Measuring **In-vivo** and **In-situ Ex-vivo** the 3D Deformation of the Lamina Cribrosa Microstructure under Elevated Intraocular Pressure

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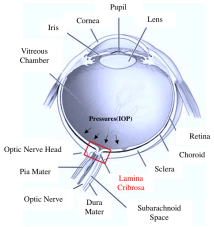
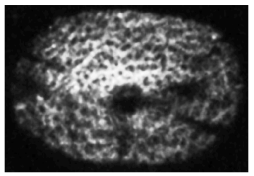
Introduction

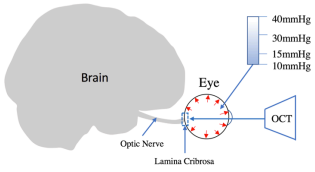


Human Eye

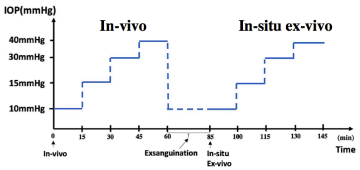

Lamina Cribrosa

Introduction → Motivation → Objective → Challenges

Experimental Setup

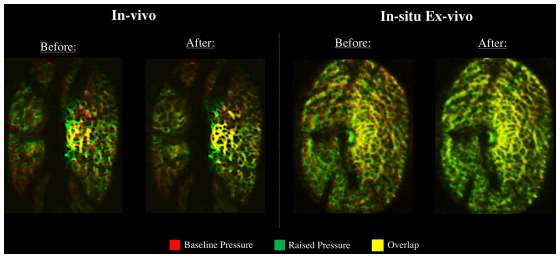


The brain and eye configuration for In-vivo and In-situ ex-vivo OCT scans



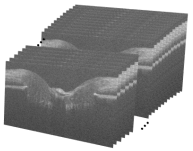
IOP was raised stepwise from 10mmHg to 40mmHg with each pressure step lasting about 15 minutes

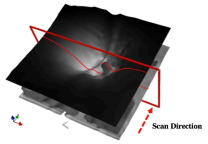
Deformation Validations



Motivation

- Previously, ex-vivo LC deformation studies
- OCT, In-vivo imaging
- Differences between measurements


OCT



3D OCT Reconstruction

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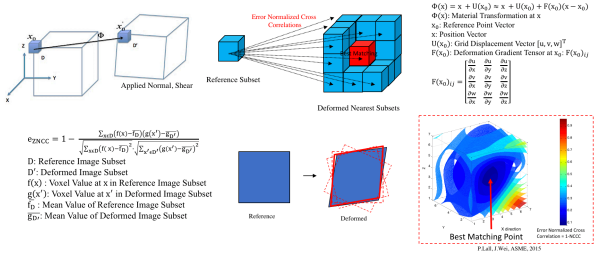
Digital Volume Correlation



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Objective

- To present a new in-vivo method
- To measure deformations
- To compare in-vivo and in-situ ex-vivo deformations

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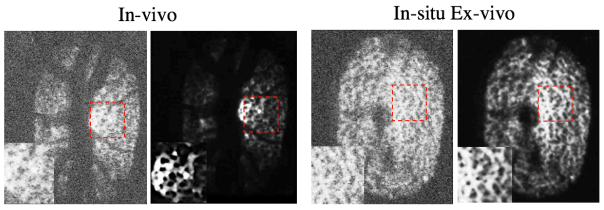
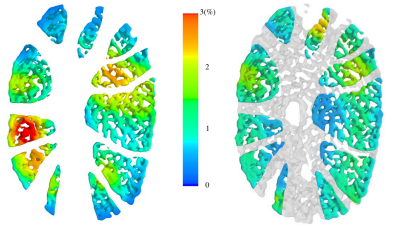
OCT 3D Image Processing



LC Shear Strain



In-vivo 10-15mmHg

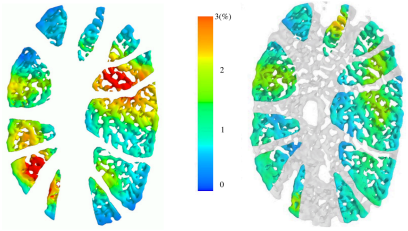
In-situ Ex-vivo 10-15mmHg

$E = \frac{1}{2}(F^T F - I)$

E: Lagrangian Strain Tensor
F: Deformation Gradient Tensor
I: Identity Tensor

$E_{max\ shear} = \frac{|P_1 - P_3|}{2}$
P_1: First Principal Strain
P_3: Third Principal Strain

LC Effective Strain



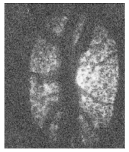
In-vivo 10-15mmHg

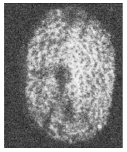
In-situ Ex-vivo 10-15mmHg

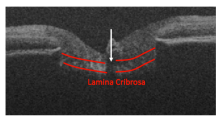
$E_{effective} = \sqrt{\frac{2}{3}\varepsilon'_{ij}\varepsilon'_{ij}}$
$\varepsilon'_{ij} = \varepsilon_{ij} - \overline{\varepsilon_{ij}}$: Deviatoric Strain
$\overline{\varepsilon_{ij}} = \frac{1}{3}\delta_{ij}\varepsilon_{kk}$: Hydrostatic Strain

Challenges in OCT

- Noise
- Lamina visibility reduced by blood vessel "shadows"
- Eye movements introduce rigid-body motions


In-vivo OCT


In-situ Ex-vivo OCT



An OCT Scan shows the cross-section of the Optic Nerve Head

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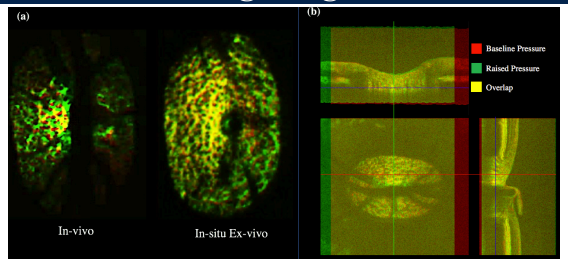
3D Image Alignment



Summary and Conclusions

- We developed a novel 3D OCT experimental and analysis technique to measure 3D LC deformations.
- The LC deforms when IOP is raised, and in-vivo deformation of the LC was larger than the in-situ ex-vivo deformation between 10 and 15mmHg.
- For studying the LC deformation contribute to glaucoma and vision loss, the ability to measure the in-vivo deformation of the LC is important.
- In-vivo measurements of LC deformation could be used as a tool for the early detection, diagnosis, and tracking of glaucoma.