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EXPERIMENTAL AND NUMERICAL STUDY ON THE ELASTIC-VISCOPLASTIC BEHAVIOR OF FACIAL SOFT TISSUES

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Abstract

Understanding the mechanical behavior of facial soft tissue has become an important aspect in problems concerning computational simulation of surgical intervention, the evaluation of optimal surgical and suturing procedures and the design of prosthetic devices. Being able to predict the response of soft tissues to mechanical loads is essential in improving the accuracy of numerical simulations [1, 2]. For this purpose physically or phenomenologically based continuum constitutive soft tissue models were proposed.
Alongside the advancements in modeling, the experimental characterization of time dependent material behavior of facial tissues allows to develop and validate models due to data available for pre-conditioning, stress relaxation at constant strain, and hysteresis loops in cyclic loading and unloading. Rubin and Bodner [3] introduced a three-dimensional nonlinear model for dissipative soft tissue response which considers changing material properties through history dependent state-variables that are governed by evolution equations. Specifically, the tissue is considered as a composition of an elastic component and a dissipative component. The purely elastic part of this model formulation was used in an anatomically based finite element model of the face, introduced by Barbarino et al. [4], which allowed to investigate the mechanical response of superficial soft tissue under different loading conditions.
The work presented here, aims at applying the full set of elastic-viscoplastic constitutive equations by Rubin and Bodner [3] to the face model. The elastic-viscoplastic constitutive model consists of a set of material parameters that characterizes the dilatation, the elastic distortion of the elastic and dissipative components, the inelastic time-dependent and time-independent responses, and the hardening due to fluid flow through the tissue.

To this end, an extensive experimental campaign based on the suction method is performed for the identification of the model parameters. The Cutometer and aspiration [5] device provide means of assessing the behavior of different layers of facial tissue. The new constitutive models are apllied for realistic simulation of facial tissues response for pull-up experiments, as presented by Barbarino et al. [6].
The inverse problem for the material parameter identification was solved using a new mixed finite element formulation that was derived for the specific form of the elastic-viscoplastic model. This implementation requires the integration of the evolution equations governing the tensorial measures of the elastic distortional and the dissipative part. For this purpose a strongly objective integrator was developed. Our integration scheme is based on a relative deformation gradient mapping the motion from time increment t_n to time increment t_{n+1} which not only allows for objective integration, but most significantly, it circumvents the requirement to store the reference configuration.

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