

COMPUTATIONAL MODEL OF HUMAN EYE FOR STUDY OF RETINAL PATHOLOGIES

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Abstract

Computational modeling of human eye is crucial in understanding various retinal pathologies such as myopia, retinal schisis, staphylomas, retinal detachment and others. An accurate eye model has many applications in the field of ophthalmology. Myopia is a refractive error of the eye and is characterized by an increase of its axial length. Concepts of mechanics suggest that the sclera of myopic patients deforms more than usual and results in the distension of the eye. The aim of this project is to build a computational model of the human eye using Finite Element Analysis (FEA) and the ABAQUS® software to simulate the eye axial growth for myopic patients. Several models were simulated in order to find the most suitable model for the objectives of the project. The material properties were based on the literature, except for the cornea and sclera that were obtained from an uniaxial experiment and fitted to the Neo-Hookean material model.¹ Using this data, a model with linear and nonlinear materials was built to simulate axial eye growth using appropriate boundary conditions. The stress and strain distributions of the model were similar to those observed in the literature. The model can be used to study the development of myopia due to mechanical loads. This work will primarily contribute to the identification of patients with potential for retinal pathologies and helping physicians to decide when a possible surgery is required.

Key words: Finite Element Analysis (FEA), myopia, biomechanics

Introduction

Understanding the mechanism of axial elongation of the eye for myopic patients is helpful for ophthalmologists to do more accurate diagnosis before of pathologies development.

A 2-D axisymmetric finite element model of a myopic eye was generated to study the induced stress and strain distributions and integrity of the retinal layer aiming to identify patients with retinal complications.

Results and Discussion

In addition to retina, structures as cornea, sclera, ciliary body, zonules, lens, vitreous and aqueous are present in the model (Image 1a). Their material properties were obtained from the literature, except the cornea and sclera that were fitted to the Neo-Hookean material using uniaxial experimental data. Springs were used along the curvature of the external layer (sclera) to simulate the fixation of the ocular globe. A full-Newton solution technique was used for the iterations. A mesh with 3-node linear axisymmetric triangle elements with distortion control was used.

The axial elongation of myopic eyes was simulated and maximum radial and circumferential stresses and logarithmic strain components were higher at retina on the posterior pole (Image 1b). Such results indicate that this region would be most vulnerable to mechanical changes occurring in axial myopia. This result can be seen in the literature, once this axial elongation is associated with many ocular pathologies localized on the posterior pole.²

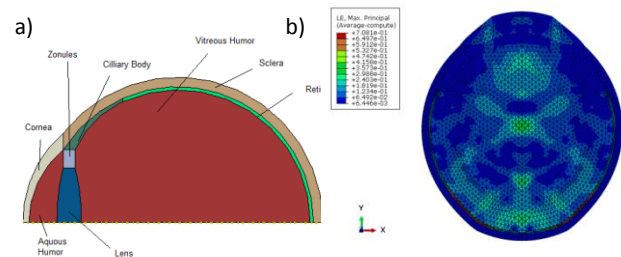


Image 1. a) Eye model and its respective structures; **b)** logarithmic strain maximum principal on a myopic eye

Conclusions

The model developed in this study is highly versatile and applicable to a wide range of myopic eye research. The model can be developed further to reveal the mechanical factors driving degenerative changes such as staphylomas, retinal schisis, macular degeneration and a progressive high myopic eye. In addition, the model can be easily adapted to study the effects of glaucoma, hyperopia and similar ocular diseases on the retina.

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¹ LIU, X.; WANG, L. "Mechanism of traumatic retinal detachment in blunt impact: A finite element study". *Journal of Biomechanics*, Vol 46, pp 1321–1327. 2013.

² BENDRE, A. A., "Finite element analysis and preliminary experiments to study the effects of high myopia in macular degeneration". Mechanical Engineering Master's Theses. Northeastern University. Boston. 2009.