# Numerical Simulations and Finite Element Analysis of Normal, Osteoarthritic and Prosthetic Knee


## Abstract

The joints osteoarthritis, one of the major chronic diseases usually found in people of middle age and old age, affects a very large number of populations. This disease is accompanied by pain, often by an inflammatory response, and can lead to constraints on mobility, to longer-term disability and to an increased morbidity. About 40% of all persons over the age of 70 are affected by osteoarthritis of the knee. About 80% of persons with osteoarthritis suffer from limited mobility. About 25% of osteoarthritic persons can no longer perform the most important basic activities of daily life. World Health Organization estimates that several hundred million people already suffer from bone and joint diseases including osteoarthritis, with important increases expected due to a doubling in the number of people over 50 years of age by 2020.

Knee osteoarthritis involves a degenerative process of cartilage in the knee joint leading to its loss. This degenerative process can be generally caused by aging process, by obesity, by knee misalignment (deviation of the mechanical axis in the frontal plane) by excessive physical activity, by joint trauma, immobilization or excessive sport activities, menisci lesion, instability due to the knee ligament injuries. Total knee replacement (TKA) are cost-effective treatments, reducing pain, increasing mobility, and improving the quality of life. It is estimated that, due to the dramatic increase of osteoarthritic cases, by 2030, in USA the TKAs will increase with 3.48 million procedures (about 673%) between 2005 and 2030.

In this paper a virtual 3-D model of the complex knee joint is presented and, by using Finite Element Analysis, the damage phenomenon of cartilages in the osteoarthritic (OA) knee and the influence of misalignement and overweight on producing it and on increasing its magnitude is studied. The complex 3D virtual knee model is obtained for normal knee and for OA knee, using embedded applications: DesignModeler and SpaceClaim under AnsysWorkbench 14.5 software package. A number of 15 distinct cases of complex knee joint assembly, depending of the misalignement angle are developed. Stress maps and the values of the maximum von Mises stress on the femoral cartilage and on the tibial cartilage, for a total number of 90 analyses (for a set of 6 loading forces, comprised in interval [800N; 3000N] applied to each of 15 cases of misalignement), were obtained. The results of our study show that the contact areas of initial cartilage damage are changing with overweight and misalignment, determining the increase of the stress magnitude and the damage magnitude which could determine progressive cartilage erosion, the damage magnitude.

Starting from the virtual model of the human knee joint, and existent knee prosthesis, often used in total knee arthroplasty, we developed 3D models of the prosthetic components. The study investigates the effects of antero-posterior tibial slope on contact stresses in all components of total knee prosthesis using finite element analysis. A finite element analysis of the normal and prosthetic knee model will help surgeons and biomechanical researchers to develop improved devices for rehabilitation movements of patients suffering diseases.

The parameterized virtual models of the knee and of the hree components of the knee prostheses allow different changes in shape, dimensions and other mechanical properties, changes which can lead to the optimization of the implant and to the improvement of the prosthetic knee biomechanics.

The Finite Element Method Analysis is a modern and very power full method, useful for understanding the biomechanical behavior of human joints (normal and pathological).

The advantage of the numerical simulations consists in the fact they can be done in advance in order to evaluate the normal human joints or prosthetic or orthotic joints behavior, without an invasive intervention.