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THE MODEL OF A PROSTHETIC SYSTEM FOR HUMAN KNEE JOINT

Abstract: *Obesity, sedentarism, and other disadvantages of the modern age have led to the emergence of unknown pathological situations a few centuries before. At the same time, the development of medicine, orthopaedic surgery has led to finding ways to solve these situations. The present paper proves that the use of high-tech methods used in engineering can generate solutions in the field of orthopaedics both for obtaining new prothesis models, but also by creating virtual environments for tests. Several CAD techniques and techniques have been explored, coupled with medical imaging, can provide exciting solutions for obtaining virtual environments that can allow "in vitro" analysis of various normal, pathological or prosthetic joints. In this paper we have detailed how to obtain a prosthetic knee joint in a parameterized environment. This joint was tested virtually. In the final of the paper, main conclusions were made.*

Key words: *Virtual bone components, virtual knee, prosthesis, femur model, tibia model, virtual tests.*

1. INTRODUCTION

Sedentarism and predisposition for obesity have led to today's society's increasing incidence of locomotion system disorders. Fortunately, medical technology has successfully managed to keep up with these issues and we can talk more and more about medical awards.

A prosthesis is a medical system made to replace a missing bone or a human joint or to support a pathological bone. Internal fixation is an orthopaedic surgery involving surgical implantation for the repair of a bone..

Orthopaedic prostheses are made of stainless steel or titanium alloys covered with high density polyethylene to act as cartilage [1], [2], [3].

The knee is the complex joint in the human body and consists of the inferior epiphysis of the femur, the upper epiphysis of the tibia, and the patella. The place where these bone components come into contact is covered by cartilage to ensure the movement of this important human joint.

Meniscus are located on the tibial plateau. These components have the role of absorbing shocks that can appear in the knee joint.

The femur and tibia are held together by resilient ligaments (cross-links) that provide stability, and the thigh muscles confer the strength of the knee.

All these components are covered with a thin membrane, named the synovial membrane.

Normally, all these components work harmoniously. But a condition or an accident can disrupt this harmony and can cause pain, lowering muscle strength, and diminishing mobility.

The first knee prosthesis intervention (knee arthroplasty) took place in 1968. Since then, innovations in materials and surgical techniques have contributed significantly to improving the performance of this intervention, total knee arthroplasty representing one of the most successful procedures in all medicine.

Considering these aspects, the need for these implant elements to be brought into virtual environments parameterized to be modelled and tested virtually appears more and more [1], [3]. These parameterized virtual environments allow for the simulation of the various situations occurring in the knee orthopaedics such as: simulating normal walking, running, various pathological cases or pre, intra or post-surgical situations. Also, implant or prosthesis elements can be tested using the finite element method.

2. THE VIRTUAL MODEL OF THE INTEGRAL AND PROSTHETIC JOINT OF THE KNEE

To achieve this goal, the tomographic images of the three important bone components, namely the femur, fibula and tibia, were used in a first phase.

These three components, which are of major importance in the knee biomechanics, were scanned together with a plastic bar known for their size. This reference was used to make a correct scaling of tomographic images.

Fig.s 1 and 2 show six tomographic images of the femur and tibia [4], [5], [6].

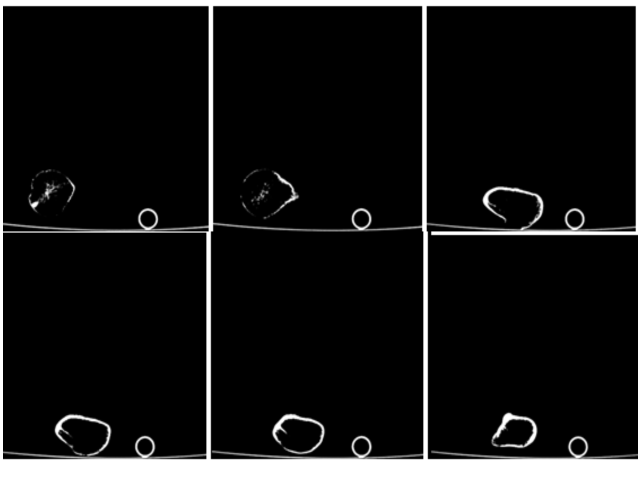


Fig. 1 Six tomographic images of the femur.

