Institute of Medical & Biological Engineering

Development of a Preclinical Natural Knee Simulation Model for the Tribological Assessment of Osteochondral Grafts

UNIVERSITY OF LEEDS

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Introduction and Aim

In order to develop novel regenerative osteochondral intervention therapies for the patient, there is the requirement to develop robust and stratified preclinical tests methods, facilitating the detailed evaluation performance in the natural knee environment. Tribological assessment of osteochondral grafts is limited to simple geometry and basic whole joint studies (1-4). Currently, there are no published studies describing the development of an in vitro whole joint simulation model, capable of the preclinical assessment of early intervention osteochondral therapies in the knee

The aim of this study was to develop an in vitro whole joint simulation model for the preclinical assessment of the tribological performance of osteochondral grafts in the natural knee joint. The study also aimed to quantify and characterise cartilage surface damage, wear and deformation using an optical profiler.

Materials & Methods

All tests were conducted using a whole porcine joint model in a natural knee simulator (6 degrees of freedom; Pro Sim, Simulation Solutions, UK) with a physiological gait input profile (Figure 4). Anterior-posterior displacement and shear force outputs were recorded and analysed for all tests. Additional test parameters are provided in Table 1.

1

Porcine joint braced in natural position, ligaments removed, menisci left in situ (Figure 1 & 2)

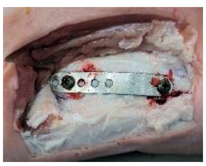

Figure 1: Window cut in porcine leg to allow bracing in natural position

Figure 2: Porcine joint braced & dissected

2

Sample mounted in physiological position (Figure 3) in the simulator.

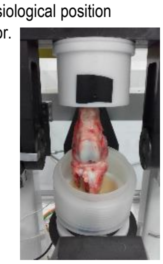

Figure 3: Porcine joint mounted in simulator

3

Sample run as negative control (Figure 5) for 900 cycles at 1 Hz.

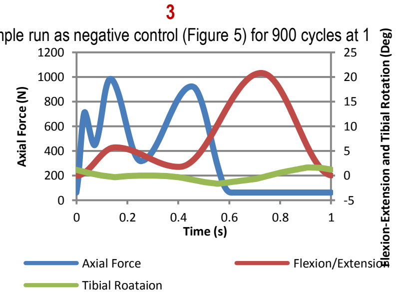

Figure 4: Input Gait Profile

4

Allografts, cartilage defects or stainless steel pins inserted centrally in medial condyle; tests run for 7200 cycles at 1 Hz (Figure 5 & Table 1)

Table 1 : Test Parameters

Experimental Groups	N = 4
Lubricant	PBS + 25% (v/v) Newborn Calf Serum
Allografts & Stainless Steel Pins	6 mm diameter x 10 mm length
Cartilage Defects	6 mm diameter (full thickness)
Optical Profiler	Alicona Infinite Focus G5

5

Meniscal (opposing tissue surface) replicated with silicon.

6

Surface volume of meniscal surface measured with optical profiler (measure of surface damage, wear & deformation; Figure 6) and compared to negative controls.

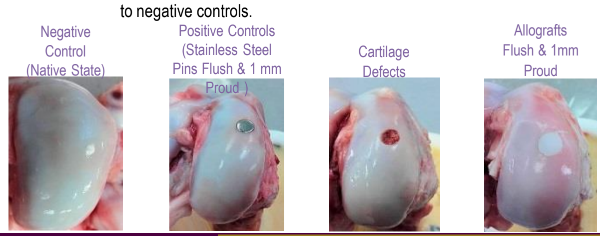

Figure 5: Overview of experimental & control groups

Results

Surface wear and damage in the allograft flush group was low (0.17 mm^3; Figure 6). Cartilage defect group damage and wear was also low (0.26 mm^3), possibly attributable to a reduction in contact area and additional fluid load support. Allograft 1 mm proud group had increased levels of surface damage and wear attributable to increased edge effects. Wear and damage levels were significantly different to the negative controls and most severe in the stainless steel flush (3.5 mm^3) and 1 mm proud (20.9 mm^3) groups (Figure 6). There was no change in anterior-posterior shear force or displacement following insertion of allografts, defects or stainless steel pins.

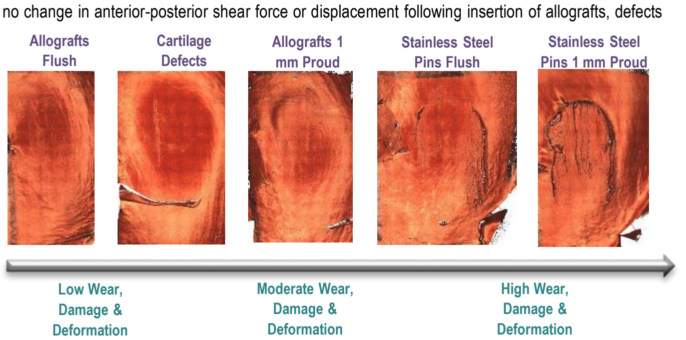

Figure 6: Schematic highlighting damage & wear observed in the experimental groups. Images are of the medial meniscus taken using an Alicona Infinite Focus optical profiler. Mean negative control group volume 0.089 mm^3.

Significance

- Osteochondral allografts demonstrated the potential to restore the joint surface with low levels of subsequent surface damage, wear and deformation.
- The development of the pre-clinical simulation model represents a significant step in the preclinical testing of osteochondral grafts.
- The model may be applied in the future to test regenerative osteochondral interventions (e.g. synthetic / decellularised scaffolds), human tissue models and aid in the development of stratified interventions.
- Robust preclinical evaluation of osteochondral repair interventions will aid in the development of current and future therapies for the treatment of osteochondral defects in the knee.

References

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