Optic Nerve Head Biomechanical Strain as a Potential Biomarker for Progression in High and Pathologic Myopia

Donny Q.V. Hoang, M.D., Ph.D

Financial Disclosure: None relevant to this project

Johnson & Johnson (grant support)

Overview

- Purpose: To determine if biomechanical changes in the optic nerve head (ONH) can serve as a biomarker for progression in high myopia (HM).
- Methods: 53 eyes of 53 subjects: 11 low myopia (LM), 17 HM and 25 pathologic myopia (PM), underwent macular and ONH SD-OCT scans in: (0) primary gaze, (1) with acute IOP elevation (to ~40 mmHg) through ophthalmodynamometry. (2) 20^{o} adduction, (3) 20^{o} abduction, and (4) supine.
  - Scans were segmented for prelaminar tissue (PLT) and lamina cribrosa (LC) using deep learning and digitally-aligned before performing digital volume correlation (DVC) analysis to quantify IOP- and gaze-induced PLT and LC displacements and calculate the effective strain.
- Conclusion: HM eyes tend to be more sensitive to IOP elevation as compared to LM eyes. PM eyes experienced abnormally high strains and they were equally influenced by IOP elevation and adduction.
- ONH strain differs significantly between LM, HM and PM eyes and has the potential to serve as a biomarker for progression.

Background

- A link between myopia and glaucoma has long been reported, with HM eyes shown to have increased susceptibility to glaucoma, and glaucomatous characteristics present in myopic optic discs. *(Nagaoka et al. PLoS One. 2015)*

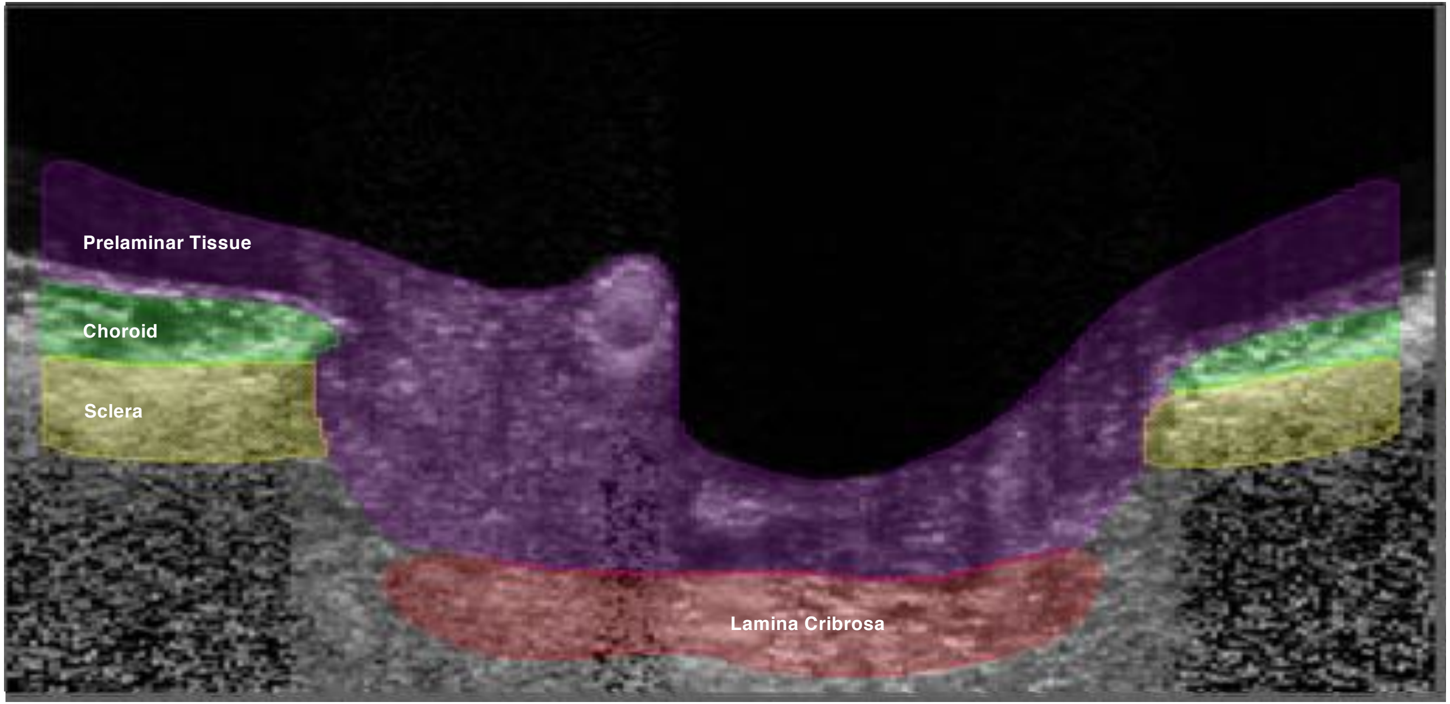
- Although many studies have explored palliative therapies for the vision-threatening changes in high myopia and glaucoma, only a fundamental understanding of the biomechanical alterations in scleral tissue underlying these changes will allow for preventive therapies.

