INSTRUCTION

The meniscus is a crescent-shaped fibrocartilaginous structure that lies between the cartilage of the femur and tibia of the knee joint. Two menisci are present in the knee joint, one medial and one lateral, together that cushion and stabilize the knee joint (see Figure 2). A meniscectomy is the surgical removal of all, or a part of a torn or damaged meniscus. Tears in the menisci are common in knee joint injuries and depending on the location and severity of the tear, orthopaedic surgeons who perform meniscectomies will make surgical decisions based on the age, health and activity level of the patient, as well as the meniscus’s ability to heal.

AIM

To develop an intact (natural, no-defect) knee model from patient specific data, and then perform two partial meniscectomy virtual surgeries of different resection lengths (30mm & 35mm) based on a typical defect. Use the models developed to assess the change in knee mechanics and loading with variation in resection length and surgical outcome. Implement a method to rank and grade the various partial meniscectomy virtual surgeries relative to the intact natural (no-defect) model.

METHOD

MRI imaging data was obtained from a 48 year old Caucasian male (weight 78kgs) with no previous history of hip, knee or ankle problems. 3D Slicer v4.6 [11] software was used to segment the MRI data & obtain the required geometries for the model (Figure 1). A literature review of knee kinematics and modeling techniques was performed [5-10], to assess current methods & techniques utilised in the field. From this review, three models were developed with the appropriate loads, boundary conditions & material relations. The knee domains & features implemented in the knee model are presented in Figure 2. A defect location was defined on the posterior side of the medial meniscus based on literature. Two virtual partial meniscectomy surgeries where performed on the intact model, namely 30mm & 35mm resections on the posterior side of the medial meniscus. The three models developed including, a) natural (no-defect), b) partial meniscectomy (30mm resection), c) partial meniscectomy (35mm resection), are illustrated in Figure 3.

Figure 3. natural (no-defect) menisci compared to partial meniscectomy models (superior views of menisci, tibia cartilage & tibia)

The material models implemented include hyper-elastic (neo-Hookean), linear orthotropic & isotropic material models. The material models are based on the work by [6, 9-10]. A summary of the material models utilised in the model for each knee component is provided in Table 1. Frictionless contact was assumed between all articulating surfaces [8][11]. The load & boundary conditions applied to the knee model included two load cases namely; 1) standing, & 2) walking gait. Only the standing load case data is presented.

RESULTS

Displacement magnitudes, contact pressures & stress magnitudes were assessed & compared to the intact (no-defect) model. Figure 4, presents the displacement differences between the models on the axial plane only. From this, the displacements from the conserving 30mm resection model is a closer match to those of the intact model.

Figure 4. menisci anterior-posterior & lateral-medial direction displacement magnitudes for standing load case (superior views only)

The contact pressure & loading patterns for each model are presented in Figure 5. Again based on the observed contact footprints and contours on the lateral side of the joint are very similar for all cases. However, there are large differences seen on the medial side of the joint, where again, it can be seen that the contact footprint in the conserving 30mm resection model is more evenly distributed across the postero-medial side of the medial meniscus, and is a closer match to the natural (no-defect) model.

Figure 5. contact pressure & loading pattern between the various bodies and loading patterns for standing load case (superior views only)

CONCLUSION

A knee model has been developed to help assess the change in knee mechanics & virtual partial meniscectomy surgical options.

References