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DEVELOPMENT OF A PRE-CLINICAL EXPERIMENTAL MODEL TO MEASURE MEDIAL MENISCUS POSITION DURING A SIMULATED GAIT CYCLE OF THE HUMAN KNEE JOINT

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Disclosures: Genevieve A. Pounds (N), Dr Aiqin Liu (N), Dr Alison C. Jones (N), Professor Louise M. Jennings (5 – Mathys, DePuy Synthes, Invibio, MatOrtho)

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Introduction

- Meniscus extrusion is a condition where an abnormal meniscus position accelerates the onset of osteoarthritis [1] (Figure 1)
- Meniscal position is an important measure of function and an important metric to preclinically assess meniscus interventions [2]. However, this has rarely been performed in a functional in-vitro environment
- The meniscus withstands compressive, tensile and shear forces in-vivo. However, the pre-clinical mechanical assessment of interventions using physiological loads and motions remains underrepresented in the literature

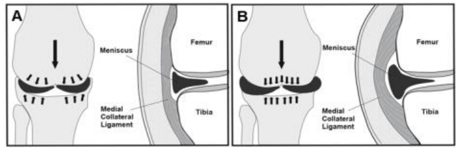
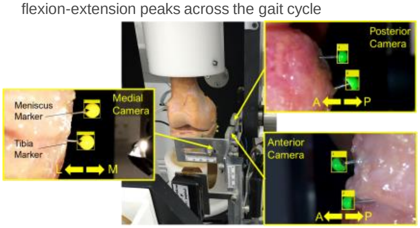


Figure 1. (A) healthy meniscus and (B) extruded meniscus; increasing the contact pressures across the knee joint.

Aim: To develop a novel and low-cost method, which is sufficient to measure changes in meniscal position in a human tibiofemoral joint model performing a simulated gait cycle.

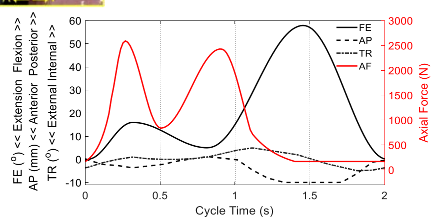
Methods

- A motion capture method using MatLab (The MathWorks Inc.) and a camera system (Raspberry Pi) was developed and preliminary assessed using porcine knee joints prior to human (Figure 2)
- N = 4 human tibiofemoral joints were dissected and cemented for knee simulation [4]. Coloured meniscus and tibia markers were attached to the medial, anterior and posterior regions of the medial meniscus. Each camera was positioned to video the corresponding regional markers
- The Leeds high kinematics gait profile was driven at 0.5 Hz speed in a Prosim knee simulator [3] (Figure 3) and the relative displacement of the meniscus marker relative to the tibia marker was calculated over the duration of cycle 10
- The conditions tested were the intact, the capsule removed, partial tear and complete posterior root tear of the medial meniscus. A repeated measures one way ANOVA was used to compare means between the conditions (*p<0.05*). Means were generated from the range (max – min) and specific timepoints relating to the axial force and flexion-extension peaks across the gait cycle



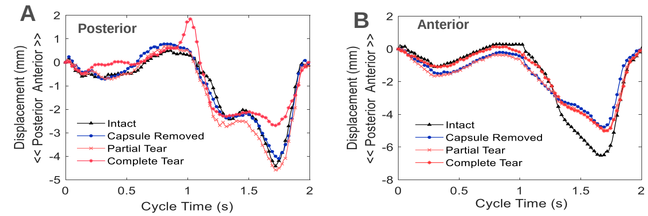
◀ **Figure 2**. Test set up of a human tibiofemoral joint in the knee simulator with three miniature cameras viewing the meniscus and tibia markers in the anterior, posterior and medial regions. The MatLab script inserts yellow boxes around the markers and tracks the medial-lateral (M-L) and anterior-posterior (A-P) displacement of the markers across the gait cycle in the video.

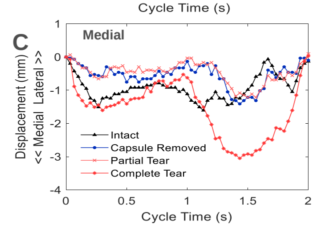
▶ **Figure 3.** Leeds High Kinematics Gait Cycle parameters including the: flexion-extension angle (FE), anterior-posterior tibial translation (AP), internal-external tibial rotation (TR) and the applied axial force (AF). The adduction-abduction angle axis was left free.



Results

- The motion capture method was able to measure the relative meniscus displacement for all left and right human knees across a simulated gait cycle in the anterior, posterior and medial regions (Figure 4)
- All human knee samples presented unique meniscus, tibia and relative displacement profiles across one gait cycle, creating a large amount of variation between samples and generating no significant differences between the conditions (p > 0.05)
- When the root was completely torn, changes occurred in the both the meniscus marker and tibia marker displacement results, causing minimal changes in the relative displacement





◀ ▲ **Figure 4 A-C.** Relative displacement results of the meniscus marker relative to the tibia marker in the video, for each dissection and root tear condition. Measured in the (A) posterior region, (B) anterior region and (C) medial region from one human sample.

Discussion

- The novel motion capture method was able to measure the relative meniscus displacement throughout a continuously driven simulated gait cycle, however, changes in response to dissection and root tear conditions were difficult to compare and analyse
- Intact relative meniscus displacement results were in a similar range to those reported in previous in-vivo and in-vitro literature using radiographical methods [5,6]
- Limitations include:
  - Low sample size
  - Difficult to control the amount of connective tissue dissected
  - Local movement of the marker pins within the tissue

Summary

- A novel motion capture method was developed to measure dynamic meniscus position during a simulated gait cycle in human cadaveric knee joints
- Each sample produced a unique profile of relative medial-lateral and anterior-posterior medial meniscus displacement in the medial, anterior, and posterior regions
- This work establishes a potential pre-clinical method to assess the dynamic movement of meniscus interventions in a functional in-vitro environment

References: [1] Costa et al., *AJR*. 2004; 183(1), pp.17-23. **[2]** Mohamadi et al., *BMC Musculusketet Disord*. 2021; 625(22) pp.1-13. **[3]** Liu et al. *J Biomech*. 2015; 48(12): pp. 3004-3011. **[4]** Liu et al. *PLOS One*. 2020; 15(10): pp. 1-15. **[5]** Vedi et al. *J Bone Joint Surg*. 1999 ; 81(1): pp. 37-41. **[6]** Vrancken et al. *The Knee*. 2014. 21(6): pp. 1033-8.

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