A COMPARISON OF TWO MODELS OF TOTAL KNEE PROSTHESES

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Keywords: arthroplasty, knee joint, total knee prosthesis, femoral and tibial components.

Abstract In Knee arthoplasty, parts of the knee joint that has been damaged, usually by a form of arthritis, are replaced by an appropriate prosthesis. Currently on the market there are numerous types of prostheses, according to different types of diseases. This paper presents two models of total knee prosthesis and revision prosthesis, and a comparison of the two proposed models. Basic descriptions of materials and prosthesis geometry are provided. There are compared the shapes, functions, advantages and disadvantages of the proposed prostheses, and the loss of bone mass also.

1. Introduction

Knee problems are very common, and they occur to people of different ages. To determine the nature of a knee problem the patient must do one or more tests like: X ray, CT, MRI, arthroscopy, biopsy investigations.

There are many diseases that can affect the knee. The most common is osteoarthritis; it may be caused by joint injury or body weight, and most typically begins after 50 years. Frequently the patient feels pain and stiffness around the joint, loss of mobility and flexibility of the joint. If the problem can't be treated with medication, or by other methods, the only chance for the patient is the knee arthroplasty.

Knee arthroplasty, is the surgical procedure that replaces the knee joint surfaces, to relieve the pain and disability caused by osteoarthritis. There are many types of knee replacements on the market today, so the prosthesis is selected for each patient depending on their individual requirements.

The main problem for the long-term quality of total knee arthroplasties (TKA) is the correct placement, especially for the femoral prosthesis. In total knee arthroplasty (TKA), maximal implant coverage on the bone surface minimizes the stress applied to the bone-implant interface. A good shape of the knee prosthesis which matches the resected surface of knee has been reported as a factor for long-term survivorship in TKA. In general, the geometry of the tibial component should match the resected surface as much as possible which will provide the best stability and load transfer for both cemented and cement less fixations [2], [3]. Primary total knee arthroplasty (TKA) with modern implants results in more than 95% good to excellent results [1].

Knee prostheses can be partial, total and revision prostheses. Partial knee prosthesis (PKP), also called uni-compartimental knee prosthesis, replaces only one compartment, medial or lateral component. It is an option for some patients who present a less advanced unilateral osteoarthritis with a healthy anterior cruciate ligament. Total knee prosthesis (TKP) is the surgical procedure that replaces the cartilage between the femur and the tibia, and the damaged bone with total knee prosthesis. Revision knee prostheses (RKP) are implemented in patients' bone, after losing the first prosthesis.

The choice of implant is dictated by the extent of bone and soft tissue destruction following the removal of failed implants. There is a spectrum of implants available from posterior cruciate ligament (PCL) sparing resurfacing implants to "mega-", tumour- or bone-replacing prostheses [4].

ASTM F2083 - 08e1 *Standard Specification for Total Knee Prosthesis* classifies the knee prostheses into three kinds according to degree of constraint [8]:

- The first type is considered constrained which prevents dislocation of the prosthesis in more than one anatomic plane and consists of either a single, flexible, across-the-joint component or more than one component linked together or affined.
- The second one is a semi-constrained joint prosthesis which limits translation or rotation, or both, of the prosthesis in one or more planes via the geometry of its articulating surfaces. It has no across-the-joint linkages.
- The third type is a non-constrained joint prosthesis which minimally restricts prosthesis movement in one or more planes. Its components have no across-the-joint linkages.

The general structure of the knee prosthesis is presented in figure 1.

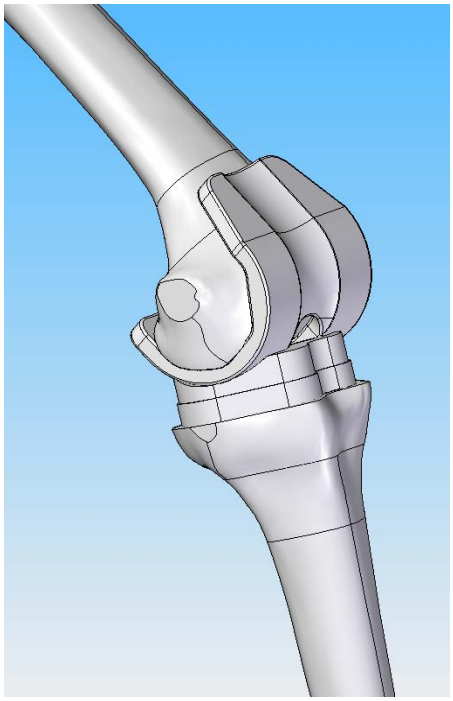

Fig.1. Knee prosthesis - general structure

The success of the knee replacement surgery procedure depends on the rehabilitation period that follows the surgery. The rehabilitation program after knee replacement begins immediately.

