



DOCTORAL STUDIES IN TOTAL KNEE ARTHROPLASTY

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Summary: *The presented thesis studies the knee arthroplasty, in order to contribute to the improvement of knee prostheses. The main subjects treated in the research activity consist in: biomechanical study of the knee joint; 3D reconstruction of the knee joint starting from the ct images; conception and design of new models of partial and total knee prostheses; experimental motion analysis of patients having different pathologies (implanted and non-implanted); manufacturing of the designed models of knee prostheses; testing of the manufactured prostheses.*

Key words: *total knee prosthesis, knee replacement, knee arthroplasty, numerical analysis, motion analysis, testing, manufacturing*

DOKTORSKE STUDIJE U OBLASTI POTPUNE ANTROPLASTIKE KOLENA

Rezime: *Prikazani rad proučava antroplastiku kolena, kako bi se doprinelo usavršavanju proteza za koleno. Glavne teme koje su obrađivane u ovoj istraživačkoj delatnosti su: biomehaničko istraživanje zgloba kolena; 3D rekonstrukcija zgloba kolena počev od ct (skener) slika; osmišljavanje i oblikovanje novih modela delimičnih i potpunih proteza kolena; eksperimentalne analize kretanja pacijenata sa različitim patološkim pojavama (urođenim i neurođenim); izrada dizajniranih modela proteza za koleno; ispitivanje izrađenih proteza.*

Ključne reči: *potpuna proteza kolena, zamena kolena, antroplastika kolena, numerička analiza, analiza kretanja, ispitivanje, izrada*

1. INTRODUCTION

It is well known that the knee is the most complex joint of the human body, and one of the most exposed to stress. Therefore, the cases when it comes to prosthetic devices are very common. The diseases which affect this joint have different effects, leading to the necessity to replace the natural joint by a prosthesis with a very diversified geometrical construction,

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complex and closer to the anatomical shape of the joint.

Knee replacement is a routine operation for knee pain when the knee joint has been severely damaged, most commonly by arthritis. Knee replacement, or knee arthroplasty, is a surgical procedure in which damaged parts of the knee joint are replaced with artificial parts (artificial joint), to relieve the pain and disability of osteoarthritis. There are two main types of surgery, depending on the condition of the knee: total knee replacement and partial knee replacement [1], [2], [3], [4]. In general, the surgery consists of replacing the diseased or damaged joint surfaces of the knee with metal and plastic components shaped to allow movement of the knee [1], [2]. The artificial joint or prosthesis generally has two components, one made of metal, which is usually cobalt-chrome or titanium. The other component is a plastic material, which is usually polyethylene.

The general goal of total knee replacement is designed to provide painless and unlimited standing, sitting, walking, and other normal activities of daily living. There are currently over 100 different prosthetic knee designs available to the orthopaedic surgeon.

The subject of this thesis represents a continuity of the research in the fields of biomechanics of human lower limb. The subject of the diploma project (Bachelor programme) was focused on the biomechanics of the hip joint. A total hip prosthesis was design and analysed using Finite Element Method.

In addition, the research activity for this thesis is developed in the frame work of the Centre for Modelling the Prosthetic Appliances and Surgical Operations on Human Skeleton in Politehnica University of Timisoara. The research fields of the CMPICSU Research Centre are:

- Theoretical and applied Biomechanics;
- Implantology and prosthetics;
- Modern technologies for manufacturing;
- Testing of medical devices;
- Acquisition and processing of biomedical signals and images.

The infrastructure of this research centre consists in highly equipped laboratories, able to support the achievement of the thesis goal, both experimental and technological.

The main subjects treated in the research activity consist in:

- Biomechanical study of the knee joint;
- 3D reconstruction of the knee joint starting from the CT images;
- Conception and design of new models of partial and total knee prostheses;
- Experimental motion analysis of patients having different pathologies (implanted and non-implanted);
- Manufacturing of the designed models of knee prostheses;
- Testing of the manufactured prostheses.

2. METHODS AND RESOURCES

The research activity in the knee joint biomechanics consists in the development of theoretical and numerical models to better understand clinical problems associated to the human joint. Some of the points of interest are: joint forces, joint kinematics, soft tissues and bone modeling.

The research activity is also focused on 3D reconstruction of the knee joint starting from the CT images and numerical analysis of the knee joint and the interface between bone and

implants. The Medical Imaging Laboratory uses computer tomography (SIEMENS SOMATOM Plus 4 Power), providing image acquisition and processing of the necessary anatomical elements. The patients can be scanned using the computer tomography. The obtained images can be imported in Mimics software in order to perform the image processing. 3D reconstruction offers better information about the joint anatomy, diseases that the patients suffer from, anatomical differences between the patients joints regarding age, gender and stature.

The kinematic analysis is performed using the CMS-HS Zebris measuring system and a FDM measuring system for force distribution. The Zebris measuring system performs a simple and fast analysis of all important parameters of the human gait (*fig. 1*). The FDM measuring system consists of a sensor platform and its respective software enabling a fast, simple analysis of the recorded measuring data on the PC.