- We therefore use ophthalmodynamometry, deep learning and digital volume correlation analysis to quantify effective strain in the posterior layers of LM, HM and PM eyes.

Overview

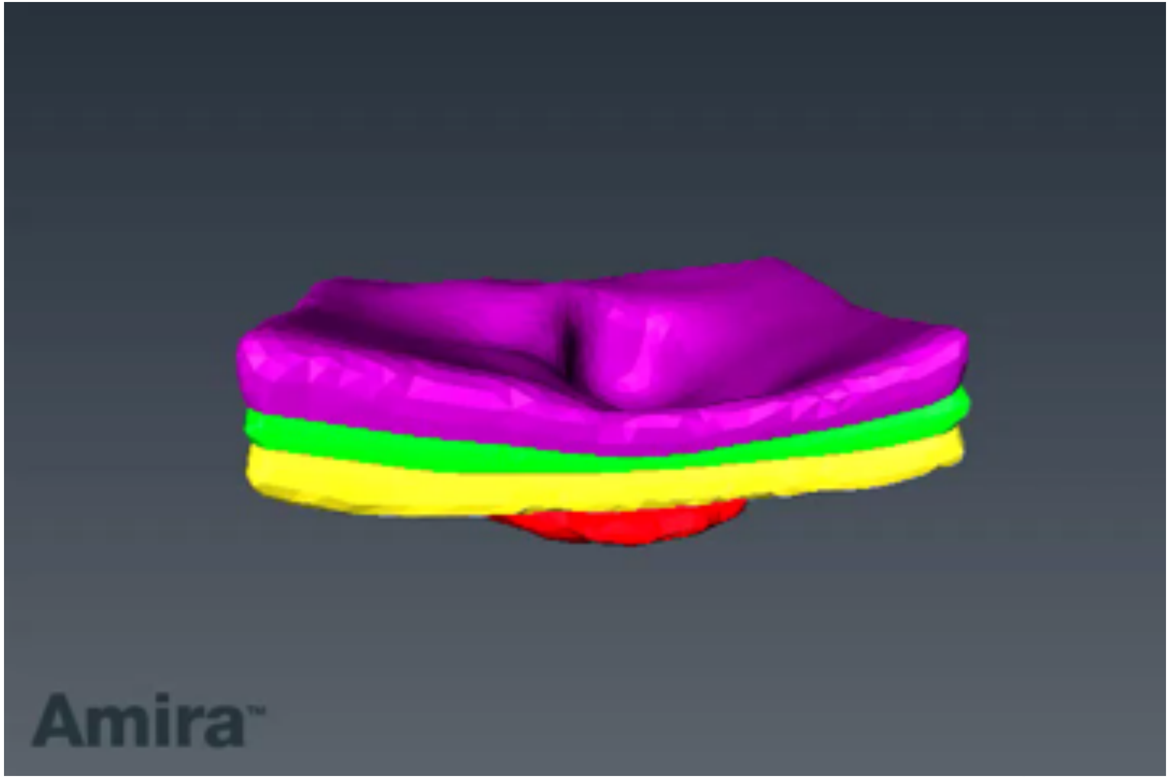
- 3 Conditions – Low Myopia (11), High myopia (17), Pathologic myopia (25)
- 4 Loads – Acute IOP elevation, 20^{o} Adduction, 20^{o} Abduction, Supine (CSFP elevation)
- 4 Tissues analyzed – Prelamina, Choroid, Sclera, Lamina
- Outputs – Effective strain, displacement magnitude, posterior displacement magnitude with respect to BMO
  - Each volume has approximately 3000 tracking points, each point has the corresponding output parameters mentioned above.

