DIGITAL TWIN VALIDATION FOR SHOULDER JOINT BIOMECHANICAL SIMULATION

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DOI: https://doi.org/10.6036/10565

Glenohumeral joint is the main responsible of the shoulder's movement. In this moment, Shoulder arthroplasty is increasing rapidly [1] to treat both arthritis and bone fractures. However, there are limited studies about their biomechanical behaviour. The number of studies reduces even more if reverse shoulder prosthesis, a type of prosthesis in which the component that recreates the humeral head is placed in the glenosphere, are considered. After the placement of these prosthesis to solve a fracture, usually in four fragments, some cases of reduced bone density (bone remodelling) have been noted, causing long term problems due to the loss of muscular insertions.

In this context, this document presents a methodology to generate digital twins of the shoulder joint from clinic images [2], prepared to perform finite element (FE) simulations on which the prosthesis can be included and perform virtual surgeries.

The methodology starts with clinical images (Argus CT, Sedecal Molecular Imaging SLU®) of the shoulder joint, which enable surface detailed models with the program 3D SLICER. These models are imported into the program SPACECLAIM developed by ANSYS® for their debugging, their conversion into solid models and their combination with the prosthesis. After that procedure, the meshing of these models is generated.

In order to assign the bone's mechanical properties, a program named BONEMAT is used. In this program, the meshes of the model and the images are imported and the program assigns to every node of the mesh the mechanical properties of the Houndsfield units of the images. The mechanical properties of the prosthesis' mesh are defined by their manufactured material. The last step in this methodology consists in reintroducing the meshes into ANSYS [3], applying the boundary conditions and performing the simulation.

This FE simulations have been validated with a lab test performed on pork bones with a reverse shoulder prosthesis (INTEGRA Titan Reverse Shoulder Prosthesis), on which a load test has been performed, using a triaxial testing machine *Walter & Bai*. To do so, the bone have been tomographied and applying the methodology previously described, the displacement was calculated under the conditions of the lab test (figure 1).

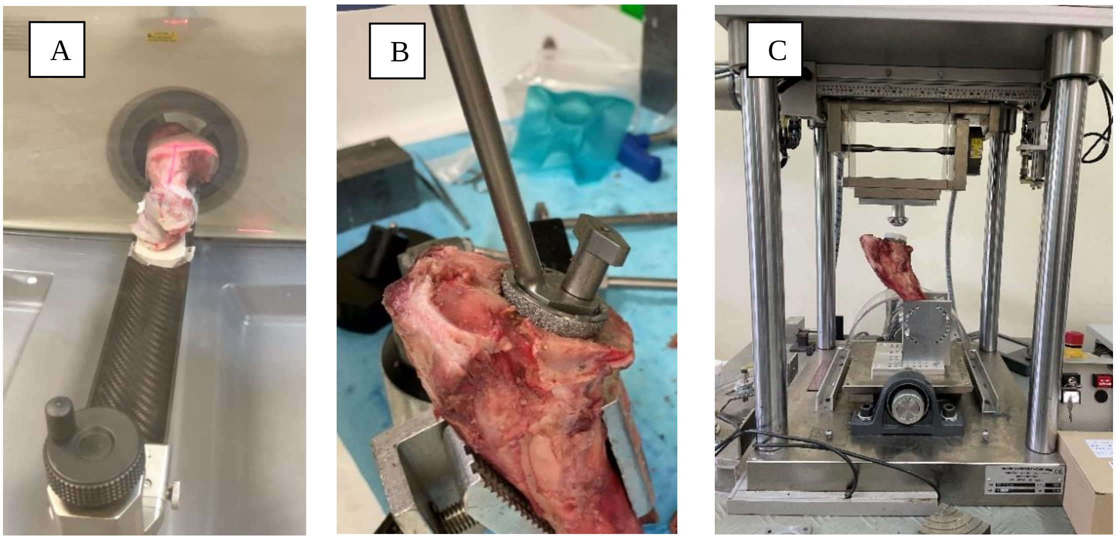

Figure 1 · Tomograph (A), surgical technique (B) and testing machine (C)

The data was acquired from the control system of the testing machine (force and head displacement) which were compared with the simulated tests. The analysis shows a difference between the real and simulated tests lower than 15%.

The main conclusion obtained from this work is that performance simulations of the shoulder joint are possible. To allow this procedure, a partnership between medical personnel and engineers is critical. The results of these simulations can help the medical team with their predictions of the behaviour of the joint, possible problems with internal stresses, bone remodelling and the degree of integration of the prosthesis in the patient.

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ACKNOWLEDGEMENTS

This work has been partially funded by the Gijón City Council through the University Institute of Industrial Technology of Asturias (Ref. IUTA-20-GIJON-23). We are grateful to María Rabanal Rubio and Pablo Roza Miguel (MBA Institute and MBA Institute Chair of Medical Research and Biomechanics of the University of Oviedo) for their support in the methodological definition of the study and its logistical organisation. We also thank Rubén Suárez Antuña for providing us the access to the bones of the study.