Institute of Medical & Biological Engineering

In Vitro Methodology for Simulation of Natural Hip Joint Biomechanics

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Introduction

Different hip pathologies cause geometric variation or abnormal morphologies of the femoral head and acetabulum. These variations contribute to **altered contact mechanics** that affect the tribology of the natural hip joint and increase the stress distribution on the articular surface and/or labrum leading to mechanical failure.

The use of **hip joint simulators** to investigate the natural hip joint has been limited, as it is challenging to replicate the mechanics of the natural hip joint. Successful simulation would improve our understanding of the mechanical environment of the natural hip.

The **aim** of this study was to develop a repeatable methodology for in vitro simulation of the natural hip considering different scenarios of sample dissection and to assess their effect during subsequent **testing** on the articular surfaces and labrum.

Materials and Methods

- ❑ Porcine hip joints (n=10) were dissected and mounted into an Anatomical Hip Simulator (AHS; a single station six degree of freedom hip joint simulator)
- ❑ The porcine hip joints were prepared for testing in three different ways (see sample conditions)
- ❑ A simplified twin-peak human gait cycle, scaled down to be used on porcine tissue
- ❑ Tests were conducted for 4 hours with Ringers solution as a lubricant
- ❑ Photogrammetry was used to characterise the appearance of the articular surface and labrum pre*, during (2 hours) and post (4 hours) experimental simulation

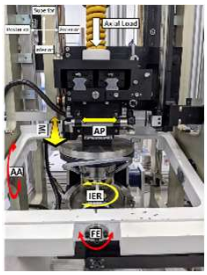

Figure 1. Anatomical Hip Simulator (Simsol, UK)

Sample Conditions

- ❑ Disarticulated joint (DT) (n=4)
  - Synovial capsule removed and the teres ligament sectioned
- ❑ Disarticulated with trochanter removed (DNT) (n=4)
  - Same as DT + additional resection of greater trochanter
- ❑ Intact capsule (IC) (n=2)
  - Synovial capsule, teres and trochanter remained intact.
- ❑ The femoral diaphysis was kept intact
- ❑ 15mm of periacetabular bone remained to enable fixation.

Sample Conditions

Figure 2. Disarticulated joint (DT)

Figure 3. Disarticulated with trochanter removed (DNT)

Figure 4. Intact capsule (IC)

Sample Setup

- ❑ Cementing rigs and simulator holders were designed to provide correct sample alignment so as the AHS and porcine hip had concentric CoRs
- ❑ Adaptable for different sizes of samples and to alter the angular rotation on the joint

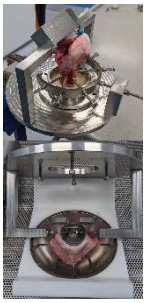

Figure 5. Stainless steel potting jigs for acetabulum and femur

Figure 6.Porcine hip joint mounted into the anatomical hip simulator. Acetabular inclination angle =35

Simulation Scenarios

A simplified gait cycle was applied to the simulator to mimic in vivo lading and motion:

- Twin peak axial load of 1300N
- Flexion – Extension ± 20 °
- Abduction – Adduction 8.8° to -4.8°
- Internal – External rotation -10° to 2°
- Duration: 4 hrs (14400 cycles); frequency : 1 Hertz

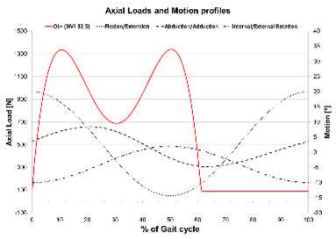

Figure 7. Input profile for simulation (Scaled down ISO 14240)

Results

- ❑ A reproducible set up method was established
- ❑ The methodology was technique sensitive and dependent on the accuracy of the sample set up
- ❑ Alignment of the centres of rotation of the joint and AHS is key for a successful simulation
- ❑ Appropriate alignment meant post simulation damage was consequence of the loading conditions
- ❑ Results from all the tests were consistent regardless of sample preparation method and even with the elevated load (compared to previous testing)
- ❑ Simulations did not present any damage on the articular surface or labrum

Photogrammetry

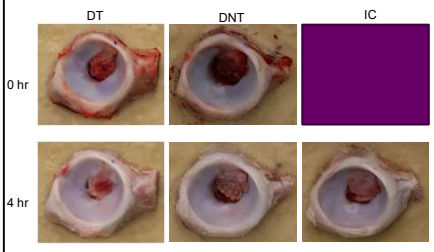

Figure 8. Comparative of the articular surface for the different preparation methods at different time periods.

Discussion

- ❑ The sample preparation method did not affect the results and provided flexibility in sample preparation in future testing plans
- ❑ Experimental simulation observations
  - No damage to the cartilage or labrum surfaces
  - Appropriate methodology and loading regime for in vitro studies on porcine hips
  - Provides control data for comparing when abnormal conditions (changed geometry etc) are simulated
- ❑ Surface assessment by photogrammetry provided an appropriate approach to evaluate the surfaces during and after simulation
- ❑ The developed methodology will be transferred to analyse:
  - The biomechanics of the hip when different morphologies occur
  - The damage provoked when the angles and position on the joint changes
  - Tests on cadaveric human tissue

Significance/Clinical Relevance

- ❑ The simulations provide a better understanding of the mechanical damage mechanisms in the natural hip.
- ❑ The developed methodology can be implemented to test the biomechanics of cadaveric human hips with different bone morphologies and evaluate the effect of surgical procedures to restore normal contact mechanics of the joint.

Acknowledgements

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