EVALUATION OF KNEE MENISCUS KINEMATICS USING AN MRI COMPATIBLE LOADING RIG

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Introduction

The meniscus plays an integral role in the load transfer and kinematics of the knee joint [1]. However, deficiencies have been highlighted in previous *in vitro* meniscal kinematics studies, in particular the lack of comprehensive description of its kinematics under physiologically relevant load conditions in intact knees. In this work, a Magnetic-Resonance (MR) compatible load rig was developed with the aim of capturing more accurate morphological behaviour of the meniscus within an intact knee joint, for the longer-term purpose of calibrating constitutive models of the meniscus.

Methods

An MR compatible loading rig was developed using a combination of non-metal rods and springs (LeeP™ Plastic Composite, NY, USA) to displace and load a whole cadaveric or large animal knee joint under compression and in two configurations of flexion (Figure 1-A). Three porcine knee joints (3 months old, ~90 kg) were dissected leaving the femur, tibia, fibula and capsule intact. The samples were aligned and potted with PMMA cement to fit into the rig. After an initial preload of 30N, the samples were loaded to ~1.5 kN in steps of ~500 N for the 0° flexion and to 1000 N in the 22.5° flexion configuration. After each load step, including the initial pre-load, the samples were imaged at an isotropic resolution of 0.3 mm (3T Magnetom Prisma, Siemens, Germany), following a relaxation period of ~8 min. MR images of different load cases for a given flexion configuration were registered using the femur; which was assumed to be rigid. For all the load cases, radial displacements of the external surface of the menisci were measured from reference points (P1 & P2 in Figure 1-C) defined using tibial bony features. The total medial-lateral displacement was defined by finding the mid-plane in the coronal direction.

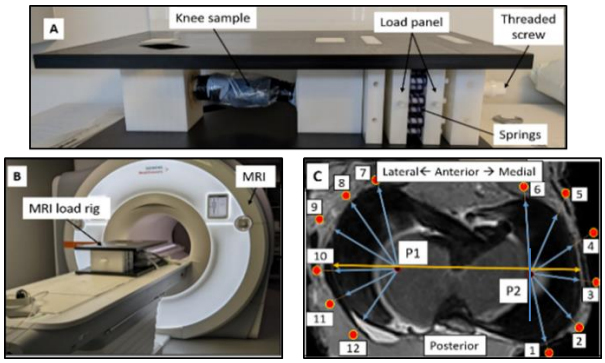

Figure 1: Specimens were loaded in a rig (A) and MR imaged (B). Measurements were taken of radial displacement (blue) and meniscal width (yellow) (C).

Results

Increasing the load led to an increase in width of the menisci for all the samples (mean 4.4% at 1.5kN axial load, Figure 2). This increase was caused more by deformation of the cross-section than by the whole meniscus moving outwards. While the radial displacements varied, there was generally more displacement in medial-lateral direction (Figure 3).

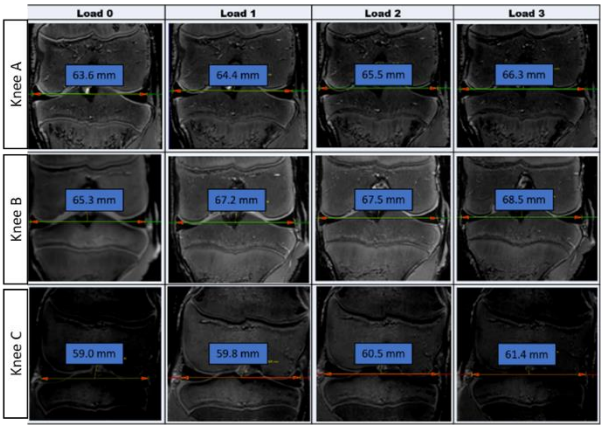

Figure 2: Lateral meniscal measurements with increasing load for the three samples used.

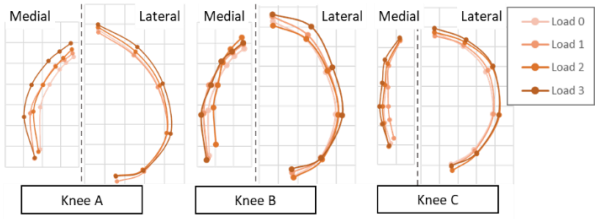

Figure 3: Visualisation of the radial displacements of the medial and lateral menisci under increasing load.

Discussion and Conclusion

A new method for measuring meniscal displacements *in vitro* was developed. The radial displacements collected from the experiment provide data for estimating meniscal material coefficients through inverse finite element approaches [2]. The method also provides a tool to examine the effects of degeneration or injury, and potential repair strategies or meniscal allografts.

References

1. Imeni et. al, Biomech Model Mechanobiol 19, 1979–1996 (2020).
2. Zantiba et. Al, CMBBE, 2023.

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