MODELING OF DAMPING PROPERTIES OF ARTICULAR CARTILAGE DURING IMPACT LOAD

T. Klekiel[1], R. Będziński[1], J. Wodzisławski[2]

[1] Faculty of Biomedical Engineering, Department of Mechanical Engineering, University of Zielona Góra, Zielona Góra, Poland

[2] Military Clinical Hospital, Wrocław, Poland

1. Introduction

The paper presents some details about difficulties in modeling of articular cartilage. The most useful method to simulate a mechanisms of tissue deformation during load is Finite Element Method (FEM). FEM allows to define constitutive models of materials, including nonlinear characteristics[1]. Many experimental studies confirm viscoplastic properties of the cartilage [2]. Articular cartilage plays a major role in damping vibrations and dissipating energy in result of impact loads [3]. Nowdays there is no sufficiently good model describing complex properties of cartilage. In this paper the authors shows approach to modeling damping in articular cartilage of ankle joint.

2. Biomechanics of articular cartilage

In the typical joint there are two concave and convex surfaces. Generally the convex surface is more inflexible. With age, the cartilage is more thick in center of convex surface. In the same time the thickness of concave surface decreases. The cartilage thickness varies depending on the type and location of the joint. The average thickest cartilage in the kneecap is 6mm and in the range 0.5-2 mm. There is no relationship between the volume of cartilage and age, weight and body height.

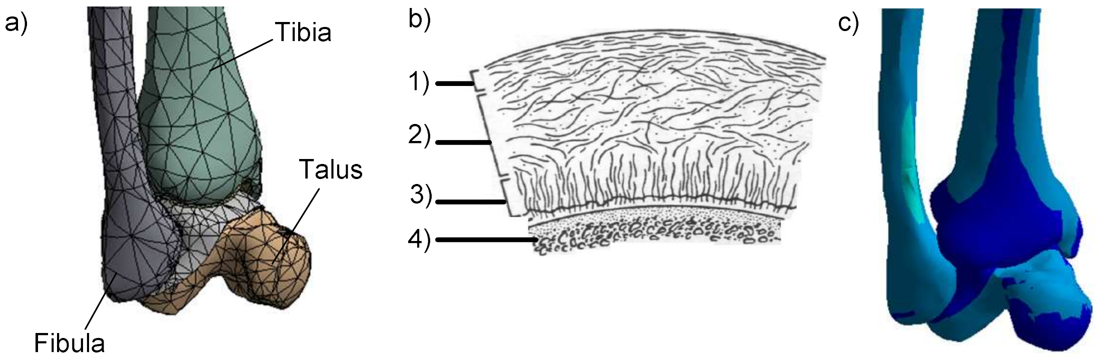

Figure 1. The upper ankle FEM model. a) Model of bones, b) The layers of articular cartilage: 1-external layer, 2-middle layer, 3-internal layer, 4- bone, c) The map of stresses on the bones

The biomechanical properties of articular cartilage are defined mainly due to the physicochemical properties of the glycosaminoglycan which represents in 80% to 90% mass of proteoglycans. The hydroxyl groups arranged in series are ionized. In result, the large number of water molecules are attracted to proteoglycan by electrostatic forces. Dipoles of water, due to the accumulation of negative charges are organized in multilayer systems around this charges. This leads to the formation of osmotic gradients and induction of swelling pressure. In result, this phenomena makes that the bigger load the greater ability to load transfer of cartilage. The damping mechanism of articular cartilage is specially shown in ankle joint. The ankle joint has smaller surface than knee joint but both joints can transfer the same forces.

3. The model of articular cartilage

The basic model of articular cartilage is of two-phased model proposed by Mow et al. [4]. This model is built with assumption that the material is the isotropic mixture of rigid body and fluid. In other the cartilage behavior is represented by Mooney-Rivlin or Neo-Hookean hiperelastic model[5]. This study concerns to analise the model of upper ankle. The numerical model contains the geometry of the articular cartilage obtained by MRI[6]. The deformability research of the cartilage during the impact load was based on the load of the upper ankle joint. The model consists of the bones: Tibia, Fibula and Talus. The upper joint of ankle is divided by two layers of cartilage with average thickness measured by MRI. Furthermore, in the model of ankle joint the main ligaments are needed for stabilization. The bones have isotropic properties for both: cortical and trabecular layers. The model was optimized for performance and computation time. The cartilage was modeled in two variants: as surface and as solid element.

4. Summary

The results obtained from the experiments were compared with data from literature. The deformation of cartilage was evaluated with assumption that average contact of cartilage surfaces under a load is similar to real conditions[7,8]. The reaction of cartilage on the impact load was obtained taking the load as the force generated during the contact feet from the ground at the time of bounce[2]. The numerical experiments shown that there is a relationship between the thickness of the articular cartilage and the ability to absorb energy. Futhermore, the results confirm that the susceptibility to deformation of the cartilage affects the level of forces transmitted by the joint during the axial load.

5. References

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