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Development of numerical analysis through 3D modeling

Abstract

In the medical field, one of the main tools that has enabled advancements in surgical treatments is 3D modeling. This allows for a visualization of the anatomical structure of the human body. This, in turn, thanks to its tools, allows for manipulation of the element, greatly aiding in the application of chiropractic or surgical treatments without having to make any type of incision. For example, the case of the knee with the pathology genu valgum. Therefore, the development of a model, also called a biomodel, allows for work and identification of malformations or pathologies through the implementation of prostheses or implants that allow compatibility with the patient's structure, thus helping to achieve greater control over rehabilitation techniques.

Keywords: biomodels, anatomical structures, genu valgum

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Introduction

Currently, the use of biomodels to understand the functioning of the human body is used thanks to their contributions in numerical simulations that allow visualizing the behavior of various mechanical, structural, thermal, etc. components. This has allowed evaluations of some pathologies without resorting to physical tests that involve being invasive, especially in those that require some type of destructive testing. Therefore, the use of a tool such as the finite element method is of great importance because it allows the development of numerical calculations for the resolution of linear or nonlinear problems. Although the method offers solutions close to real ones, an exact solution will never be obtained due to the external agents that affect the element. However, the result maintains very high levels of precision, making it a reliable tool for situations involving physical and technological scope.

Methodology

The importance of methodology helps manage a project. In this case, it will support the understanding of the necessary parameters and tools that will facilitate the segmentation processes in software modules using the DICOM (Digital Imaging and Communication in Medicine) files required to obtain images.

The process begins with the acquisition of images obtained from a CT scan, which allows the density of different biological tissues to be captured. In this case, images of a knee with genu valgum are obtained. After obtaining the necessary images, they are imported into computer programs such as Mimics Medical®, which allows the element to be modeled using layers. This allows the quality of the images obtained to be improved by reducing the noise captured by the CT scan. This allows the generation of specific masks for each element. Bone structures such as cortical bone or trabecular bone are different from each other, so masks are required to add individual properties (Figure 1).

Once the model is obtained, it is exported to another program that allows the solidification of the element, since up to this step it is only considered a set of points and not a complete element.

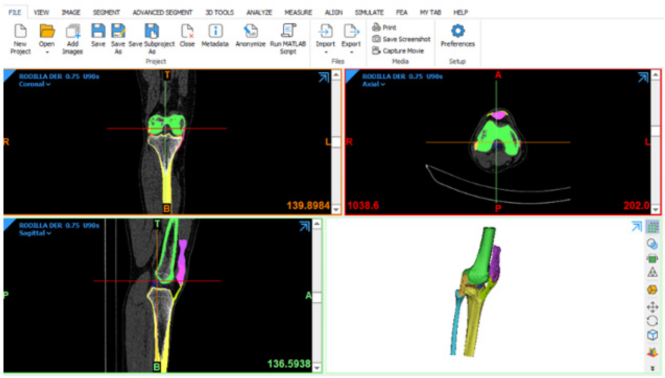

Figure 1 Interaction window of the Mimics Medical® software.

For this project, the 3-matic® program is used. This allows the use of different modeling formats and helps to create 3D textures, structures, and models for 3D printing. Once imported into this program, surface corrections are made since this three-dimensional model does not have a structure that allows the transfer of the model directly to a solid, which is necessary for analysis (Figure 2).[1–3]

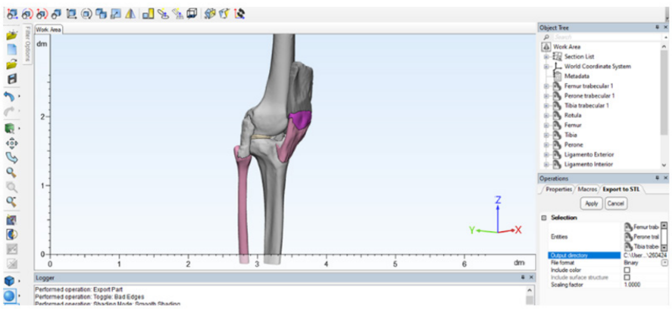

Figure 2 Smoothed knee model in Materialise 3 matic® software.