AI-based Segmentation to identify ONH Tissue on OCT

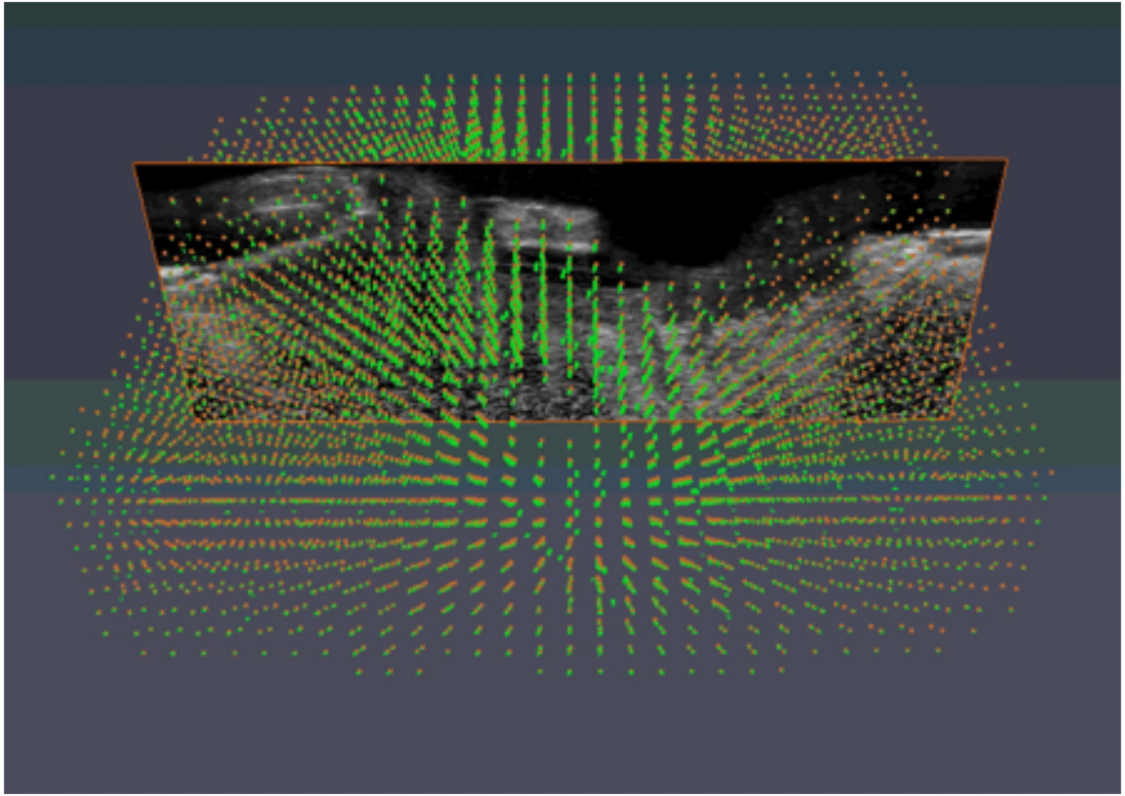


Baseline (Normal Gaze) Scan

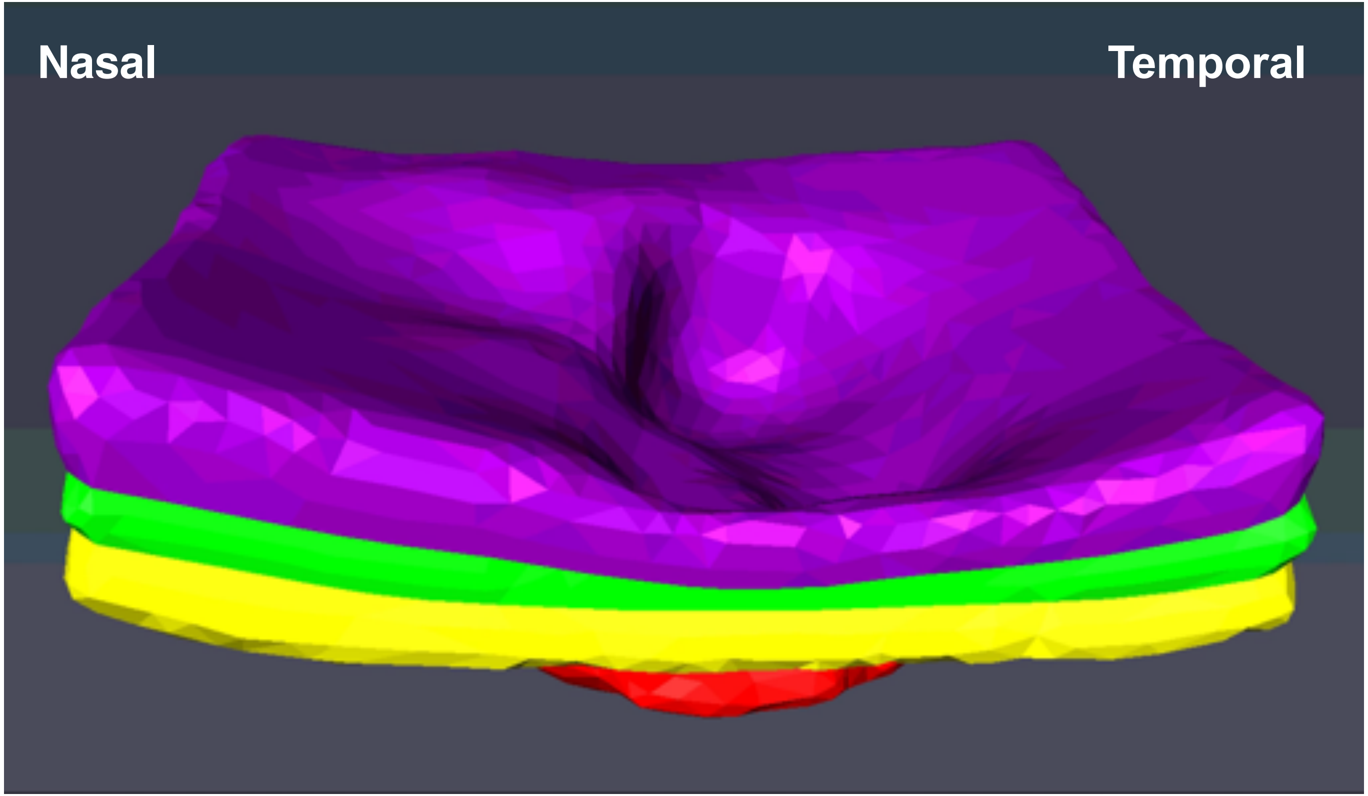
