KNEE CARTILAGE MECHANICS IN FINITE ELEMENT ANALYSIS USING INPUTS FROM DIFFERENT MUSCULOSKELETAL SOFTWARE

Joose Peitola (1), Amir Esrafilian (1), Atte Eskelinen (1), Michael Skipper Andersen (2,3), Rami K. Korhonen (1)

1. University of Eastern Finland, Finland; 2. Aalborg University, Denmark; 3. Center for Mathematical Modeling of Knee Osteoarthritis, Aalborg, Denmark

Introduction

Computational modeling has been widely used for estimating knee joint mechanics, predicting the progression of musculoskeletal (MS) diseases, and simulating the effects of rehabilitation exercises. Different MS-software have been used for these purposes, and some studies have already investigated the effects of using different MS software on estimations of e.g. muscle forces and joint contact forces (JCF) [1,2]. Although these studies have shown some differences in the body- and joint-level mechanics, no studies have yet investigated the effects on tissue-level mechanics. In this study, we utilized a musculoskeletal–finite element (MSFE) modeling workflow [3] to compare the tissue-level differences of the knee joint cartilage mechanics between the models driven by two widely used MS-modeling software, AnyBody and OpenSim.

Methods

Motion data and ground reaction forces from gait trials of one subject were utilized in the MSFE-workflow (Fig. 1, top). The two MS-modeling software used in the comparison were AnyBody (V.7.4.2, AnyBody Technology, Denmark) and OpenSim (V.4.4). The models used for the analysis were the Twente Lower Extremity Model v.2.1. [4] (AMMR 2.4.2) for AnyBody and the model by Rajagopal et al. [5] for OpenSim. Conventional pipelines were used in both MS-software to estimate knee joint angles, joint moments, knee JCF, and muscle forces. The knee flexion angle, tibio- and patellofemoral JCF and moments were used as inputs in the FE analysis where the cartilages and menisci were modeled as fibril-reinforced poroviscoelastic material (Fig. 1, middle). The FE analysis was done with Abaqus (V.2020), and the geometry of the model was adapted from a study by Esrafilian et al. [6]. The inputs from both MS-software were used to estimate tissue-level knee mechanics (such as, the maximum principal stress) during the stance phase of the gait cycle.

Results

The values of the maximum principal stresses were similar on both medial and lateral tibial cartilage between the workflows with AnyBody and OpenSim, at the time of the maximum load during the stance phase (Fig. 1, bottom). The locations of the highest stresses were also similar in the medial cartilage but located more on the posterior side in the lateral cartilage with AnyBody workflow compared to OpenSim.

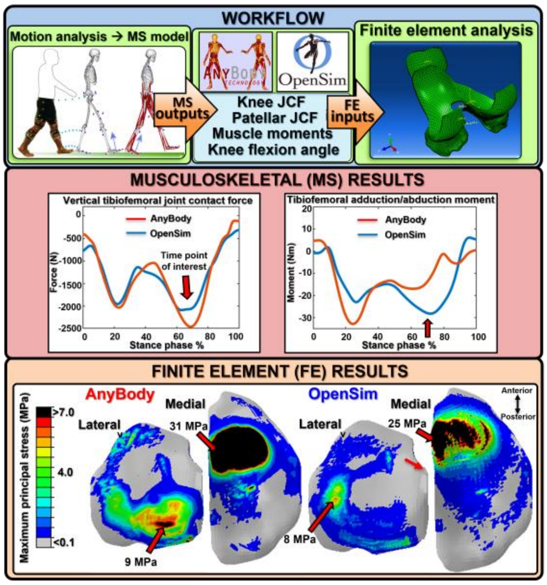

Figure 1: Workflow of the study and the results of the MS and FE analyses. The figures shown here are illustrating representative parameters and differences between AnyBody and OpenSim driven MSFE-workflows. At the bottom, red arrows are indicating the maximum values (average from 10 adjacent elements).

Discussion

This study showcases some similarities and differences between estimated knee cartilage mechanics in FE models using two widely used MS-software to obtain loading inputs. The small differences in the maximum principal stresses are most likely caused by the slightly higher vertical JCF and the smaller abduction moment estimated with AnyBody. The results suggest that acknowledging the characteristics of different MS-software in MSFE-workflows could be important, since they can affect the numerical predictions of tissue failure and knee osteoarthritis progression.

References

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