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A Study on Tibiofemoral Joint Contact Area Stresses using Finite Element Method

Anjeza Gjini
Polytechnic University of Tirana, anjezagjini@hotmail.com

Altin Bidaj
Polytechnic University of Tirana, altinbidaj@yahoo.com

Enio Deneko
Polytechnic University of Tirana

Drilona Disha
Polytechnic University of Tirana

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Anjeza Gjini[1], Altin Bidaj[2], Enio Deneko[3], Drilona Disha[4]

[1,2,3,4]Polytechnic University of Tirana, Faculty of Civil Engineering
Department of Mechanics of Structures Tirana, Albania
anjezagjini@hotmail.com[1], altinbidaj@yahoo.com[2]

Abstract. The joints of the human body act as mechanical or building structures joints. Joints connect different segments by enabling the movement of these segments. The design of a joint that provides durability or static support differs from that one which provides only movement. Joints of the human body, as organic joints, are considered more complex than other types of joints. Finite element models help to comprehend the knee structure behavior under the action of dynamic and static loads. Deformations in the articulating cartilage and the distribution of loads from meniscus provide data to understand the effect of loads in different parts of the knee. This study aims to calculate the stresses in the contact area of the tibiofemoral joint, using the finite element model. During this process, it will be an approximation of geometric shape of the femur, tibias and articulating cartilage to their real shape, taking into account the physic-mechanical characteristics of their components. The study, based on results of numerical calculations, aims to provide practical recommendations for dimensioning the tibiofemoral articulating cartilage and for the quality of the materials, to be used in knee prosthesis industry.

Keywords: Tibiofemural joint, articulation cartilage, contact area, FEM

1. Introduction

In Albania, the use of prostheses is already one of the main solutions and long-term knee problems. There is no comprehensive study on the use of the method of finite element method in this field, making the analysis, treatment and control of models made abroad and methods for which there is no evidence to the technical and financial effect that they have in Albania.

In terms of engineering, finite elements method is part of modern methods of numerical analysis. The study of this method and its application in calculation of complex structures, such as tibiofemurale node, completes the field of study and its use in the calculation of engineering structures.

The dynamics of life in developed countries has led to increased risk for knee injuries, injuries which in most cases requires local or total replacement of his prosthesis. The main factors are overweight and age damage. According to studies, in America counted on average about 700,000 cases per year of operations for total knee replacement through dentures. Expetations are that by 2030 this figure will go to 3.48 million patients / year. In European countries also counted about 230,000 cases per year. Under the same percentage they are added cases in our country.

Referring to the data obtained from INSTAT in 2014, in Albania 44% of the population is over the age of 40 years and it tends to grow in the coming years (referring 2010, figures until 2014 have increased by 4%). Also, referring to data obtained by the WHO (World Health Organisation) in 2008, shows that 20.4% of men and 23.1% of women in Albania are obese (age get in the study over 20 years).

Based on these data, the next few years is expected an increasment of the cases of damage to the knee node, taking main factors obesity and age, without adding other factors such as increased road accidents, negligence during physical activity, etc.

Prosthetic knee has more than three decades that was widely used in the world, with results generally excellente. Their study with finite element has taken 10-year-old recent development and is an area in advanced stage of development.

One of the main challenges is the increasing Orthopedic medicine movement conformity in life activities of individuals who have undergone knee replacement with prosthesis. This requires the creation of models that approach as more realistic model, taking into account all factors static, kinematic and dynamic node.

2. The Aplicated Model

Dimensions of the model are obtained relying on different studies that have been done. For this stage of the study, since the aim is to analyze the constraints arising in the area of contact between the femoral cartilage and tibias, are not considered ligaments and tendons. The modeling can be done quite easily in ABAQUS.

