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Modelling the degeneration of the collagen architecture in a microstructural model of the human cornea

We propose an enriched micromechanical model of the collagenous reinforcement of the eye stromal tissue. As a departure from an over-simplified model proposed a few years back (pandolfi et al, 2019), where collagen and chemical bonds were modeled as linear elastic trusses, here we describe the chemical bonds by means of a more realistic generalized Lennard-Jones potential. In keeping with the original model, we disregard the multi-layer nature of the cornea and the continuum nature of the filling elastin matrix. The under-constrained locally orthogonal network of collagen fibrils is stabilized by crosslinks that provide the rigidity of the system and confer the ability to sustain the action of the intraocular pressure. In the previous work it has been shown that the weakening and the bulging of the cornea due to ectasia can be ascribed to the reduction of the density of the chemical bonds. The introduction of a pseudo-chemical potential supplies a more realistic model: any mechanical, enzymatic, or chemical cause of the degradation of the tissue observed in ectasia can be effectively introduced in a multi-physic potential, disregarding the adoption of phenomenological models. In numerical calculations, the high non-linearity of the model is suitably controlled by adopting a robust explicit solver based on dynamic relaxation.

This is a joint work with Maria Laura De Bellis, Alessio Gizzi, and Marcello Vasta