different clearances using blood as lubricant, +*McMinn DJW; *Daniel, JT; **Kamali, A; ***Sayad Saravi, S; ***Youseffi, M; *Daniel J; **Band, T; **Ashton, R
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INTRODUCTION
Metal on metal bearings produce less wear than conventional bearings and offer the prospect of lower failure rates. Wear and friction in these bearings are influenced by several factors including load applied, material hardness, surface roughness, bearing diameter, sliding speed, radial clearance and the viscosity of the lubricant.

In vitro studies continue to be conducted to determine the optimum clearance for a given bearing diameter. Hip friction studies employ bovine serum with added carboxy methyl cellulose (CMC) as the lubricant, since this combination is believed to simulate the viscosity of synovial fluid. A viscosity of 0.96 Pa s is considered to be the physiological viscosity (simulating the fluid obtained from an arthritic joint or a replaced joint). However, this combination (serum + CMC) does not contain the macromolecules contained in synovial fluid. It is known that macromolecule shear affects friction in a metal-metal joint.

In real life, as soon as the joint is implanted, the joint is actually bathed in blood and not even synovial fluid. Blood contains macromolecules and cells which measure 5 to 20 microns or more. The effect of these on friction is not fully understood.

Most modern cementless joint prostheses have a low clearance Birmingham Hip Resurfacing device (Smith and Nephew Orthopedics Ltd, Bromsgrove, UK) with a low clearance Birmingham Hip Resurfacing device (Smith and Nephew Orthopedics Ltd, Bromsgrove, UK) which stabilises the component in the early weeks. This allows bony ingrowth or ongrowth to occur which in turn provides durable long-term fixation. Increased bearing friction in the early weeks and months after implantation can lead to micromotion and has the potential to prevent effective bony ingrowth from occurring. Therefore, friction in the early postoperative period can be critical to the long-term success of the fixation. This has been one of the concerns raised in a recent clinicalaradiological study,1 of metal-metal bearings with closely controlled 100µm clearance. A progressive radiolucent line (arrows in fig 1) around the socket component, seen in some of these cases at follow-up raises the possibility that increased friction is affecting component fixation. This phenomenon was not observed in the devices with regular (higher) clearances.

We were unable to find any study on friction in metal-on-metal bearings with varying clearances in the presence of blood or a fluid containing macromolecules as lubricants. The purpose of this investigation was to identify the optimum clearance for a given bearing diameter in the presence of blood, which is the fluid that lubricates the joint immediately after the operation.

Fig 1. A 1-year radiograph of a patient with a low clearance Birmingham Hip Resurfacing, showing a progressive radiolucent line around zones 1 and 2 of the acetabular component, suggesting increased friction and micromotion resulting in poor fixation.

METHODS
Six Birmingham Hip Resurfacing devices (Smith and Nephew Orthopedics Ltd, Bromsgrove, UK) with a nominal diameter of 50 mm each and a range of diametral clearances (50, 135, 175, 200, 243 and 306 µm) were used in the study. Initial and final surface roughnesses were measured using a Form-TalySurf 50 (Taylor Hobson, Leicester, UK).

Frictional measurements of all the joints were carried out on a Prosim Hip Friction Simulator (Simos Simulation Solutions, Stockport, UK). The acetabular cup is positioned in a low-friction carriage below and the femoral head in a moving-frame above. The carriage sits on pressurised hydrostatic bearings generating negligible friction compared to that generated between the articulating surfaces. A pneumatic mechanism controlled by a microprocessor generates a dynamic loading cycle and the load is measured by a piezo-electric force transducer. Friction measurements were made in the ‘stable’ part of the cycle.

The loading cycle was set at maximum and minimum loads of 2000N and 100N respectively. In the flexion plane, an oscillatory motion of amplitude ±24° was applied to the femoral head with a frequency of 1Hz. The angular displacement, frictional torque (T) and load (L) were recorded through each cycle. The frictional torque was then converted into friction factor (f) using the equation \( f = T/rL \), where \( r \) is the femoral head radius. An average of three independent runs was taken.

Initially, the test was conducted with blood (whole blood with Lithium heparin to prevent clotting) as the lubricant for each joint. Viscosity of the blood was found to be 0.0086 Pa s. The test was then run with a combination of bovine serum (Harlan Sera-Lab, total protein content 61.27 mg/ml which had been sterile filtered to 0.1 mm) and aqueous solutions of CMC to achieve viscosities of 0.001, 0.003 and 0.01 Pa s.

RESULTS

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<th>Friction factor with BS, serum, CMC</th>
<th>Friction factor with BS, CMC</th>
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Fig 1. Friction factors with whole blood as lubricant and BS/CMC of similar viscosity

DISCUSSION
The engineering issues surrounding optimal metal-metal bearings have been the centre of much debate and research in the past. Ongoing research into the in vitro wear performance of these bearings as a function of macrogeometry (bearing diameter, clearance, and component thickness) and microgeometry (roundness and surface finish) are done in hip function simulators with lubricants that are believed to simulate the natural joint fluid in terms of viscosity.2 However these lubricants have the limitation of being unable to simulate the frictional effects of macromolecules.

Factors such as cellular and macromolecular shear that can affect friction in these bearings, in vivo, have not been specifically investigated in vitro before. Progressive radiolucent lines that appeared in a few patients with low clearance bearings alerted us to the need to study this issue of increased friction in these bearings.

The results of this study suggest that reduced clearance bearings have the potential to generate high friction especially in the early weeks after implantation when blood is indeed the in vivo lubricant. Friction factors in higher clearance bearings are much reduced in comparison. This higher friction in the low clearance bearings may produce micromotion and hamper bony ingrowth resulting in impaired fixation with long-term implications for survival.

REFERENCES

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