LATERAL MENISCUS ANTERIOR ROOT AVULSION INCREASES CONTACT PRESSURES: A FINITE ELEMENT STUDY

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Introduction

Deleterious consequences of posterior meniscal root detachment have been related to variations in contact pressure (CP) distribution seen in biomechanical investigations. However, little is known about the biomechanical effects of lateral anterior root avulsions (ARA), despite clinical studies reporting it as a lesion concomitant with anterior cruciate ligament (ACL) injuries and tibial fractures [1,2] and as an iatrogenic injury during ACL reconstructions [3,4]. This work analyzes variations in CP due to lateral meniscus (LM) ARA using a knee finite element model (FEM).

Methods

A human cadaveric specimen was used to create and validate a knee FEM to compute the tibio-femoral CP distribution in three conditions of the LM: intact, with ARA and with posterior root avulsion (PRA).

Meniscus, cartilages, femur and tibia were segmented from MRI data (T1, thickness=3.5mm) using 3D Slicer®. From the point clouds extracted, solid models were built and assembled in Solidworks®. Cartilage models were refined using a 3D Laser Scanner (Picza LPX-1200, Roland DG, Hamamatsu, Japan). From the assembly, a FEM was defined in Abaqus®. Ligament insertions were identified in MRI images (Figure 1).

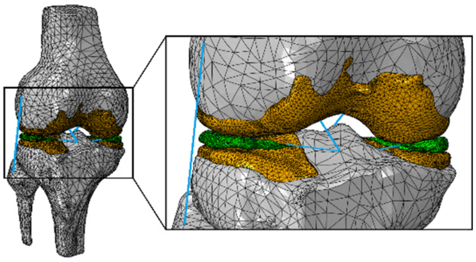

Figure 1: Knee FEM developed in Abaqus®.

Bones were assumed rigid. Meshes of cartilages and menisci were created using 1.5mm second order tetrahedral elements. Linear isotropic elastic materials were applied to the menisci (E = 59MPa) and cartilages (E = 5MPa). Menisci root and ligaments were modelled as nonlinear elastic axial springs with material properties extracted from the literature [5,6]. Surface-to-surface contact was defined at all menisci/cartilage and cartilage/cartilage interfaces.

To validate the model, the same specimen with intact menisci was subjected to an experimental axial compression test with the knee in extension under a 1000N load. A pressure sensor (K-scan 4000, Tekscan Inc., Boston, MA) placed between menisci-tibial cartilage captured the CP.

Boundary conditions were replicated in the FEM and CP given by the two methods were compared. The validated model was used to compute the CP distributions in the three pre-stablished conditions of the lateral meniscus.

Results

In the intact condition, the CP distributions of experimental and FEM methods were similar (Figure 2). In ARA and PRA, the CP increases and the contact area decreases (Table 1).

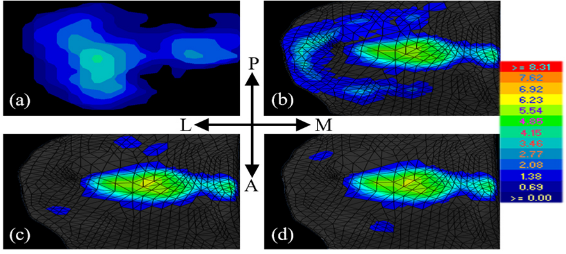

Figure 2: Tibial cartilage CP: (a) Intact experimental; (b) Intact FEM; (c) ARA FEM; (d) PRA FEM.

FEM	Pmax	Pavg	Contact Area
Intact	6.40MPa	1.02MPa	578.28mm^2
ARA	6.92MPa	2.00MPa	387.01mm^2
PRA	6.81MPa	1.98MPa	367.49mm^2

Table 1: FEM contact area, maximum and average pressures in the three conditions of the lateral meniscus.

Discussion

Changes observed in knee contact biomechanics after lateral meniscus ARA indicated potential for similar cartilage damage than observed after a PRA. Since most daily activities and sports are done in low flexion angles in which anterior roots bear most of the load, an ARA could be even more critical. Therefore, special attention should be paid to diagnostic and treatment of this injury.

References

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Acknowledgements

This work was supported by MCIU/AEI/FEDER, EU Grant RTI2018-094339-B-I00 and the University of Malaga.