DESIGN AND PRINTING OF KNEE AND A TOTAL KNEE PROSTHESIS

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Abstract: The objective of this project is the research and the development of a knee prosthesis with a short printing time, expecting to reduce the material used. For this reason, it is important to develop intelligent prostheses to control the actuators and thus emulate the walk of a person.
For this, the design of a knee prosthesis and a total knee prosthesis was carried out using the 3D Slice software and Blender, which provides an image of the elements in a stl image format for study and 3D printing, to improve the knee prosthesis that already exist

1 INTRODUCTION

The models of total knee prostheses are currently numerous and new designs are continually appearing that, in summary, respond mainly to two different concepts in their notion: Hinge prostheses that carry great bone reactions and covering prostheses that require less bone sacrifice
Knee replacement is a surgical technique with more than 4 decades old that has been evolving, since the first knee replacement operation for a prosthesis in 1968, design defects have been eliminated, producing improvements to provide greater durability, better stability, and increased mobility of the patient. In addition, the danger of loss of contact between the prosthesis and the bone has been significantly reduced [2]. Improvements in cementation techniques, better instrumentation and greater attention to the alignment of the leg have allowed very satisfactory long-term results. [3]
Currently prostheses are designed to be used with or without bone cement. The quality of the cement and the techniques used are notably superior, in some cases the metal parts of the prostheses are covered with surfaces specially designed so that the bone grows intertwined with the metal [4]
For the development of the design, biomechanics must be understood, determining the main parameters that influence the design such as forces, moments, displacements, and angles that intervene in the mechanism. Once all these aspects are understood, the computer-assisted design is carried out. (CAD) of the knee joint according to anthropometric studies to finally place all the loads that intervene in said mechanism and obtain the static analysis through the finite element method. [6]
To date, no knee prosthesis has been developed with a useful life of more than 20 years and at a very high price.
The main drawback in the development of these prostheses is that the machines to make the impression are very expensive and it is also expensive if you want to rent one of them to make the impression, since the impression lasts many hours and the cost per impression is for hours, plus there are delicate pieces that might need to be reprinted. The carbon fibers with which the prostheses are made have high prices and in addition trained people are needed for the design and implementation and adaptation of the prosthesis in the patient. [7].
The objective of this project is the development of a prosthesis with a short printing time, which is expected to reduce the material used, with a covering prosthesis, better instrumentation and greater attention to the alignment of the leg according to the user for long-term results. For this reason it is important to develop intelligent prostheses, with the sensors being in charge of taking the biological signals from the muscle to proceed to signal processing and emit a certain signal to control the actuators and thus emulate the walk of a person.

2 METHODS

The knee is a major joint and therefore it is one of the most exposed to injuries, accidents and natural wear, etc. Arthritis being the main cause of this condition. These problems can occur in people of any age. The knee joint is made up of the lower end of the femur, which hinges on the upper end of the tibia, and the patella, which slides between the space formed between the femoral condyles. Knee replacement involves reconstruction of the same with a prosthetic piece, there is a component that replaces the terminal part of the distal femur, the proximal part of the tibia and in most cases, a small plastic component on the patella.[8]

The models of the patient's radiographs are obtained, in which the knee and its measurements for the elaboration of the prostheses can be observed. These files are generally obtained in DICOM format that are later processed to obtain the segmentation of the same in stl formats that can be handled as a CAD element, in which the respective configurations are made to make the implants according to the measurements and requirements of the bone. of the patient. Once the configuration of the implant is finished, the 3D impression of it is made, together with a part of the healthy bone, to check the compatibility of the sizes of the bone with the implant.

The prosthetic component must be of the same dimensions: size, shape and thickness as the removed cartilage. For the procedure on the femur, medical cement is applied to the removed portion and the femoral component is placed. The same procedure is followed for the patella. In the tibia, the damaged cartilage is resected and the plate is placed to measure, medical cement is applied and the titanium component is applied and the polyethylene insert and its locking mechanism are made. Then follows a recovery process with physiotherapy. [9]

3 RESULTS

Series #	Series description	Modality	Size	Count	Date added
1	Loc (Right)	MR	256x256	27	2022-01-...3:04.111
3	Sag FRSE PD FS	MR	512x512	22	2022-01-...3:04.142
4	Cor FSE PD	MR	512x512	20	2022-01-...3:04.159
5	AX. FSE PD	MR	512x512	24	2022-01-...3:04.175
6	Sag FSE T2	MR	512x512	22	2022-01-...3:04.192
7	Cor FSE T1	MR	512x512	20	2022-01-...3:04.206

Figure 1: Patient Tomography Table.

The DICOM files obtained directly from medical centers were downloaded, the patient's tomography is presented in the table and as can be seen, there are between 20 and 27 slices, therefore, the resolution is not very good, series number 6 was the selected one.

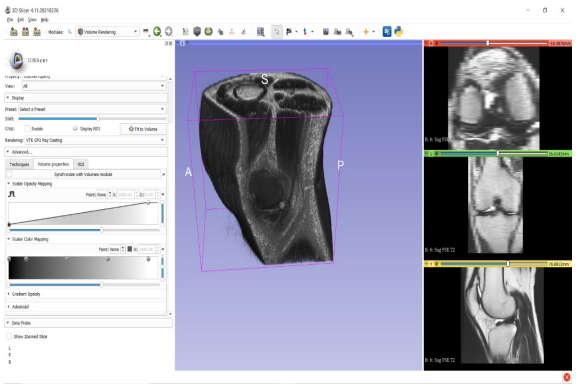

Figure 2: Patient 3D Tomography.