The materials generally used for TKP are:

- Metal alloys: Titanium and Cobalt-chromium;
- Polymers: Ultrahigh molecular weight polyethylene (UHMWPE);
- Ceramics.

The construction materials used for knee prostheses must meet several criteria [6]:

- They must be biocompatible; that is, they can function in the body without creating either a local or a systemic rejection response.
- Their mechanical properties must be able to duplicate the structures they are intended to replace; for example, they are strong enough to take weight bearing loads, flexible enough to bear stress without breaking, and able to move smoothly against each other as required.
- They must be able to retain their strength and shape for a long time. The chance of a knee replacement lasting 15 to 20 years is about 95 percent.

The paper proposes two models of knee prostheses: a total knee prosthesis and a revision knee prosthesis.

2. Design and Materials

Several types of total and revision knee prostheses were 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 were proposed several solutions, both for partial and total prostheses.

Both the total and revision knee prosthesis consists in: femoral component, tibial component and polyethylene component. Depending on the prosthesis type there are some similarities and differences taking into account the shapes and dimensions.

The femoral component, usually made from metal, curves around the femur condyle and has an interior groove so the kneecap can move up and down smoothly against the bone as the knee bends and straightens [6]. Thus, generally, the femoral components must have the shape of the femoral condyles. This component is implanted after the damaged part of the knee was removed. TKP allows a better bone fixation of the femoral component (figure 2) using two pegs of 20 mm length. The femoral component of RKP (figure 3) is set in the bone, with a peg of 80 mm length.

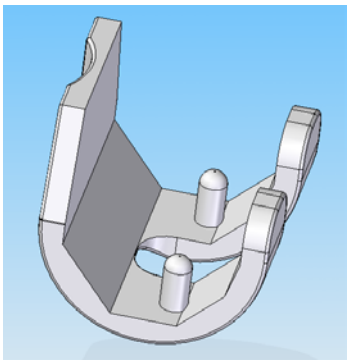

Fig.2. Femoral component of the TKP

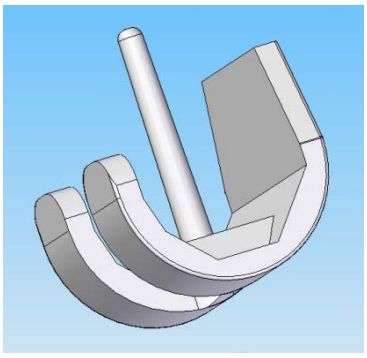

Fig.3. Femoral component of the RKP

The tibial component is a flat metal platform with a polyethylene cushion [6]. The tibial component (figures 4, and 5) is placed on the tibial tray both in TKP and RKP, after the damaged bone and cartilage were removed. The difference between the two models is the length and the thickness of the stem, which sets the prosthesis in the bone. In TKP case, the stem has a length of 80 mm, and 10 mm diameter. The stem of the RKP has a length of 120 mm, and 20 mm diameter.

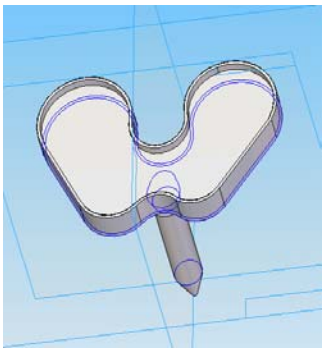

Fig.4. Tibial component of the TKP

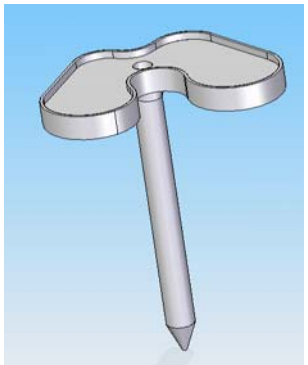

Fig.5. Tibial component of the RKP

Between the tibial component and femoral component a polyethylene part (figure 6) is placed in both models of knee prostheses.

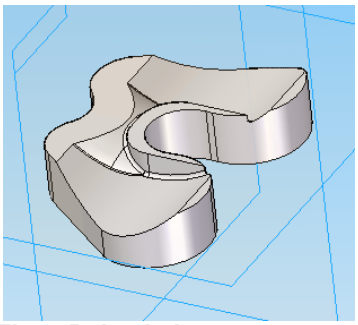

Fig.6. Polyethylene component

Both prostheses replace the joint cartilage and the damaged bone; eliminate the pain and discomfort of the patient.Each of these types of knee replacements has its own advantages and disadvantages.
In total knee arthroplasty (TKA) the preserved bone mass is greater that in revision knee arthroplasty (RKA). The loss of bone mass is shown in figure 7 for the TKA and figure 8 for RKA.

