AnnMarie Hipsley et al., J Clin Exp Ophthalmol 2016, 7:3 (Suppl)
http://dx.doi.org/10.4172/2155-9570.C1.033

Novel 3D computational model demonstrates the complex role of ciliary muscles and effects of age-related changes on the accommodative mechanism

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Purpose: The goal of this study was to develop a multi-component 3D Finite Element (FE) model of the accommodative mechanism that includes the ciliary muscle, lens, zonules, sclera and choroid, to characterize the role of complex ciliary muscle action in producing the lens changes required for accommodative function. We further developed both a model in the younger/healthy eye and in the aging/presbyopic eye in order to illuminate age-related effects on the accommodative mechanism.

Setting: Academic Research Study at Biomedical Engineering Department of University of Virginia Charlottesville, Virginia, USA

Methods: Representative 3D models of the ocular structures were developed based on extensive review of literature defining the anatomical geometry and material properties of the young and old resting human eye. Geometric meshing and FE analysis was performed using AMPS technology with simulated zonular pre-tensioning of the lens to the unaccommodated state and ciliary muscle contraction to the accommodated state, to measure the resultant movements of ocular structures. Ciliary muscle fiber groups were activated in isolation to quantify each contribution to accommodative action. Model predictions were validated by comparing to literature values and dynamic imaging of accommodation in human subjects.

Results: The FE models were able to demonstrate contractile forces of the ciliary muscle and the resultant changes to the ocular structures during accommodation. The model predicted lens deformations and displacements related to accommodative amplitude changes that were consistent with experimental observations from the literature. The model revealed specific contributions of ciliary fiber groups to lens changes, with radial fibers contributing most to anterior displacement and circular fibers contributing most to circumferential deformation. Sensitivity analysis of the differences in accommodation between the young/healthy and old/presbyobic eye identified the age-related changes that contribute most to symptoms of presbyopia.

Conclusions: This computational 3D model provides novel insight into the interactions of the components of the accommodative mechanism through incorporation of decades of previous research. The model results were effectively validated with existing data. New appreciation of ciliary muscle function gained through simulations of its specific actions motivates hypotheses for understanding age-related effects on the accommodative mechanism with presbyopia as well as translational clinical applications for targeted therapies. Future use of the model is planned to test effectiveness of various hypothesized therapies to treat presbyopia by restoring accommodative function to the old/presbyopic eye model.

Biography

AnnMarie Hipsley has received her Doctor of Physical Therapy (DPT) from Boston University's Sargent College of Rehabilitation Sciences. She has received her PhD in Biology with emphasis in Neurophysiology from Redding University. She holds BS in Zoology from The Ohio State University. She is the Founder of Ace Vision Group Inc., and also iAware Inc., organization for the promotion of awareness of age-related ocular disease. She leads the company as the Founder & CEO.

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