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Dissertations-Kurzfassung

A Study of Aberrations in the Human Eye by Zernike Phase Plate Precompensation and Finite Element Modeling Methods

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Optical aberrations of the human eye play a major role in degrading both visual quality and retinal image quality. In this dissertation, two methods are presented to study optical aberrations of the human eye.

By studying the characteristic of higher-order aberrations of the human eye (mainly coma and trefoil aberrations), a method of using pairs of rotating Zernike phase plates to compensate for higher-order aberrations of the eye is proposed. In practice, one specially designed, compact compensation unit with pairs of rotating Zernike phase plates was developed and successfully implemented to the confocal scanning laser ophthalmoscope (cSLO). Significant improvement in contrast of the retina imaging is demonstrated.

On the other hand, finite element modeling method (FEM) is employed to study the biomechanical properties of the human cornea and reconstruct the corneal shape, since the imperfection of corneal curvature directly impacts human vision and the quality of retina imaging. A new non-linear, three-dimensional, non-homogeneous model of the cornea is developed to estimate three-dimensional stresses and finite strains in the cornea; the “Apical-rise vs. IOP elevation” study shows a nice prediction of biomechanical response of the cornea compared to the published experimental data. In the proposed model, 144 three-dimensional elements are used to construct the corneal shape and each element is associated with 8 nodes. The wall of the cornea is assumed to be heterogeneous with a subset of elements that are made stiffer to simulate Bowman’s layer. Three-dimensional stresses and strains within the cornea are calculated by finite element analysis under both normal and abnormal intraocular pressures. Different locations are chosen for further quantitative evaluation. The boundary conditions at the limbus are varied to study how clamping conditions affect the stress and strain estimates. In addition, two modified corneal models are proposed to predict the surgical outcomes of the femtosecond laser, intrastromal refractive surgeries.