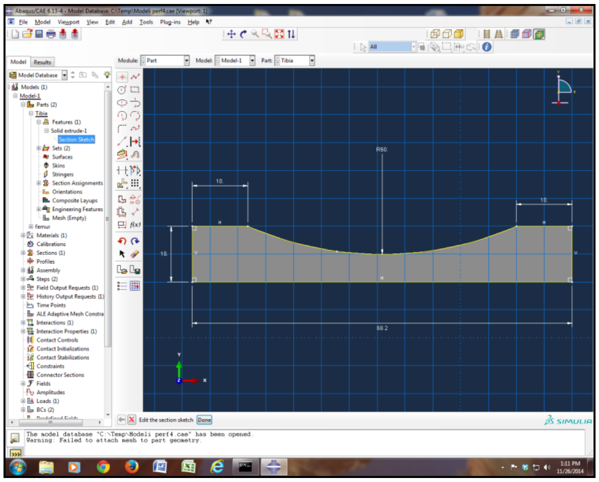

Fig. 1. Modeling of tibia cartilage

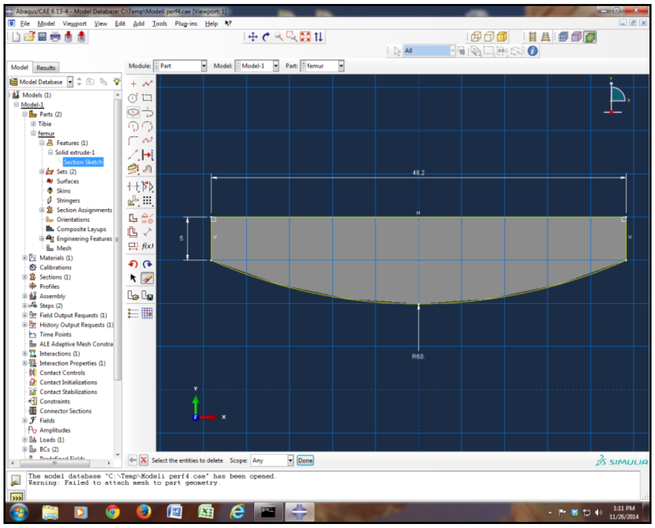

Fig. 2. Modeling of femoral cartilage

The Mash of the element is also done in ABAQUS 6.13-4, based on the geometric model tibiofemurale node structure. As shown in the figure below, the program generated 5668 tetraedrik elements linked to 10,418 nodes.

