

# Analysis of the Microstructure of an Artery and Modeling Aspects Considering Collagen Cross-Linking

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## Abstract

The three-dimensional ultrastructure of a fibrous tissue can be reconstructed, and the complex nanoscale arrangement of collagen fibrils, including neighboring proteoglycans, can be visualized even in the stretched, loaded state [1]. In particular, experimental data on collagen fibers in human artery layers have shown that the fibers are not symmetrically dispersed [2]. In addition, it is known that collagen fibers are cross-linked and that the cross-linking density in arterial tissue has a stiffening effect on the associated mechanical response (aging). An attempt to characterize this effect on the elastic behavior is presented, and the influence of cross-link density on the mechanical behavior under uniaxial tension is demonstrated [3]. An extended constitutive model considers dispersed fibers connected by randomly distributed cross-links [4]. A simple shear test focusing on the sign of the normal stress perpendicular to the shear planes (Poynting effect, [5]) is also analyzed. In [6], it was experimentally observed that, unlike rubber, semi-flexible biopolymer gels exhibit a tendency to approach the top and bottom surfaces under simple shear. This so-called negative Poynting effect and its relationship to the cross-links, the fibers and the cross-link dispersion is investigated. References [1] A. Pukaluk et al.: An ultrastructural 3D reconstruction method for observing the arrangement of collagen fibrils and proteoglycans in the human aortic wall under mechanical load. *Acta Biomaterialia*, 141:300-314, 2022. [2] G.A. Holzapfel et al.: Modelling non-symmetric collagen fibre dispersion in arterial walls. *Journal of the Royal Society Interface*, 12:20150188, 2015. [3] G.A. Holzapfel and R.W.

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