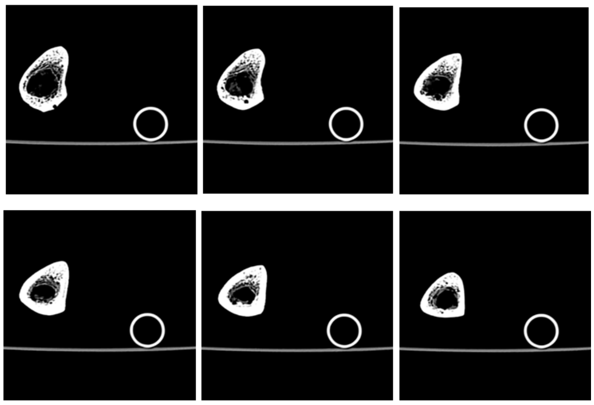


Fig. 2 Six CT images of the tibia.

Following certain CAD techniques of virtual reconstruction, in a parameterized environment, the inner and outer closed curves of the bones were obtained. By way of example, these primary curves of the femur are shown in Fig. 3 [5], [6], [7].

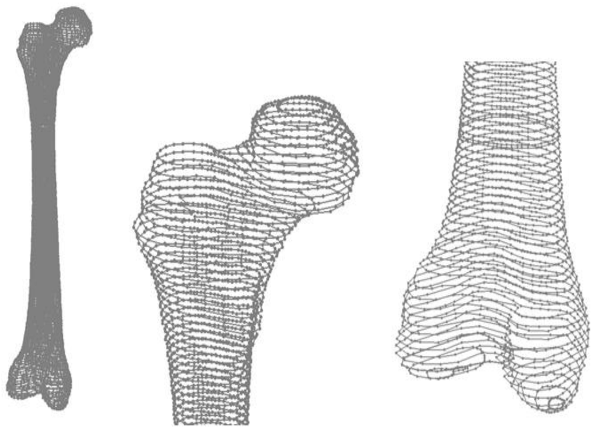


Fig. 3 Curves used for the virtual reconstruction of the femur.

Similarly, these curves were also defined for tibia and fibula.

For the virtual reconstruction of bone components, a software program used in engineering SolidWorks was used.

The SolidWorks program allows you to obtain a solid by "joining" cross-sections drawn in parallel drawing planes. The shape that "solidifies" these sections is called Loft and defines the solid starting from these sections and a program-defined curve automatically defined by the program. Fig. 4 shows the loft definition scheme for the femur as guide curve and cross sections [7], [8], [9].

No additional guiding curves and Loft shape settings were required because the shape of the cross sections is similar and each section has the same number of segments.

In the inferior area of the femur, two Loft forms are defined for the definition of the two condyles and have the definition schemes shown in Fig. 5.

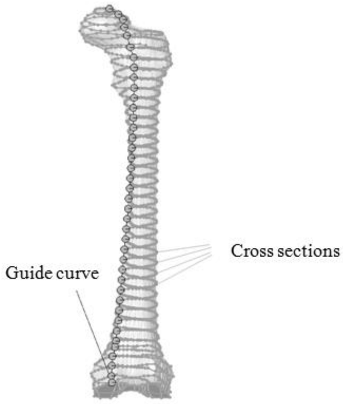


Fig. 4 Initial parameters for defining the virtual femur.

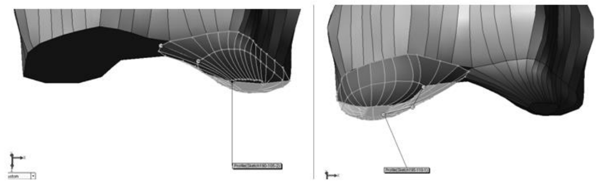


Fig. 5 Loft schemes to define the two condyles.