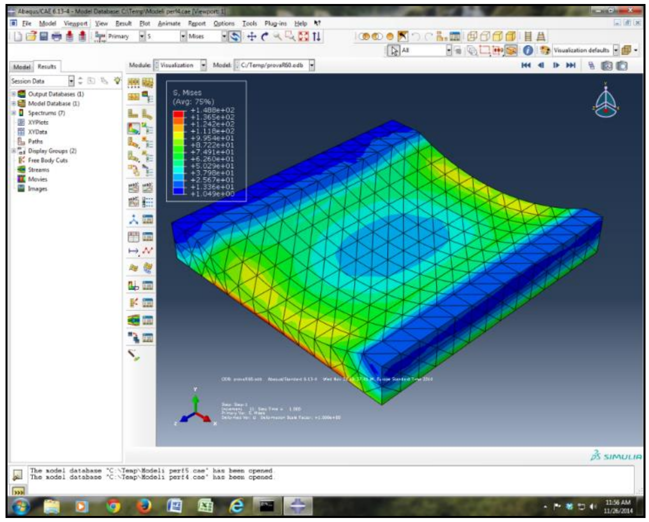

Fig. 3. Stresses in the femur-tibia contact area, R1/R2 = 1

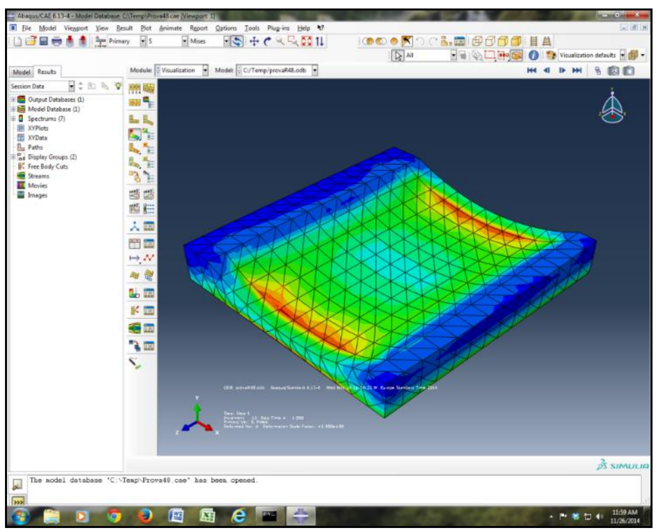

Fig. 4. Stresses in the femur-tibia contact area, R1/R2 = 1.5

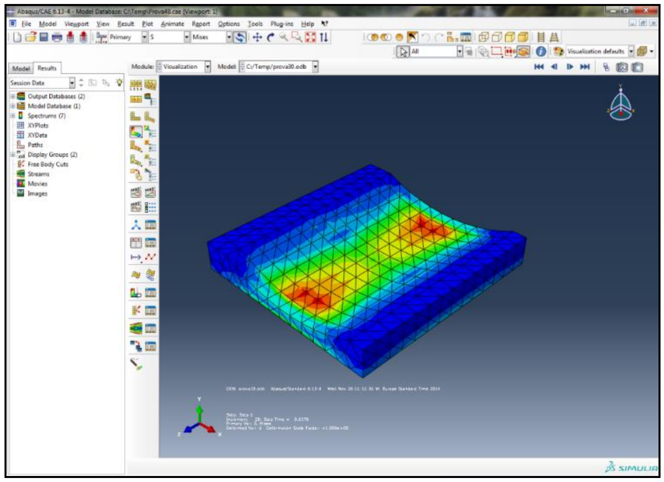

Fig. 5. Stresses in the femur-tibia contact area, R1/R2 = 2

Conclusions and Results

For this study, are taken three models to determine the stresses at the contact surface of the femoral cartilage articulation and tibias in tibiofemurale node. In each of the models is changed the femoral radius of curvature (R1), while the radius of tibias was kept constant (R2).
As it is seen from the results, with increased contact area between the tibias and femoral cartilage, reduced strains and vice versa. (as shown in Fig. 4)
From this study, it shows that, during the modeling and production of prostheses that femur and tibias, particularly cartilage articulation, have found a relationship between the size of these elements in the area of contact, to derive constraints as small during transmission Charging tibiofemurale node.
Solving static and dynamic problems for different structures by software, enables the modeling and study of more complex models of the human body. This development has provided solutions not only for studies in engineering or the medical field, but also in other interdisciplinary fields such as biomechanical.
With the growth of various accidents and not the movement of the body (for professional reasons, but not only) it has increased the need to use more and more of the implants, which should be designed with features physical and mechanical related and adaptable to the body biological.
One of the main objectives in the design of knee implants is to align the femur and tibias in order to increase the degree of conformity during movement.

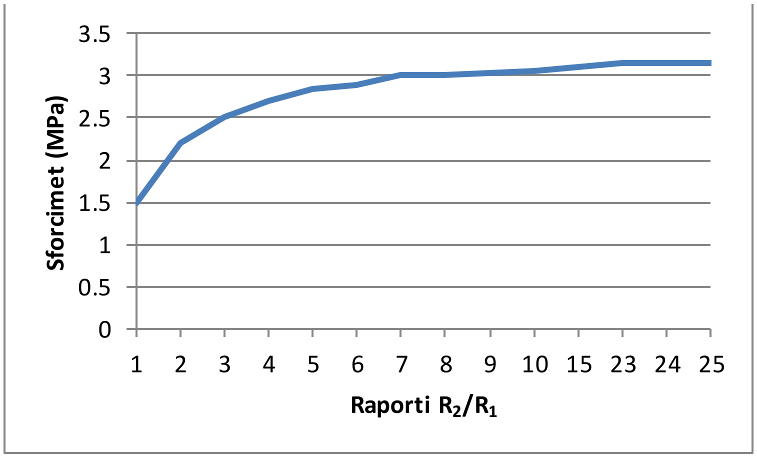

Fig. 6. The relation between stresses and R1/R2 ratio, where R1 is the femoral radius of curvature and R2 is the tibias radius of curvature

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