Example of a Fully-Segmented Volume



Displacement Vectors in Response to IOP elevation

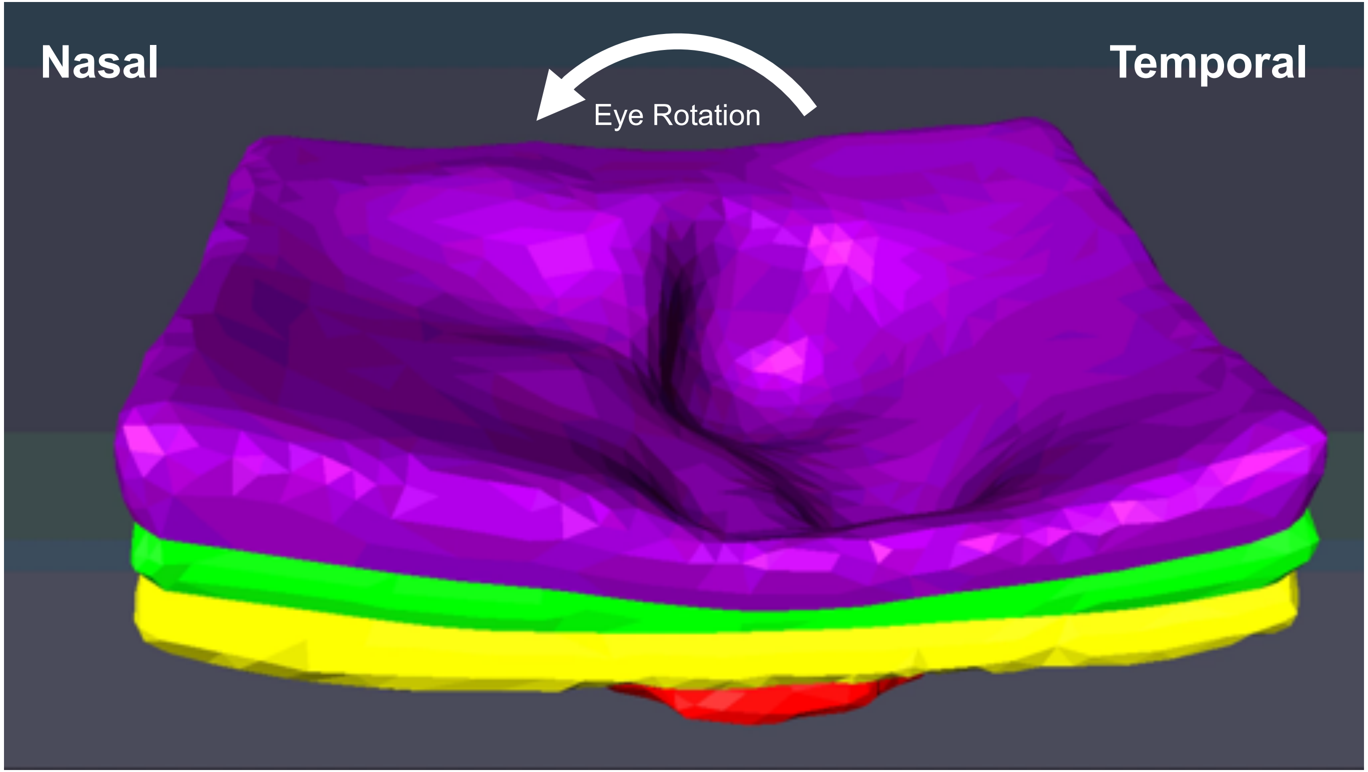


