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An *In Vitro* Simulation Model to Assess the Tribology of Decellularised Osteochondral Grafts in a Human Patellofemoral Joint

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Introduction

The patella is the most common location for chondral lesions in the knee, 40% of which are grade 3 or 4[1]. Where cartilage damage causes pain or impairs joint function, restoration of the articulating surfaces using an osteochondral graft may be appropriate. Autografts are the current gold standard approach but there are several factors which limit their use such as donor site morbidity and a limited supply of grafts. Decellularised osteochondral xenografts give a potential alternative. They are readily available, have a structure similar to native cartilage and are non-immunogenic. In the patellofemoral joint, surgical outcomes are often less successful than when similar procedures are carried out in the tibiofemoral joint. Therefore, there is a need to better replicate the mechanics and tribology of the human patellofemoral joint to assess the function of osteochondral interventions.

Aim

- **To develop an experimental method to simulate the loading and motion of a human patellofemoral joint**
- **To compare the wear and biomechanics of osteochondral autografts to porcine decellularised osteochondral grafts.**

Materials and Methods

- 12 human patellofemoral joints mean age 50.4 years (range 22-64) dissected and cemented adapting a method previously developed for the porcine patellofemoral joint[2].
- Single station 6-axis knee simulator (Figure 1) with input profiles modified from artificial patellofemoral joint simulation[3] (Figure 2). Ranges of motion: flexion/extension 17.7°; superior-inferior translation 12mm; abduction/adduction 4.5°; internal/external rotation (tilt) constrained using springs (1.61 N/mm); medial-lateral translation damped using a pneumatic cylinder.
- Studies initially run for 3 hours (10800 cycles) at a frequency of 1 Hz with an axial force up to 582N (Low load), axial force was then increased to 1165N (High load) for 3 hours.
- 25% bovine serum in Ringers solution used as a lubricant.
- Experimental groups, n=4 for each:
  - Negative control - no intervention
  - Autograft - osteochondral autografts from the condyles of the same donor
  - Porcine decellularised grafts – grafts taken from the condyles
- All grafts 8.5 mm diameter, a single graft introduced into both the patella and the trochlear groove ensuring the two grafts did not articulate against each other (Figure 3).
- Wear, damage and deformation of the joint assessed by cartilage scoring. The trochlear groove and the patella were divided into nine regions, each region was scored from 0-4 with 0 showing no damage and 4 damage through the subchondral bone.

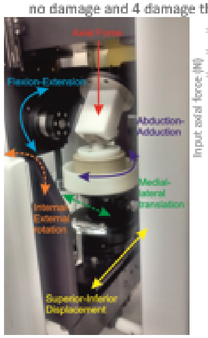

Figure 1: The axes of the patellofemoral joint simulator

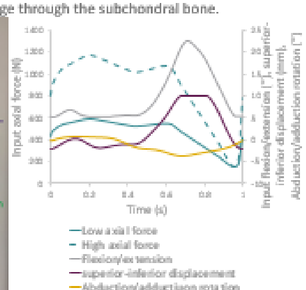

Figure 2: Input kinematics to the simulation

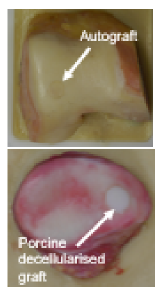

Figure 3: Grafts implanted in the trochlear groove of the femur and the patella (samples from different experimental groups.

Results

- Knees allocated to experimental groups randomly. The mean initial ICRS scores on the femur were 3.3 ± 4.8; 6 ± 1.6; 2.3 ± 5.3 and on the patella were 9.8 ± 10.2; 12.3 ± 11.0; 6 ± 5.3 for the Negative controls, Autografts and Decellularised grafts respectively. No significant difference in the initial mean cartilage score for the femur or patella (p>0.05).
- Representative photographs of the joints after 6 hours wear simulation (Figure 4), mean change in ICRS cartilage grading score compared to initial score (Figure 5 and 6).
- No clear trends to differentiate between the experimental groups
- Evidence of graft subsidence was apparent in the patella and femur of two autograft samples, no other grafts subsided >0.5mm below their initial position.
- Increasing the axial load led to further changes in the cartilage surface and also some joints became less stable under the higher load condition exhibiting an increased patella tilt. The medial-lateral patella translation was similar under both loading conditions.

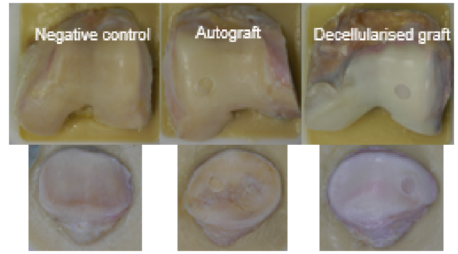

Figure 4: Representative images of the trochlear groves and patellae following 6 hours wear simulation

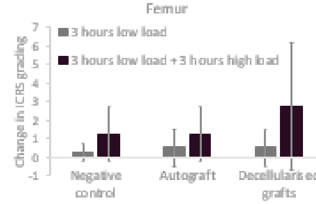

Figure 5: Mean change in cartilage grading score (±SD) on the femur following 3 hours simulation under low load and 3 hours under high load

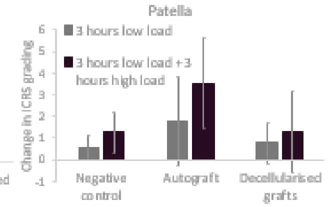

Figure 6: Mean change in cartilage grading score (±SD) on the patella following 3 hours simulation under low load and 3 hours under high load

Discussion

Over the duration of the study, wear, damage and/or deformation occurred similarly on the patella and femur but the initial condition of the tissue varied from donor to donor and it is likely that for some samples, initial tissue quality had a greater influence on cartilage wear, damage and deformation than the introduction of grafts into the knee. Subsidence of autografts occurred in 2 patella and 2 femur but due to the small sample sizes, there is insufficient evidence to draw a firm conclusion. When the cartilage lesions were >8.5 mm diameter, it was difficult to accurately assess stability. No decellularised grafts subsided >0.5 mm.

Clinical Relevance

A method to simulate the biomechanics and tribology of a human patellofemoral joint has been developed. In this model, porcine decellularised grafts behaved similarly to osteochondral autografts in terms of their stability, wear of the graft and the wear, damage and deformation of the opposing cartilage surface.

References:
[1] 1 Widuchowski, W. (2007) Knee:(14)177-182 [2] Maiti, R. (2017)JEIM:231(7)634-642 [3] Cowie RM et al (2021) PLoS ONE 16(4): e0250077

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