DEVICE INDUCED DAMAGE OF ARTERIAL PORCINE TISSUE

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1. Introduction

An aspect of intravascular medical procedures is safe device navigation to optimally position the device, while minimizing tissue damage. If the conditions under which tissue damage occurs are known, this can be used to improve the device design and in guidance tools during medical procedures. A severe type of tissue damage is puncture, but prior to puncture collagen fibers in the vascular wall rupture. The vascular wall can be described using the model developed and characterized in [1]. This model includes a description of collagen fiber rupture in the vascular wall using an internal damage parameter. This damage mechanism that occurs during loading-unloading of tissue samples corresponds to the so-called Mullins effect. The purpose of this study is to quantify the fiber rupture mechanism by lumping this micromechanical phenomenon to a macroscopic damage parameter as a function of device geometry by loading-unloading indentation of arterial porcine tissue.

2. Materials and Methods

The experimental set-up consists of a displacement-controlled holder for the medical device-mimicking indentation tool. A porcine artery is pre-strained to physiological conditions. The force exerted by the device is measured. Fig. 1 shows a schematic of the experimental set-up.

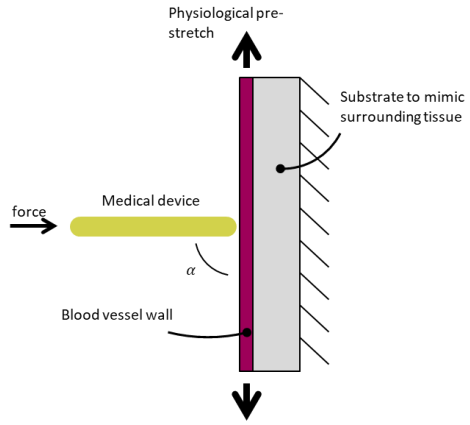

Figure 1: Schematic of the experimental test set-up.

The arterial tissue damage model developed in [1] is an extension to the hyperelastic formulation in [2] and is implemented into the finite element package MSC.Marc through a user subroutine.

3. Results

As can be observed in Fig 2, the experimentally obtained indentation force, as a function of displacement up to puncture, is in qualitative agreement with results obtained in [1]. The energy dissipated during loading-unloading cycles is assumed to be fully attributed to internal fiber damage in the vessel wall, that can be measured and analyzed with a computational model (Fig. 3).

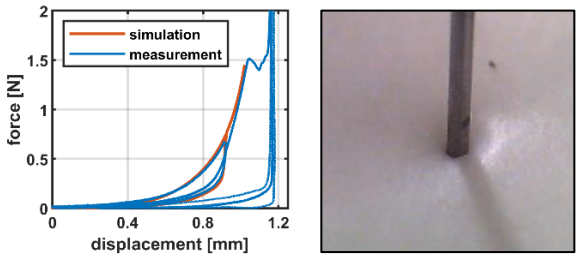

Figure 2: Example of measured force-displacement behavior during loading-unloading indentation.

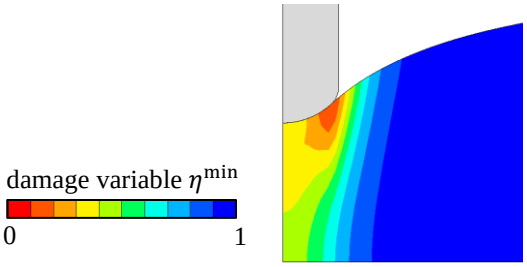

Figure 3: Calculated pseudo-elastic fiber damage variable [1] during indentation.

An experimental-numerical approach is pursued to assess the evolution of the damage mechanism in the tissue, as shown in Fig 3.

4. Discussion and Conclusions

A combined experimental-numerical procedure has been developed to analyze device-induced tissue damage up to puncture. As a next step, device tip geometries, substrates and angles of approach will be varied. Results will be used to optimize device design for minimal vascular fiber damage and for the development of guidance tools for during medical procedures.

5. References

1. Weisbecker et al., J.Mech.Behavior.Biom.Mater; 12:93-106 (2012).
2. Gasser et al., J. R. Soc. Interface; 3:15-35 (2006).

Acknowledgements

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