Knee Joint Stress Analysis in Standing

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I. Introduction

Knee joint is the most important and biggest joint of the human body that is consisted of the two separate joint; The Tibiofemoral joint (TF) and patella femoral Joint (PF) [1,2]. Knee joint components are femur, tibia, fibula, patella, plateau tibial cartilages, femoral cartilage, menisci and ligaments [3]. Knee injuries are common in young and adult person. Hence, having good knowledge of knee biomechanics helps to keep it safe. To date variety of parameters have been analyzed via experimental measurements or finite element studies [4] and Finite element Methods in the variety area of research (mechanical engineering, aviation, biomechanics, etc.) are well known as powerful tools to analysis of the mechanical respond of structures to the different loading.

Many researchers have done finite element analysis (FEA) on knee joint [5,6,7,8,9]. Guo et al. carried out 3D FEA of knee joint in gait cycle [1]. W. Mesfar and A. Shirazi-Adl investigated the biomechanics of human knee joint for flexion from 0° to 90° with FEA [10]. Explicit FEM was employed to analyze impact in knee during hopping [11]. Zhang et al. calculated contact pressure and contact area for different parts of knee compartment by 3D FEA of healthy human knee joint and found: by increasing flexion angles contact pressure and area increased, smaller contact area on lateral cartilage in comparison with medial cartilage and variable peak contact pressure on medial meniscus whereas constant contact pressure on lateral area [12].

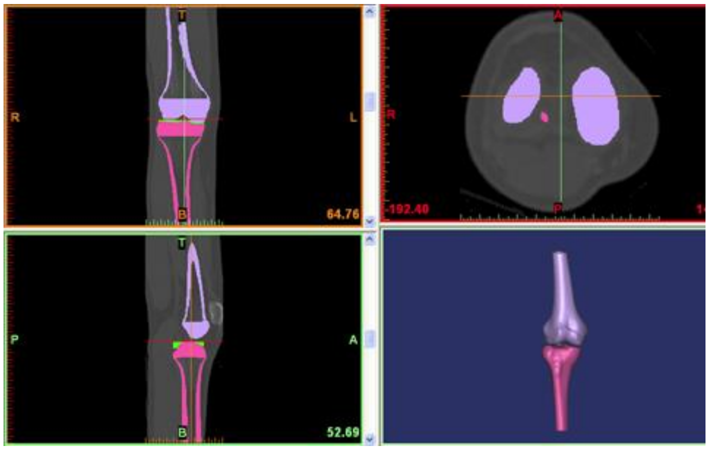
However, many studies have been done on knee joint, still there many unknown parameters, which could affect the knee joint health. Standing is the one of the phase that regularly during daily activity we faced with it. Therefore, the aim of this study was to develop a three-dimensional (3D) finite element model to investigate the stress distribution in knee joint during the standing.

II. Material and methods

Three steps for obtaining the three dimensional knee joint geometry have been carried out; (i) obtaining the surface geometry of the healthy knee using Computed tomography (CT), (ii) importing the CT images into the Materialise Mimics software (version 13.1) for constructing the 3D model of the knee, and (iii) importing the 3D model into the FE software ABAQUS (v. 6.7).

A. Creating Tibiofemoral Joint

CT images were obtained from the knee of a 24-year-old healthy female (mass 50 kg, height 162 cm). 988 images were captured using a multidetector Siemens machine with 512*512 pixels and a spatial resolution of 0.549 mm. CT images were converted using Digital Imaging and Communication (DICOM) formats and were then imported to the Mimics software. As shown in Figure 1, soft and hard tissues were identified using tissue specific threshold values of 148-1872 and 125-700, respectively and the tibia, femur, cartilages, and menisci were represented in the knee model (maximum and minimum value of threshold corresponds to the range of grey values to highlight pixels). After creating the knee components in Mimics, the 3D model was imported as into ABAQUS finite element software.



B. Defining Material Properties

Bony components (femur and tibia) and their cartilages (Femoral and tibial cartilages) were considered as linear and elastic material with Young's modulus of 11GPa and Poisson's ratio of 0.3 and Young's modulus of 5MPa and a Poisson's ratio of 0.46 respectively for bone and cartilages. Menisci were also considered elastic with a Young's modulus of 59MPa and a Poisson's ratio of 0.49.

C. Loading and Boundary Conditions

A compressive vertical load of half body weight (BW) was applied to the top of the femur. Femoral motion was limited to the Z direction while the tibia was completely fixed. Cartilages was perfectly attached to the corresponding bones, and the motion of the menisci was restricted to the lateral and medial direction as shown in Fig. 2. Frictionless contact property was assumed between TF components.

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