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Introduction

- Joint vulnerability arising from abnormal morphology of the femoral head and/or acetabulum is a recognised aetiology in the development of osteoarthritis (OA) of the hip joint [1, 2].
- Geometric variations as a causative factor for abnormal joint mechanics have been proposed as an underlying mechanism that adversely affects the tribology of the hip joint. Increased stress on the articular cartilage from abnormal loading may ultimately lead to mechanical failure and OA [3].
- In-vitro studies would be of benefit for investigating relationships between hip geometry and degenerative joint diseases (e.g. OA), and for exploring the efficacy of early interventional treatments for hip OA.

Aim

The aim of this study was to develop a novel in-vitro simulation model for conducting tribological studies on complete natural hip joints. In future studies, it is envisaged that the model can be used to assess early surgical interventions for hip OA and investigate how different hip geometric parameters affect joint tribology.

The methodology was assessed by conducting in-vitro simulations on complete porcine hip and porcine hip hemiarthroplasty joints (i.e. natural acetabulum and metal femoral head), following which the mean friction factor values for the two groups were compared.

Materials and Method

1. Hip joints harvested from donor pigs ~25 weeks old (Figure 1).
2. A method of orientating acetabula with the required angles of version and inclination using an inclinometer (Figure 2) was developed. In this study, 0° version 45° inclination was used.
3. The femurs were positioned in a pot, which was moveable in two orthogonal directions, using a potting jig. The jig enabled samples to be positioned with different orientations in the coronal, sagittal or transverse planes, whilst maintaining the joint centre of rotation. The femoral head was anatomically aligned with the acetabulum in this study (Figure 3).

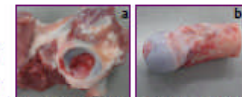


Figure 1: Porcine hip joint: the acetabulum (a) and femoral head (b) were separated during dissection.



Figure 2: (a) Inclinometer; (b) Acetabulum potted in PMMA bone cement.



Figure 3: Femoral head potting: (a) aligning head with potted acetabulum; (b) positioning femur in test pot at correct centre height using jig; (c) femur potted in PMMA bone cement.

4. In-vitro simulations were conducted for two-hours using a pendulum friction simulator (Simulator Solutions, UK) (Figure 4) on complete porcine hip joints (n = 5), and on porcine hemiarthroplasties (n = 5) using CoCr heads (DePuy Synthes, UK) size-matched to the natural head.
5. A dynamic axial loading regime of 25-800N ± 15° flexion-extension (FE) at 1 Hertz, with a 25% bovine serum lubricant was used. Frictional torque was measured using a piezoelectric transducer, from which the friction factor was calculated.

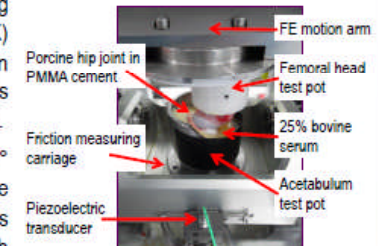


Figure 4: Pendulum friction simulator with complete porcine hip joint in-stu.

Results

Natural porcine hips were positioned with the required anatomical orientation in the simulator. An initial rapid increase followed by gradual rise in friction factor was observed in both groups. Mean friction of the complete joints continued to rise reaching $\approx 0.03 \pm 0.00$ at two-hours, however, mean friction in the hemiarthroplasty group plateaued at $\approx 0.05 \pm 0.01$ (Figure 5). Mean friction was significantly lower in the complete natural hip joint group (*t*-test; $p < 0.05$).

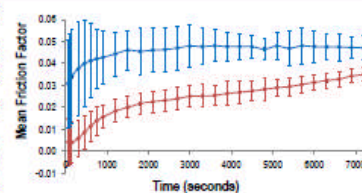


Figure 5: Mean friction factor ± 95 % confidence limits following in-vitro simulation testing of complete (n=5) and hemiarthroplasty (n=5) porcine hip joints.

Discussion

A novel in-vitro simulation model of the natural hip joint with controlled orientation of the femur and acetabulum was developed, and a non-linear increase in friction indicative of biphasic lubrication was simulated [4]. A spatially varying and time dependent load on the femoral head means slower exudation of fluid from the cartilage, and hence a slower rise in friction compared to the hemiarthroplasty model [5, 6]. A larger contact area due to better joint conformity and elastic deformation during loading in the complete hip joint group probably gave rise to the lower overall mean friction factor values [7].

Significance

This methodology will provide a robust system for testing complete natural animal and/or human hip joints using tribological in-vitro simulations, enabling morphological risk factors for the development of OA to be investigated. The model could also have an important role for pre-clinical testing tissue-engineered grafts and other interventions for cartilage and/or labral lesions.

References

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Disclosures

J. Fisher is an NIHR senior investigator, a paid consultant to DePuy Synthes, InVivo, Simulation Solutions, Tissue Regenix Group plc, and a share holder of Tissue Regenix Group plc. S. Williams is a paid consultant to DePuy Synthes.

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