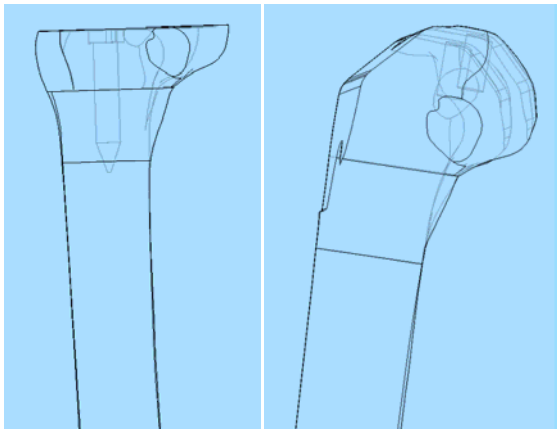

Fig.7. Loss of the bone mass in TKA

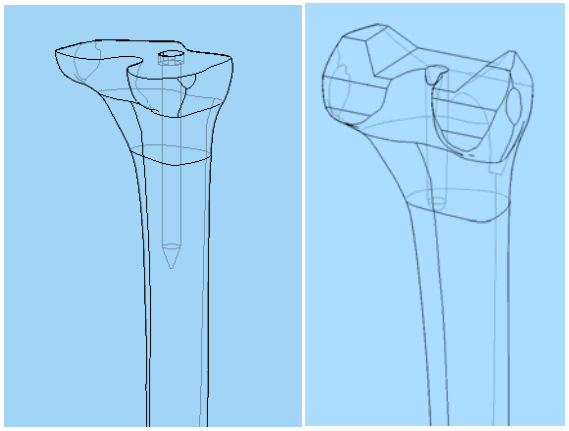

Fig.8. Loss of the bone mass in RKA

The fact that this prosthesis can't be replaced with one of the same type, in case of failure represents a disadvantage. The failure of a TKP is followed by a RKP. The advantage of the RKP existence is the fact that in case of TKP failure, the patient has the chance to lead a normal life, after RKA.
The general features of the proposed knee prostheses are shown in figures 9, and 10.

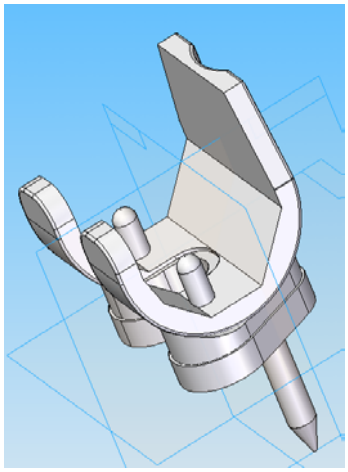

Fig.9. Total knee prosthesis

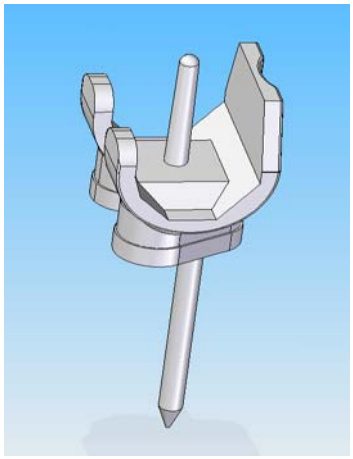

Fig.10. Revision knee prosthesis

The metalic components of the proposed knee prostheses are made of oxinium. Oxinium or Oxidised Zirconium is a metal with a coating of ceramic. In the manufacturing process, prosthetic components made of Zirconium are heated and infused with oxygen to create a ceramic surface on metal. This ceramic surface is more durable than normal metals. This material received FDA approval in 1996. After rigorous testing, this material received approval for use in knee arthroplasty [7].
The ceramic surface is extremely abrasion resistant compared to traditional metal implant materials such as cobalt chromium. It also has a lower coefficient of friction against (UHMWPE), the material typical used in total joint replacements. These two factors likely contribute to the significantly lower UHMWPE wear rates. Reducing UHMWPE wear is thought to decrease the risk of implant failure [5].
Oxinium knee prostheses are suitable for young and active patients because they have excellent chance to live longer. Polyethylene is implemented between the tibial and femoral components in order to decrease friction.
Total knee arthroplasty (TKA) aims to provide a durable prosthetic knee with nearly normal range of motion. [3]

3. Conclusions

The general goal of total and revision knee replacement is designed to provide painless and unlimited standing, sitting, walking, and other normal activities of daily living. Knee arthroplasty greatly improves the life quality of many patients. There are currently over 100 different prosthetic knee designs available to the orthopedic surgeon. Still, new models appear steadily allowing improvements in long term functionality of the prostheses.
There were proposed two solutions, one for total knee prosthesis, and the second one for revision knee prosthesis. In future works, other structural models for knee prosthesis will be designed, in order to develop prostheses that will allow the amplest movements.
The proposed prostheses are appropriated for young patients because they have a more active life.

4. Aknowledgement

This work was partially supported by the strategic grant POSDRU 6/1.5/s/13, (2008) of the Ministry of Labor, Family and Social Protection, Romania, co-financed by the European Social Fund – Investing in people.

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