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Contribution - Biomechanical simulation platform for patient-specific refractive interventions

DS applications and challenges in Medicine, Natural Sciences, and Engineering

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Abstract

Myopia characterized by near sightedness, is the most common yet underestimated ocular condition affecting global health. Projections suggest nearly 50 % of the world's population will be myopic by 2050. Corrective surgeries such as LASIK, SMILE and PRK are becoming increasingly popular but 15 % of cases fail to provide the desired correction rates. The foremost drawback in these corrective surgeries arise in the stage of surgical planning itself. The lack of patient specific information leads to a "one size fits all" approach. A possible solution to this problem is the incorporation of patient specific data like, corneal topography and tissue properties into the surgical planning for patient specific diagnosis and treatment. In this regard a patient specific geometrical model has been developed based on Pentacam elevation maps obtained from patients undergoing LASIK, PRK and SMILE surgeries. The unique surgical parameters like LASIK flap and SMILE lenticule extraction have been captured using the software GMSH 4.6 and Python 3.0. A Holzapfel-Gasser-Ogden hyperelastic mechanical model was implemented using an ABAQUS UMAT subroutine. The current collagen fiber distribution is modelled using a general structural tensor that accounts for two families of fibers, having an orthogonal orientation in the center of the cornea and circumferentially oriented in the corneal periphery. Besides fiber orientation, in-plane and out-of-plane fiber dispersions have considered in the model to account for the fact that the fibers are not perfectly aligned with the main direction of anisotropy. The model was validated by measuring the corneal curvature from the clinical data and ensuring that it was accurately reproduced at different steps of the modeling procedure. Simulations of the three refractive interventions were then conducted based on the pre-operative clinical data and the corneal curvature was examined. We aim to include patient specific collagen distribution from Brillouin imaging data and such a model would facilitate in building a simulation platform for patient specific treatment of refractive interventions by incorporating various types of medical data.