Therefore, once the process is completed, it is imported in the new parasolid format, which is used in finite element programs, in which it will be verified that the model is functional.

To continue with the analysis, it must be developed in a computational algorithm system specialized in the finite element method. For example, ANSYS®, a CAE (Computer Aided Engineering) system, develops simulations of fluid dynamics, electromagnetism, multiphysics, and structural analysis. The latter is the process that will be used in the analysis of the active element (Figure 3).

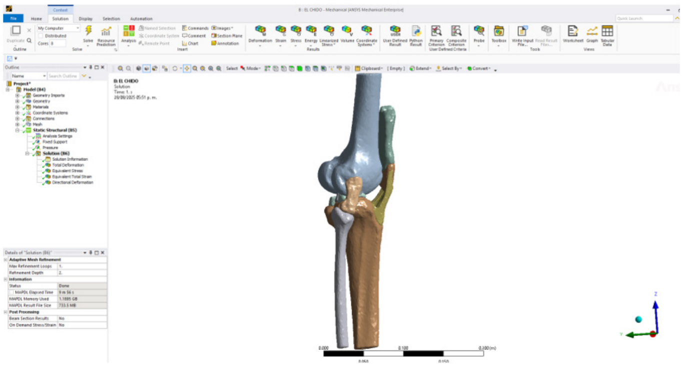

Figure 3 Biomodel exported in the ANSYS® program.

As a penultimate step, the discretization of the element can be carried out in the most convenient way, this based mainly on the geometry to be studied, which can be tetrahedrons, hexahedrons or the combination of both, depending on the need, as well as the size of the mesh, this can be more or less fine and will depend on the precision required in the analysis (Figure 4).[4]

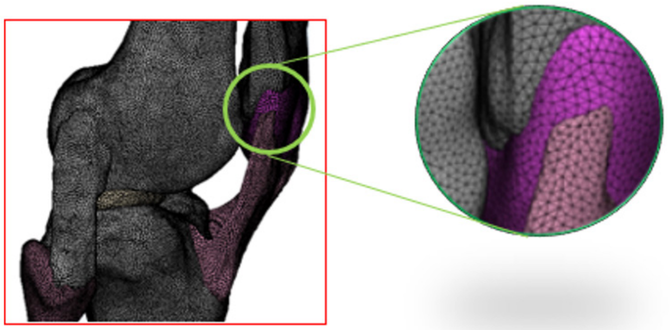

Figure 4 Complexity of the shoulder joint biomodel.

Finally, once the model is prepared, the mechanical properties and boundary conditions required for the analysis are assigned (Figure 5).[5]

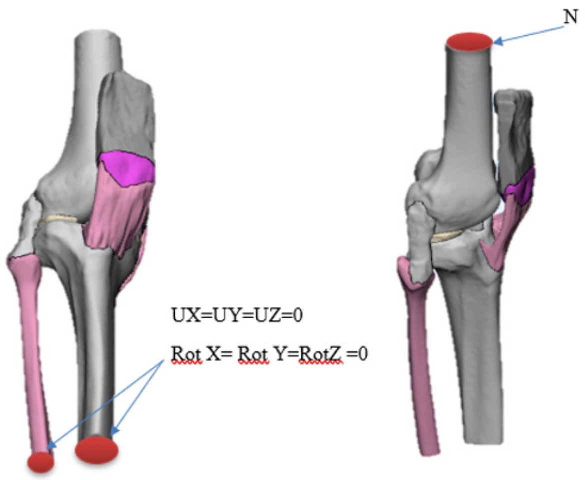

Figure 5 Boundary conditions and load application.

Conclusion

The finite method has successfully integrated different areas to achieve technological advancements in science. This has allowed numerical simulations to facilitate understanding of the anatomical structure of the human body and thus facilitate more effective rehabilitation processes and treatments based on the condition. Above all, it has identified many conditions that previously required an invasive procedure to diagnose. This also facilitates the development of personalized prostheses. This makes it possible to generate new methods and develop new technologies without the need for physical testing and to determine their results.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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