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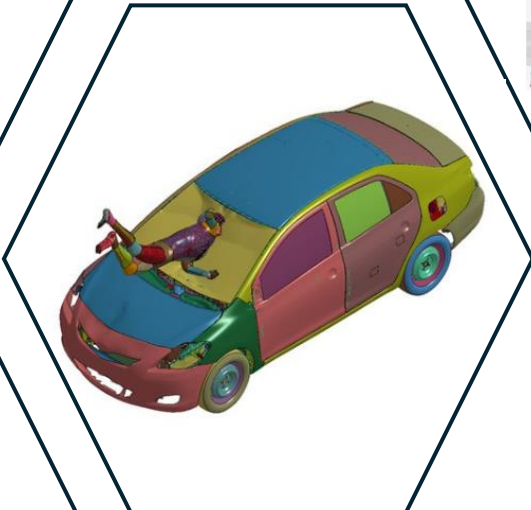
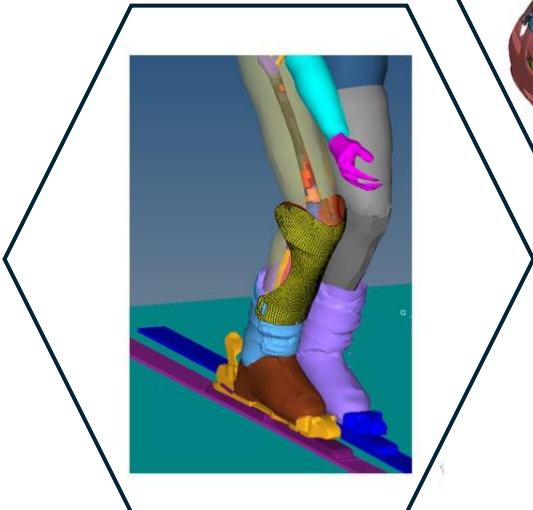
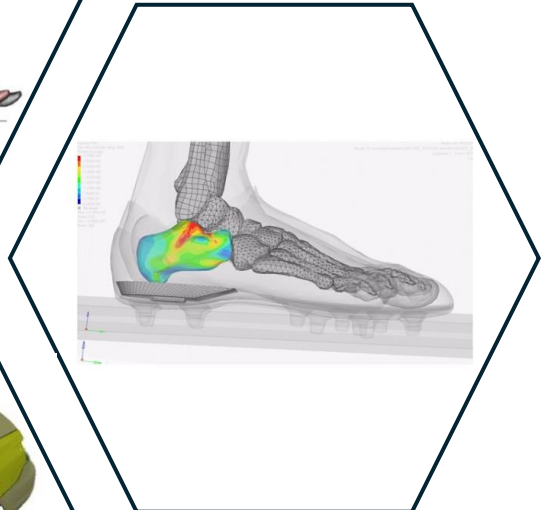
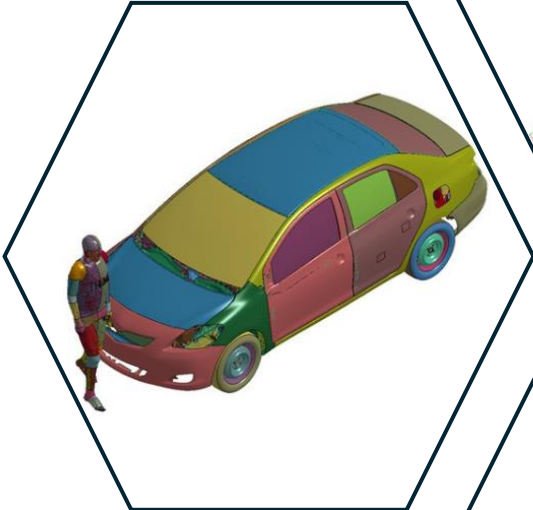
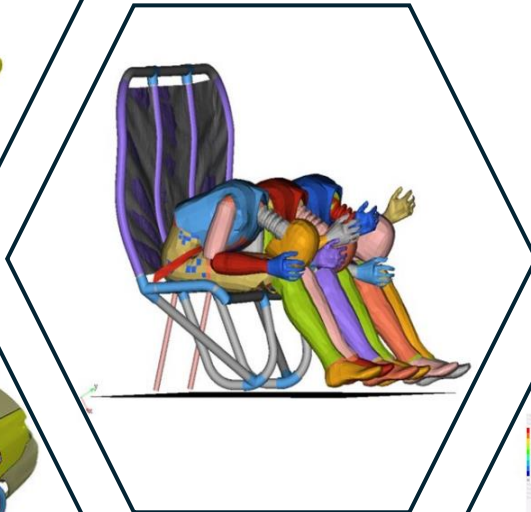
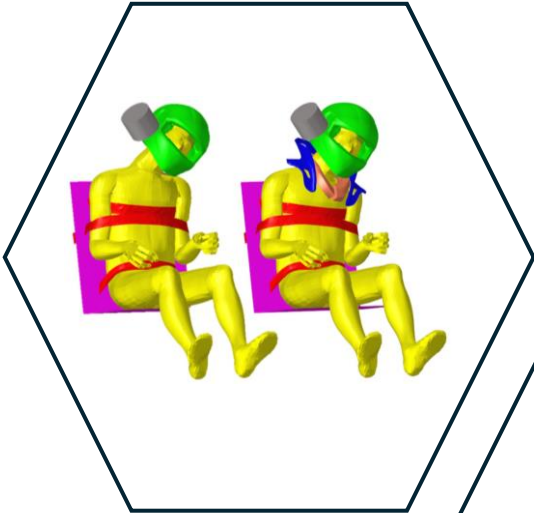


