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A numerical model for the heterogeneous mechanical behavior of human skin

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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 a complex composite with non-linear viscoelastic, anisotropic and heterogeneous properties [1]. Most constitutive models, presented in the literature, describe the behavior only for a specific type of experiment and measured properties vary orders of magnitude depending on the type of loading. The aim of the current work was to develop a constitutive material model able to describe the mechanical behavior for shear, biaxial testing and indentation with one single material model and parameter set.

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, 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. Finally, micro-indentation was performed.

Overall our constitutive model appeared to describe the mechanical behavior of human skin under shear, biaxial tension and indentation with a single parameter set although the response to indentation was slightly overestimated with the current set of parameters.

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