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Biomechanics of the Sclera

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Abstract: The sclera is a fibrous soft tissue that joins anteriorly with the cornea and posteriorly with the optic nerve head to form the stiff and tough outer covering of the eye. The tissue serves important structural and visual functions, which includes protecting the eye from external injury, providing mechanical support for the retina and optic nerve head, and maintaining an optimal eye shape for vision. Myopia, or nearsightedness, is caused by a lengthening of the eye, which moves the retina behind the focus plane. The mechanical properties supporting these functions arise from the fibrous microstructure of the tissue, which consists of densely stacked lamellae of collagen fibrils embedded in a matrix of proteoglycans. Myopia and glaucoma, a degenerative disease of the optic nerves, are associated with alterations in the fibrous microstructure and mechanical properties of the tissue. We have developed an integrated experimental and modeling approach to study the mechanical properties, collagen structure, and their alterations with age and disease. The approach includes inflation testing with displacement mapping using 3D DIC, wide-angle x-ray scattering mapping of the collagen structure, inverse finite element analysis that combine the mechanical and structural measurements, and micromechanical modeling. We applied these methods to study the influence of scleral biomechanics on the development of glaucoma in human and mouse models. Our results reveal changes in the anisotropic collagen structure and material properties with age and glaucomatous damage. These changes have opposing effects on the mechanical behavior of the optic nerve head, which may have important implications for the age-related and disease-induced remodeling process of the tissue.

Biography: Vicky Nguyen obtained her S.B. in Mechanical Engineering from MIT in 1998, and M.S. and Ph.D. in Mechanical Engineering from Stanford in 2004. Upon receiving her degree, she worked as a research scientist at Sandia National Laboratories in Livermore, CA then joined the Department of Mechanical Engineering at Johns Hopkins University as an Assistant Professor in 2007. Her research focuses on the biomechanics of soft tissues and mechanics of stimuli-responsive polymers. Dr. Nguyen was awarded the 2008 Presidential Early Career Award for Scientists and Engineers (PECASE) for her work on constitutive modeling of shape memory polymers. In 2013, she received an NSF CAREER Award to investigate growth and remodeling of collage nous tissues; the inaugural UH Eshelby Mechanics Award for Young Faculty; and the ASME Sia Nemat-Nasser Early Career Award.