The studies will be performed on patients, before implantation and after implantation of a knee prosthesis. Based on the motion analysis results (*fig. 2*), conclusions will be drawn regarding the disease's harshness, degree of the knee affection and then, and capacity of the prosthesis to replace the anatomical joint's functions.

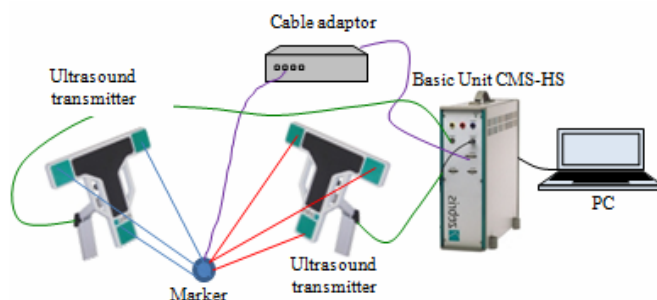


Figure 1: Zebris Measuring system

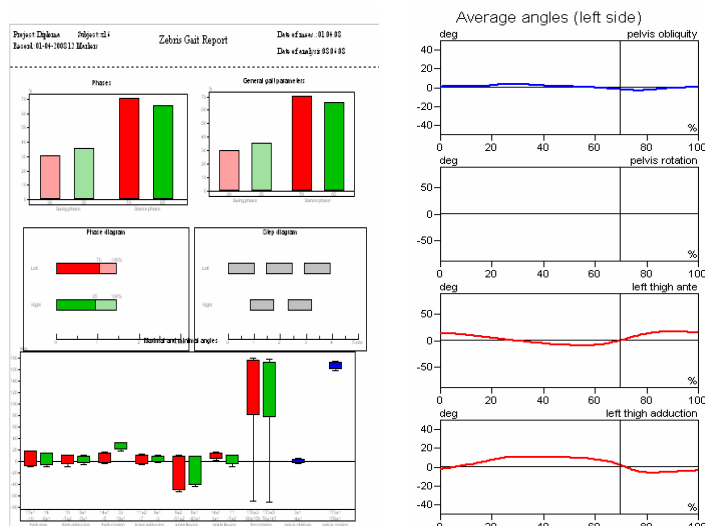


Figure 2: Gait analysis report

By collaborating with orthopedic surgeon, new models of knee prosthesis more often used in different types of diseases will be designed.

There are different types of prostheses that will be taken into account. These prostheses differ by: fixing method (cemented or uncemented), size of the replaced area (partial/total knee prosthesis), degrees of freedom, etc. There will be proposed several solutions, both for partial and total prostheses (*fig. 3*). Other structural models for the knee prosthesis will be proposed, in order to develop a prosthesis that will allow the amplest movements.

Another important subject is related to the materials used for manufacturing the proposed prostheses. The most often used material are Titanium, Polyethylene and Co-Cr. Titanium and its alloys possess suitable mechanical properties such as strength, bend strength and fatigue resistance to be used in orthopaedics applications. Other specific properties that make it a desirable biomaterial are density and elastic modulus. The polyethylene layer has the role to absorb a part of the shocks, during the patient walking (the moment when the patient touches the ground with his foot). Due to its good mechanical properties (fatigue strength, tensile breaking strength), alloys of cobalt-chromium-molybdenum, are typically used in the manufacture of orthopedic implants, especially on hip and knee prostheses. Also the abrasive properties and very high corrosion resistance, can not be ignored.

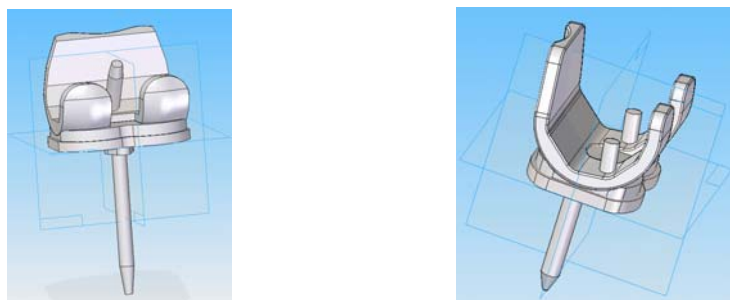


Figure 3: Types of total knee prostheses

Based on the numerical analysis, certain solutions will be selected and manufactured in Manufacturing Laboratory, using CNC machines and rapid prototyping equipments.

In vitro mechanical tests and measurements will be realized in CIDUCOS Testing Laboratory. There will be developed several mechanical tests such as: compression, torsion and fatigue, and then the results will be analyzed and interpreted.

3. CONCLUSIONS

The presented thesis *Research and contributions to the design and implementation of knee prostheses*, and the results obtained during the 3 years of study, will be used to obtain an improved knee prosthesis that allows to the patients a greater mobility.

The results obtained during the research, will be published in articles, professional journals and national and international conferences.

4. AKNOWLEDGEMENT

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