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ON THE RELEVANCE OF THE COLLAGEN ARCHITECTURE ON THE BIOMECHANICS OF THE HUMAN CORNEA

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Abstract. Two recent studies concerning the biomechanics of the human cornea are illustrated in this talk. The focus is on the relevance of the fibrous collagen reinforcement on the mechanical performance of the tissue. The first study is based on an advanced finite element model describing the in-plane organization of the stromal collagen. The model includes recently discovered features of the collagen architecture, whose relevance on mechanics of the cornea has not been quantified yet. Numerical investigations analyze the response of the human cornea to three mechanical tests, i.e., the inflation, the probe indentation, and the dynamic air puff tests. Differences in the mechanical response are observed only in dynamic tests, while quasi-static tests are not able to differentiate between the models. The study concludes that from the mechanical point of view the actual detailed architecture of the collagen has a minor relevance with respect to the main anisotropic orthogonal collagen structure that has been considered and acknowledged in the literature. The second study is a simplified micromechanical model of the collagen fibrils that accounts for crosslink bonds always disregarded in numerical simulation given their complexity. The reinforcing structure is modeled with two sets of parallel fibrils, connected by transversal bonds within the single fibril family (inter-crosslink) and across the two families (intra-crosslink). The particular design chosen for this ideal structure relies on the fact that its ability to sustain loads depends on the degree of the crosslink and, therefore, on the bond density and stiffness. The mechanical response of the system is analyzed according to the level of interlacing and of the bond stiffness. The weakening of transversal bonds is associated to a marked increase of the deformability of the system. In particular, the localized deterioration of transversal bonds due to mechanical, chemical, or enzymatic reasons can justify the weakening of the stromal tissue resulting in localized thinning and bulging typically observed in keratoconus.