Deformation Tracking for Eye undergoing IOP elevation



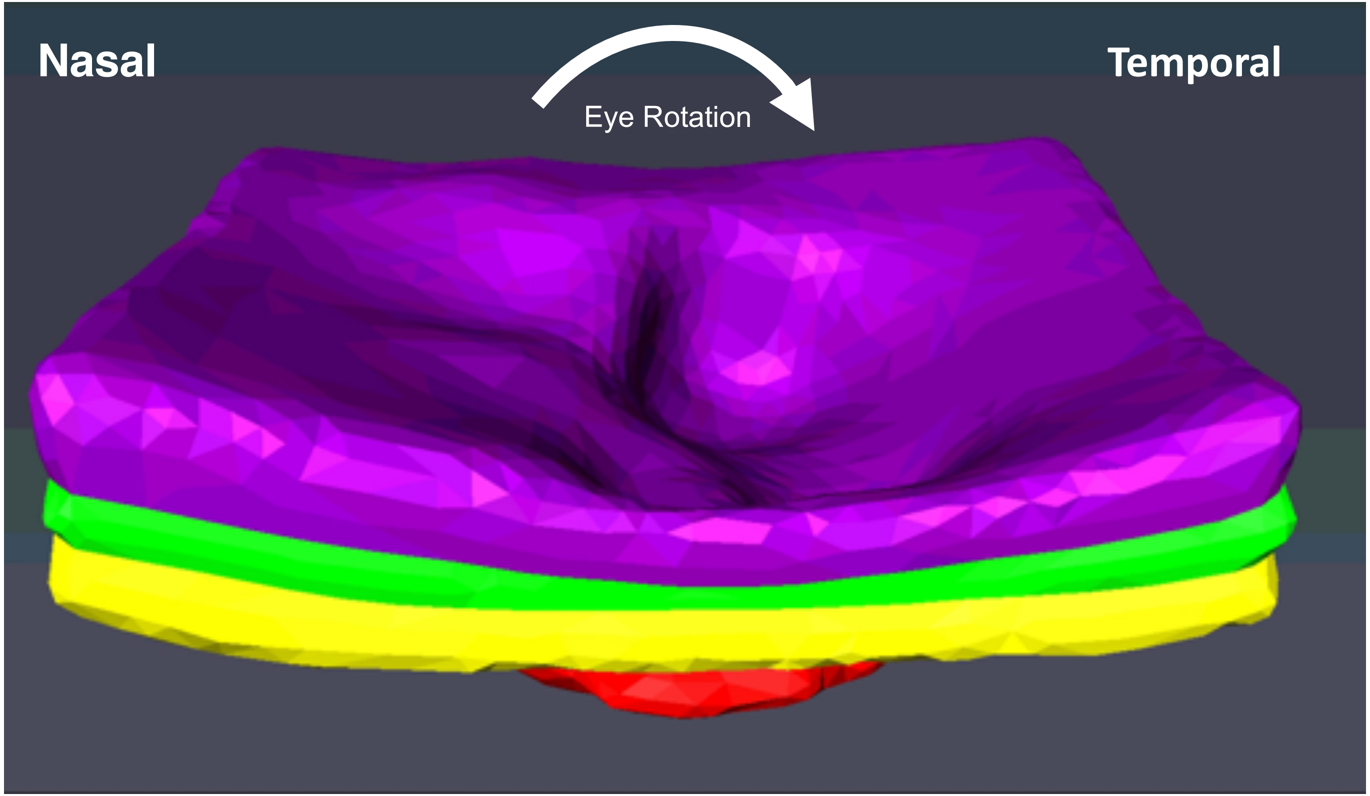
*displacement exaggerated by 5 times

