Abstract:

Soft tissues loadings on healthy knee at different physiological flexions: a coupled experimental-numerical approach

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Introduction

Knee degradation and pain when developing osteoarthritis are strongly related not only to the pressure on the cartilage, but also to the knee stability and to the subsequent loadings on the ligaments. Authors proposed the knee models without any flexion [1][2]. Knee flexion had been introduced by controlling actively muscular groups [3] or by using a full displacement-controlled model [4]. But in both cases, the pressure applied on the articulation has been questioned, the forces used to achieve the flexion being far from the physiology in the former and the bone positioning uncertainties leading to high variations in the cartilage pressure and ligament loads in the latter. Here, we propose a mixed approach, both using medical imaging (MRI, EOS X-ray system [5]) and force platform in conjunction with a finite element model.

Method

A healthy volunteer underwent a MRI and an EOS imaging of the knee. EOS images gave the exact position of the bones for five flexion angles of the knee, ranging from 0° to 85°. The subject's knee was loaded with a specific force on his foot during all acquisitions to keep consistent boundary conditions on the knee. A 3D geometrical model of the bones and cartilages was segmented from the MRI stacks; this model was meshed and smoothed for Finite Element Analysis (FEA). The bones of the model were fitted to those of the EOS images to have the physiological positions of the knee. The ligaments were then added as truss elements (under tensile forces only). The FEA was carried out according to the experimental boundary conditions (force and flexion angle), so as to ensure the global knee mechanical equilibrium.

Results

To validate this patient-specific model, its bony structure was confronted with the EOS images once the mechanical equilibrium was reached. The difference of the position was within the error range of the image registration, showing a satisfying equilibrium state. Last, this model gave us an estimation of the tension in the ligaments for every flexion as well as a pressure map on the cartilages.

Discussion

This healthy model of the knee will be completed with the menisci to have a more precise pressure map on the cartilages. It will then be used as a reference in studying arthritic knee joints for clinical cases.

Figure Caption:

Figure1: FEA (right) of the EOS imaging (left)

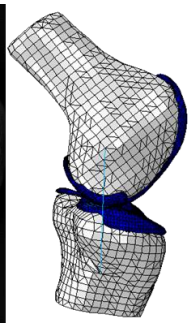

Figure2: Pressure map on tibial cartilage

References:

[1] Peña, *et al*, Journal of biomechanics 39.9: 1686-1701, 2006.
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[5] Wybier, *et al*, Joint Bone Spine 80.3: 238-243, 2013