MECHANICAL BEHAVIOR MODELLING FOR 3D-PRINTED RESORBABLE IMPLANTS OPTIMIZATION AND SOFT TISSUE RECONSTRUCTION

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Introduction

Breast cancer concerns 1 in 8 women in the world and is followed in 40% of cases by a mastectomy. Only 14% of women receive reconstructive surgery because of unfavorable clinical issues [1]. The need of innovative tissue engineering devices leads Lattice Medical company to bring a new 3D-printed device (see Fig.1), allowing the regeneration of soft tissue in order to replace the withdrawn breast. The implant, based on TEC (tissue engineering chamber) and fat-flat surgical technique, is constituted with bioresorbable thermosensitive materials to be fully absorbed by the body in several months, once the regeneration process is completed. In this industrial context, we need to assess some properties for predictive simulation: the TEC mechanical and biological properties over time, its sensitivity to implantation in the body temperature, its batch raw material variability and its structural 3D printed behavior. This would lead to a more enlightened numerical design and topological optimization work.

Methods

We use an experimental approach coupled with numerical validations. Characterization of mechanical properties and degradation kinetics of the polymer are estimated through monotonic and cyclic tensile tests with videoextensometry for local contact-less strain measurement controlled by CRAPPY software [2]. Testing were performed at room temperature (20°C) for standards requirement. Complementary testing is added at body temperature (37°C). To do so, a new experimental set-up is built, allowing to immerse tensile samples in heated water-filled closed environment regulated with a dual stream connection to a thermostatic bath. Samples were also characterized at different degradation levels and results show a strong influence of the temperature as well as batches of materials provided by the supplier. To account for these observations, a G'Sell type constitutive behavior law [3,4] is proposed (eq.1) with T the temperature, Tg the glass transition temperature of the batch, K(T) and p regulating the initial rigidity, w(T) for the plasticity, A(T) and B(T) for the threshold low, H(T) for the hardening, ε^n for the strain sensitivity, ν^m for the strain-rate sensitivity.

$$\sigma = K(T) * e^{\frac{P}{T}} * \left(1 - e^{-w(T)*\varepsilon}\right) * \left(1 + A(T)\right) * e^{-B(T)*\varepsilon_p} * \left(e^{H(T)} * \varepsilon^n\right) * \nu^m \qquad (1)$$

$$with\ \ K(T) = K *\ e^{k\left(\frac{1}{T}-\frac{1}{Tg}\right)}$$

The mechanical behavior thus identified from the experimental data is then used to perform structural scale simulations. Finite element simulations (FE) of the MATTISSE breast implant were carried out using Abaqus software (see Fig.1).

Results

This experimental campaign made it possible to determine the properties of the material and its evolution using a modified G'sell type law at the material scale. Using the previous behavior law, FE simulation of a compression on the MATTISSE implant were compared to the experimental results and show good agreement as shown in figure 1.

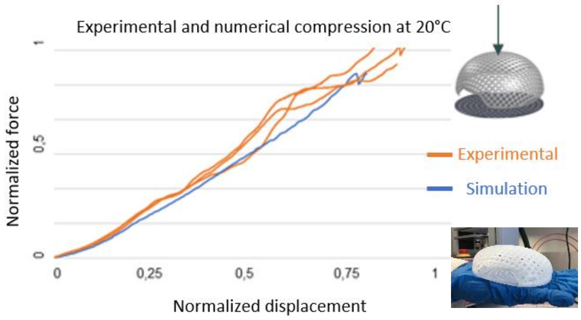

Figure 1: Comparison of experimental curves of forces over displacement (orange) versus numerical (blue)

Discussion

Complementary compression testing on MATTISSE implant with 3D full field displacement measurements using stereo-vision is currently investigated to have more relevant experimental-numerical comparison at room temperature and immerged at 37°C.

References

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Acknowledgements

The authors would like to thank the Haut-de-France region, Centrale Lille Institut and Lattice Medical for providing financial support.