The file of the selected series is exported to the 3D slicer environment, in it you can see the 3D tomography of the knee without any segmentation, additionally its axial, coronal and sagittal list is shown respectively

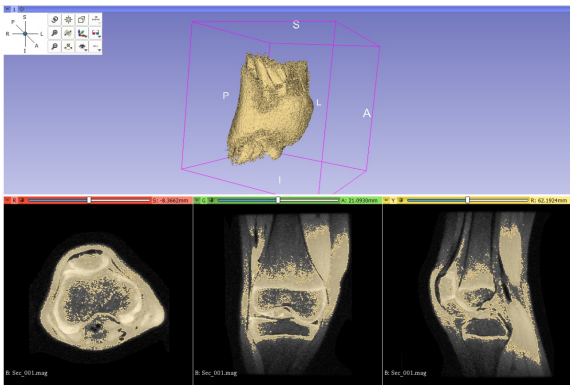

Figure 3: Segmentation IA.

An attempt was made to perform the segmentation with artificial intelligence, but since the color of the muscles and bones are similar in the tomography, due to its low resolution, it can be seen that the segmentation is not carried out completely.

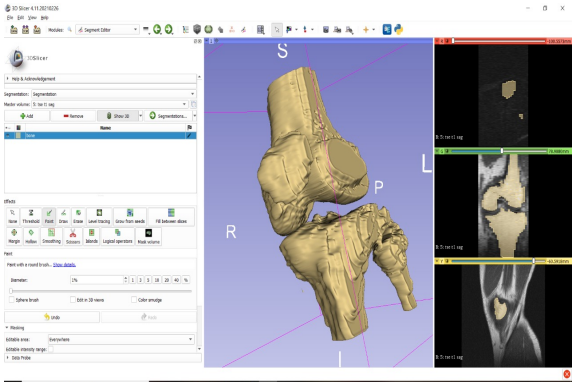

Figure 4: Manual Segmentation.

In order to carry out a correct segmentation, it was necessary to go through each image segment and manually select the area of interest.

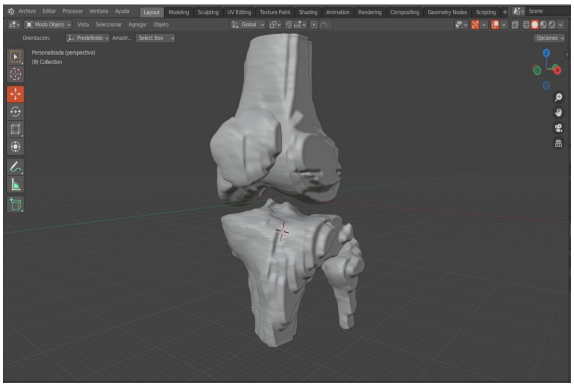

Figure 5: STL Image.

Next step, the 3d Slicer file was imported as a .stl to use it in blender and be able to make a design of the complete knee prosthesis.

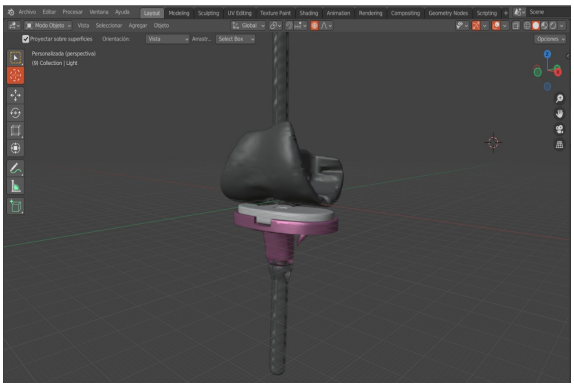

Figure 6: Prosthesis.

The prosthesis consists of 3 sections; the upper and lower ones, which are couplings to fix the bone and provide rotational movement, these must be made of titanium, and the middle pad, which is analogous to cartilage to avoid wear between the pieces of bone cement.

Figure 7: Implant.

To make the coupling of the prosthesis with the bones, the size and shape of each piece was first adapted to the size and shape of the bone, and by means of Boolean operations the intersection of the pieces and bones was cut in order to have the appreciation of what bone potions are necessary to cut and process.

4 DISCUSSION AND CONCLUSIONS

First of all, it must be clear to the patient and the doctor in charge that the design is carried out free of charge and therefore its reliability is not the same as prostheses that could be defined as high-end and are certified by some institution.

By making use of free software and existing designs, time and money can be saved when designing a total knee prosthesis, but it must be taken into account that there is no license that verifies and certifies its correct design by of the software.

To carry out tests or designs of prostheses it is not necessary to use radiography of knees in poor condition, with some injury or some defect, it is perfectly possible to use a knee in good condition simulating an injury, in order to use different prostheses and compare their possible implementation.

Taking into account that the prostheses depend on the state of gravity of the knee, different variants of the design can be made, to adapt them to problems with specific characteristics and have a greater variety of prostheses that can be chosen when presenting a solution to a patient.

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