The final model of the femur is shown in Fig. 6.

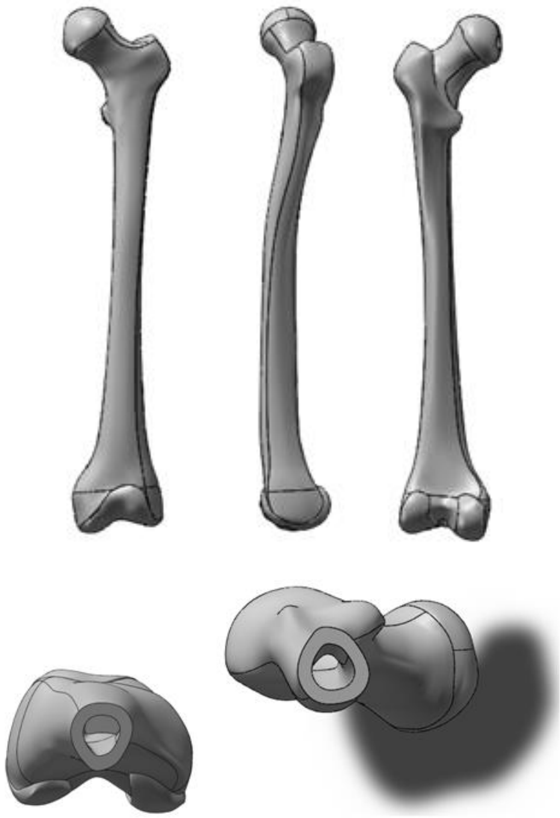


Fig. 6 The virtual model of the femur.

Using the similar modeling commands and techniques, the other components of the knee joint were also obtained. These bone components were loaded into the Assembly module of SolidWorks. The result of these operations is shown in Fig. 7.

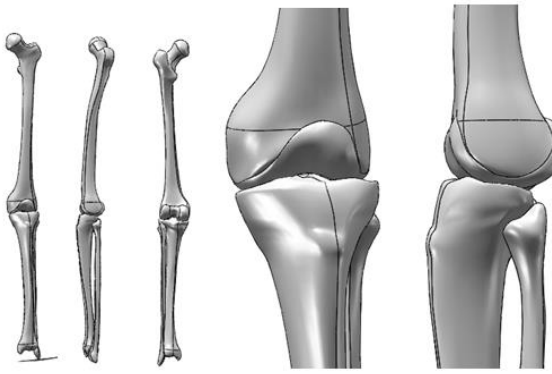


Fig. 7 The virtual model of the knee joint.

In parallel with the generation of the virtual models of the bone components, the two elements of the knee prosthesis were modeled. For this, various modeling techniques have been used, but a 3D scanner has also been used. Finally, the components of the knee prosthesis presented in Fig.s 8 and 9 were obtained [9], [10], [11].

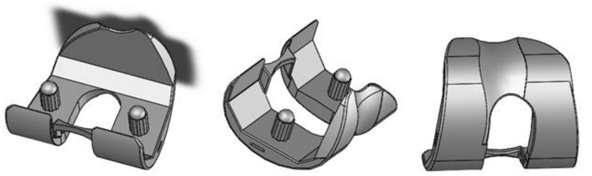


Fig. 8 The femoral component of the knee prosthesis.