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# Predicting Early-Stage Damage in Pelvic Soft Tissues Using Hyper-Viscoelastic Modeling

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**Keywords:** perineal skin; hyperviscoelasticity; Mullins effect, Relaxation, Damage

## 1. Introduction

The pelvic floor supports pelvic organs but is prone to Pelvic Floor Dysfunctions, affecting up to 32% of women worldwide. Factors such as age, menopause, and traumatic events like perineal tears during childbirth significantly contribute to these dysfunctions (Jansson et al., 2020). Preventing these tears may be possible through anticipation. In our team, we aim to achieve this by monitoring the in-situ evolution of parameters (such as viscosity) and identifying indicators that could indicate pre-damage before it becomes visible (tissue degradation, holes). The first step, and the focus of this presentation, is to conduct cyclic tensile tests on porcine perineal tissues to characterize the hyper-viscoelastic behavior and the stress softening phenomenon.

## 2. Methods

Skin tissues were extracted after dissection from porcine perineum supplied by the local slaughterhouse in Alès (SEMAAC). Rectangular shapes were sampled from tissues of pig perineum. Instrumented pure-shear tests were conducted under a constant strain speed of  $0.03s^{-1}$ . The test consisted in applying cycles every 10% of elongation, each cycle being composed of traction, relaxation and unloading phases. Digital Image Correlation (DIC) enabled the evaluation of the in-plane strain tensor (Fig. 1)(Caro-Bretelle et al., 2016).

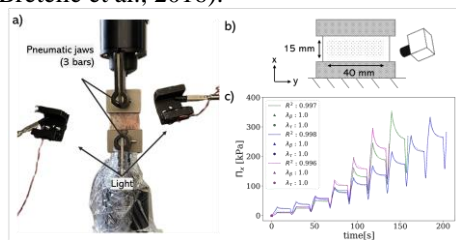


Figure 1 Device, sample geometry and pure shear stress versus elongation

A visco-hyperelastic incompressible constitutive model, which generalizes the Zener's model in large strain (Rebouah & Chagnon, 2014), allows us to express the global fitst Piola-Kirchhoff stress tensor in terms of hyperelastic ( $\bar{S}_{iso}$ ), viscous ( $\bar{Q}$ ) and volumic  $\bar{S}_{vol}$  components:

$$\bar{S} = \bar{S}_{iso} + \bar{Q} + \bar{S}_{vol}$$

with  $\tau \dot{\bar{Q}} + \bar{Q} = \tau \beta \dot{\bar{S}}_{iso}$ ,  $\bar{Q}(t = 0) = 0$ , where  $\tau$  is the relaxation time in second and  $\beta$  is an adimensional energetic parameter. The originality of this presentation is that the viscous parameters depend on the applied strain.

## 3. Results and Discussion

An optimization procedure allows us to fit experimental data with the proposed modelling. The evolution of the viscous parameters is shown in Fig. 2 for a testing on skin tissues from 3 different pigs.

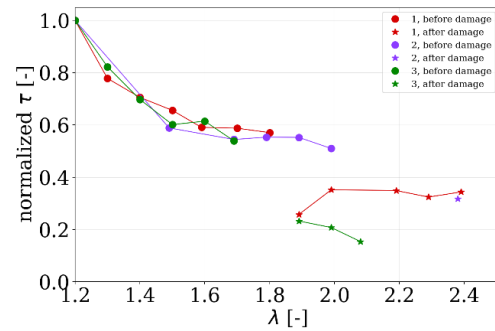


Figure 2 Time relaxation evolutions as a function of elongation

## 4. Conclusions

Evolutive viscous parameters appear to be effective in describing pre-damage in porcine soft tissues, as they provide good reproducibility and exhibit a change in behaviour as the tissue approaches a damaged state.

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