# Correlation between parameters of hyperelastic phenomenological strain energies and collagen-related soft biological tissue properties

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## ABSTRACT

The constitutive modeling of biological soft tissues has gained a lot of attention in recent years. Pure macroscopic, phenomenological approaches based on hyperelastic strain-energy functions generally appear to be robust and numerically less expensive compared to multiscale approaches. On the other hand, considering advanced microstructural effects in biomedical simulations may lead to additional valuable insights. However, both approaches rely on suitable parameter identification in order to ensure reliable predictions of the material behavior. In a series of papers, including references [1] and [2], a multiscale approach for collagenous tissues was developed that is based on parameters related to clear structural features.

The properties of a biological tissue may significantly change through lifetime and will strongly affect the mechanical material response. This characteristic feature of living tissue is summarized under the term remodeling and can be quantified in the change of the results of parameter identification. Therefore, the change of parameters may also serve as diagnostic indicator for remodeling, induced by diseases.

In this contribution we aim to correlate the parameters of two common transversely isotropic constitutive laws, introduced in [3] and [4] to the structural motivated parameters in [1] and [2]. The correlation of the phenomenological parameters and microscopic properties as the collagen persistence length, fiber radius, intermolecular cross-link density and fiber crimp amplitude is expressed with help of a regression analysis. Accordingly, the phenomenological parameters will be expressed only in terms of the structural parameters in the regression function. The required data for the regression is obtained by curve fitting in the context of numerical optimization. Further, the inverse case, i.e. gaining information on the microstructure from phenomenological parameters is addressed. This could become an interesting alternative for future approaches for gaining histological and biochemical information that could be employed in diagnosis and therapy.

## REFERENCES

[1] M. Marino and G. Vairo, “Multiscale elastic models of collagen Biostructures: From cross-linked molecules to soft tissues”, In A.Gefen (Ed.), Multiscale computer modeling in biomechanics and biomedical engineering, *Studies Mechanob Tissue Engrg Biomat 14* , Springer-Verlag, Berlin Heidelberg (2013)

[2] M. Marino and P. Wriggers, “Finite strain response of crimped fibers under uniaxial traction: An analytical approach applied to collagen ”, *J. Mech. Phys.*, **98**, 429-453 (2017).

[3] R.N. Vaishnav, J.T. Young and D.J. Pathel, “Distribution of stresses and of strain-energy density through the wall thickness in a canine aortic segment”, *Circ. Res.*, **32**, 577-583 (1973).

[4] G.A. Holzapfel, T.C. Gasser and R.W. Ogden, “A new constitutive framework for arterial wall mechanics and a comparative study of material models”, *J. Elast.*., **61**, 1-48 (2000).