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A Predictive Tool for Determining Patient-Specific Mechanical Properties of Human Corneal Tissue

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Abstract

A computational predictive tool for assessing patient-specific corneal tissue properties is developed. This predictive tool considers as input variables the corneal central thickness (CCT), the intraocular pressure (IOP), and the maximum deformation amplitude of the corneal apex (U) when subjected to a non-contact tonometry test. The proposed methodology consists of two main steps. First, an extensive dataset is generated using Monte Carlo (MC) simulations based on finite element models with patient-specific geometric features that simulate the non-contact tonometry test. The cornea is assumed to be an anisotropic tissue to reproduce the experimentally observed mechanical behavior. A clinical database of 130 patients (53 healthy, 63 keratoconic and 14 post-LASIK surgery) is used to generate a dataset of more than 9,000 cases by permuting the material properties. The second step consists of constructing predictive models for the material parameters of the constitutive model as a function of the input variables. Four different approximations are explored: quadratic response surface (QRS) approximation, multiple layer perceptron (MLP), support vector regressor (SVR), and K-nn search. The models are validated against data from five real patients. The material properties obtained with the predicted models lead to a simulated corneal displacement that is within 10% error of the measured value in the worst case scenario of a patient with very advanced keratoconus disease. These results demonstrate the potential and soundness of the proposed methodology.