



Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
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Time/Location:	10am – 12pm/Carnegie 315
Title:	Exploring Mechanical Properties of Soft Tissues using Microindentation
Chairperson:	Prof. Johannes Weickenmeier, Department of Mechanical Engineering
Committee Members:	Prof. Robert Chang, Department of Mechanical Engineering Prof. Yong Shi, Department of Mechanical Engineering Prof. George McConnell, Department of Biomedical Engineering Prof. Rafael Grytz, Department of Ophthalmology and Visual Sciences, University of Alabama at Birmingham

ABSTRACT

Maturation, aging, and disease of soft tissues are characterized by an intricate coupling between microanatomical changes and evolving mechanical properties. Despite extensive research on the mechanical properties of soft tissues and efforts to relate microstructural changes with mechanical behavior, many challenges persist. Among these, the lack of standardized protocols leads to significant variations in reported stiffness values. Indentation testing is a common method for evaluating soft tissues, offering localized mechanical data, and utilizing well-established contact models for stiffness derivation. Yet, many experimental design factors vary between studies despite their significant impact on a realistic evaluation of the tissue's mechanical behavior.

The primary goal of this thesis is to establish reliable protocols for mechanical characterization of two special tissues: the mouse brain and tree shrew sclera. I addressed four specific objectives. The first objective aimed at investigating critical indentation testing parameters to establish a robust testing framework. The second sought to create region-specific and spatially-varying stiffness maps of mouse cortex, corpus callosum, and hippocampus. The third objective aimed at exploring the local relationship between myelin content and mechanical properties in the mouse corpus callosum, cingulum, and cortex. The fourth objective aimed at establishing the relationship between myopia and mechanical properties via the inverse finite element method.

Our work has led to the development of a robust microindentation testing protocol. For the mouse brain, we observed region-specific and heterogeneous stiffness distributions. Notably, the corpus callosum was found to be up to four times softer than gray matter, with the middle region being around 2.5 times softer than the lateral region in corpus callosum. High spatial resolution stiffness maps in the hippocampus correlated well with histochemical-stained anatomical subregions. Additionally, in a cuprizone-induced 15-week demyelination mouse model, we observed region-specific stiffness changes in the corpus callosum, cingulum, and cortex. In the sclera, stiffness increased from the posterior pole's center to the lateral regions and changed with the onset of myopia. Our work laid the foundation for future studies into the relationship between diseases and their impact on the mechanical properties of soft tissues.