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MECHANICAL CHARACTERIZATION OF ABDOMINAL MUSCLE USING STEREO IMAGING

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We present a method to characterize *in vivo* the mechanical behavior of abdominal muscle, using inverse finite element analysis and image processing algorithms to estimate the properties. The aim of this technique is to help surgeon to choose the hernia mesh that better reproduces the mechanical behavior of the healthy muscle.

Experimental data. A total of six inflation tests were developed on New Zealand rabbits, half on healthy rabbits and other half on previous treated rabbits, with a defect inside of 7x5 cm. The inner pressure during the test varies from 0 to 8 mmHg. All experiments were recorded using a stereo imaging system and techniques multi-view stereo to estimate the 3D reconstruction of the rabbit surface, obtaining an accuracy of 1mm. As the surface is textureless, we paint artificial markers to set up correspondences. Taking the 3D coordinates of the null pressure, the geometry of the whole cavity was reconstructed in order to obtain an initial validate model for a FEM simulation.

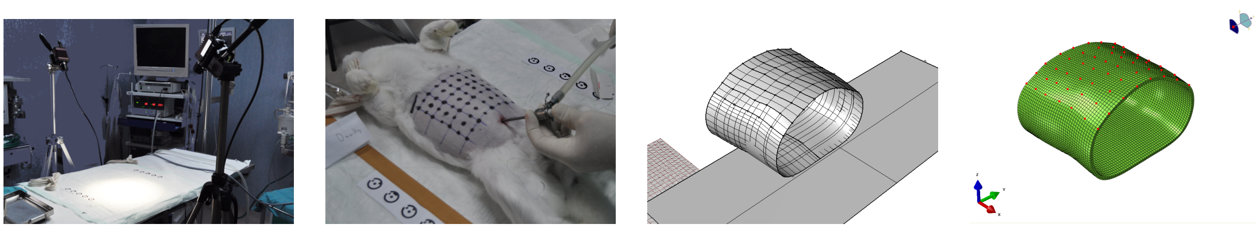

Figure 1: **Estimating abdominal cavity geometry.** First and second column: Arrangement of the stereo system and scene acquired. Third and fourth column: Shape at rest reconstruction and FE mesh.

Numerical analysis. Once the geometry is defined, it was necessary to formulate a constitutive law that defines the mechanical behavior of the tissue. A common methodology for soft tissues is to postulate the existence of a Strain Energy Function (SEF) decoupled in volumetric and isochoric responses, which in turn can be divided in isotropic and anisotropic part [1]. Based on previous biaxial tests and according to the literature [2], three material models have been proposed to simulate the muscle behavior: Neo-Hookean model, dependent on one parameter, and Demiray and Mooney Rivlin models, depending on two. To determine the value of the constants, inverse analysis method was used. A total of 500 simulations for each model were performed with Abaqus varying the parameters combinations in a specific range. For each simulation displacements of the numerical analysis u_{num} and experimental results u_{exp} were compared. Mean Square Error (MSE) (1) was defined as an objective function to evaluate the success of the numerical data.

$$MSE = \sqrt{\frac{\sum_{k=1}^{n\_puntos}((u^k_{num} - u^k_{exp})^2_x + (u^k_{num} - u^k_{exp})^2_y + (u^k_{num} - u^k_{exp})^2_z)}{3 \cdot n\_puntos}}. \qquad (1)$$

Results and discussion. A response surface of the MSE was plotted for each model. Results show that all models present a zone in the response surface that minimizes the error made by the simulation. The deformed shape of those combinations coincide and reproduce the deformed configuration of the experimental test.

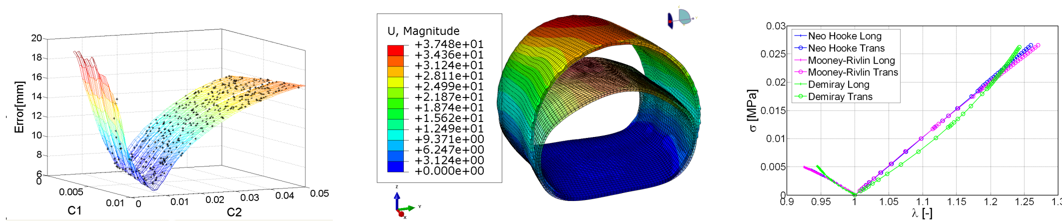

Figure 2: **Results for Mooney-Rivlin model and comparison between models.** Left column: Response surface for Mooney-Rivlin model. Middle column: FEM simulation for Mooney-Rivlin, from 0 to 8 mmHg of inner pressure. Right column: Curves $\sigma - \lambda$ for the proposed models.

Conclusions. The procedure works successfully, as far as it is able to find the specific parameters that better reproduce the muscle behavior. However, some aspects of the FEM reconstruction must be improved, such as the boundary conditions or load application, in order to fully guarantee the total reproduction of the experimental test.

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