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# CONSTITUTIVE MODELING OF HUMAN SKIN

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**Summary:** Skin mechanics is important for various fields of research. This includes research on pressure ulcer etiology and the interaction between skin and devices or materials such as shaving appliances, prosthetic liners and bed linen. For this research, prediction of mechanical response of skin is essential. From a mechanical point of view, skin should be considered as a highly dynamic and complex composite that has non-linear viscoelastic, anisotropic and heterogeneous properties. Because of this complexity its mechanical response is difficult to understand and predict, varying orders of magnitude depending on the type of loading. Therefore the aim of this work was to develop a constitutive material model that is based on experimental evidence and capable of capturing the complex mechanical behavior of skin.

The Marc/Mentat FEM software package was used for the implementation of the constitutive model. In the HYPELA2 user subroutine skin is modelled as a fiber-reinforced matrix, with an elastic fibrous component and an isotropic, non-linear viscoelastic matrix. The fibers only contribute in extension and provide anisotropic properties. Heterogeneity was included by gradually varying the stiffness over depth. Parameter optimization with respect to the experimental results was performed using an iterative parameter estimation method in Matlab.

Three intrinsically different experiments were performed on ex-vivo human skin. First, highly controlled large amplitude oscillatory shear (LAOS) was performed on a rheometer to determine non-linear viscoelastic properties of the matrix. It was combined with digital image correlation (DIC) on the cross-sectional area to assess heterogeneity. Secondly, biaxial tensile tests were performed to determine the fiber contribution, combined with DIC to determine local deformations and assess anisotropy. Finally, micro indentation experiments were performed to determine the contribution of volume change.

The model showed to be able to describe the non-linear viscoelastic response to LAOS. The anisotropic response of human skin to biaxial tensile loading was described more accurate than the well-established Ogden model. The response to indentation is slightly overestimated with the current set of parameters.

Overall our constitutive model is capable of describing the complex mechanical behavior of human skin under shear, biaxial tension and indentation with a single parameter set.