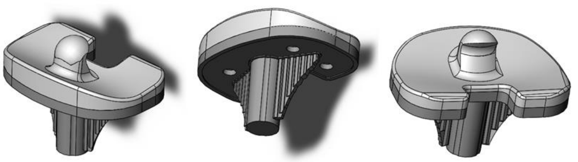
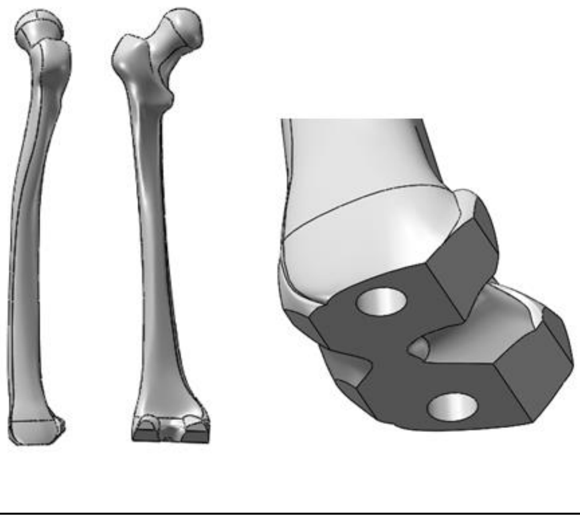


Fig. 9 The tibial component of the knee prosthesis.

Analyzing the surgical techniques specific to knee prosthesis, the bone components were prepared for virtual prosthesis [10], [11], [12]. Fig. 10 presents these components.



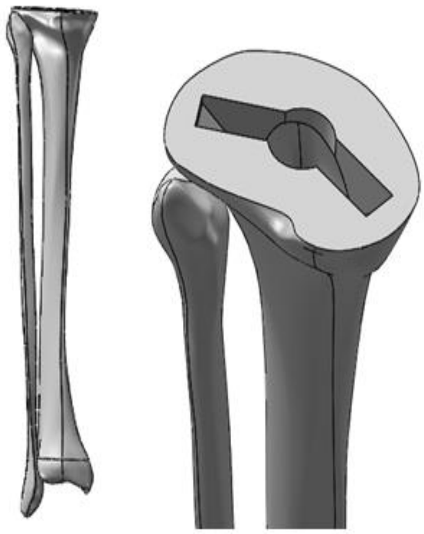


Fig. 10 The bone components of orthopedic prosthesis assembly.

Finally, in the Assembly module, the final model of the human knee was generated as shown in Fig. 11.

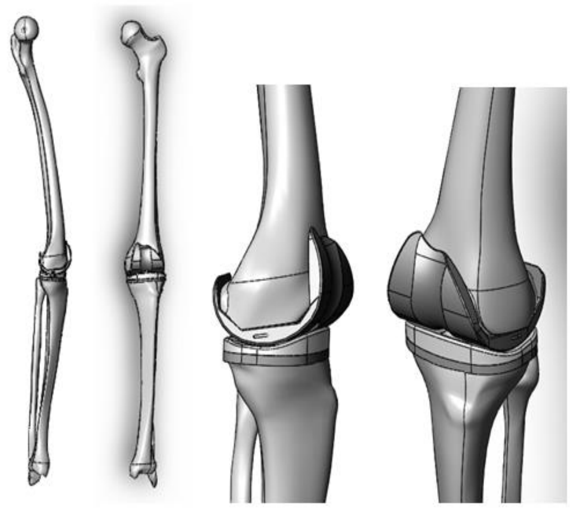


Fig. 11 The The virtual model of the prosthetic knee.

3. CONCLUSIONS

One of the most complicated joints is that of the knee, due to complex geometry, but also due to components that have different structures (meniscus, bones, ligaments, etc.). By mechanically analyzing this joint only by the shape of the bone components in contact, one might say that the knee is a sphere on the plane joint that has many degrees of freedom. In reality, the knee is about a plane rotation joint. This observation leads us to the idea that other non-bony elements also constrain this joint, such as cross-ligaments, joint capsules, etc. Analyzing the above leads to the idea that a knee prosthesis is rather complicated as geometry and it must respect the freedom of movement given by the normal joint. In this paper we have detailed some methods of obtaining the complicated geometry of the knee and its components. Also, a knee prosthesis model with femoral and tibial component was obtained with metal elements as well as high density polyethylene. The prosthesis model is parameterized, so it can be different in size and personalized. We believe that this knee knee model can be used for testing in different situations using the FEM or kinematic and dynamic simulations.

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