Deformation Tracking during ADduction



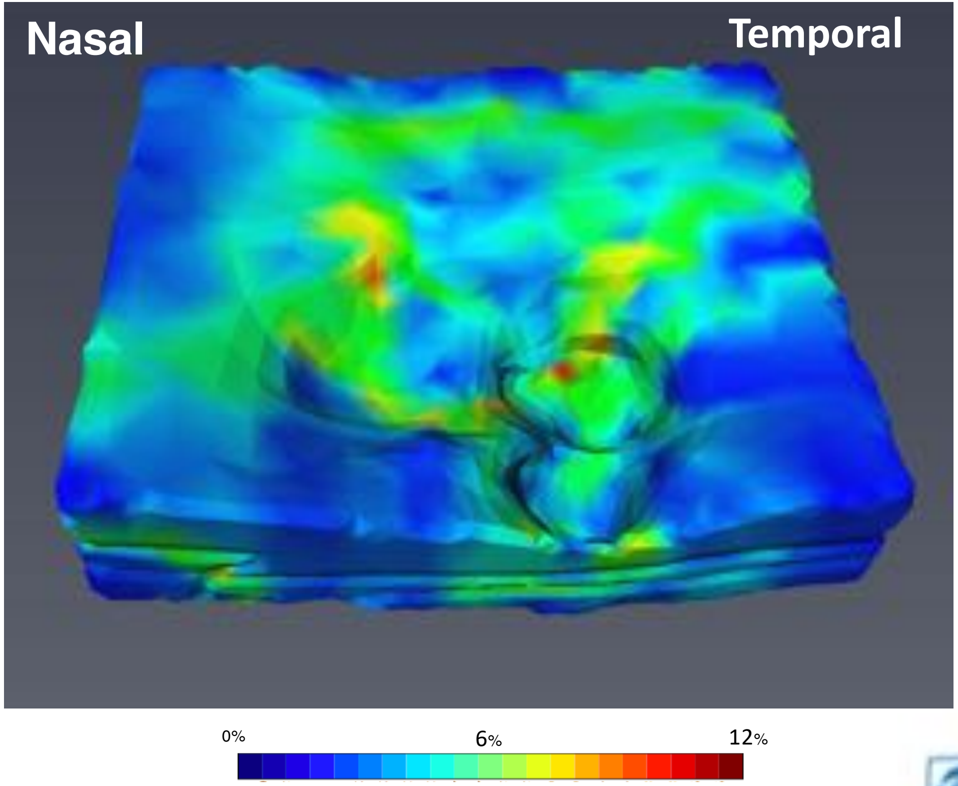
*displacement exaggerated by 5 times

Deformation Tracking during ABduction



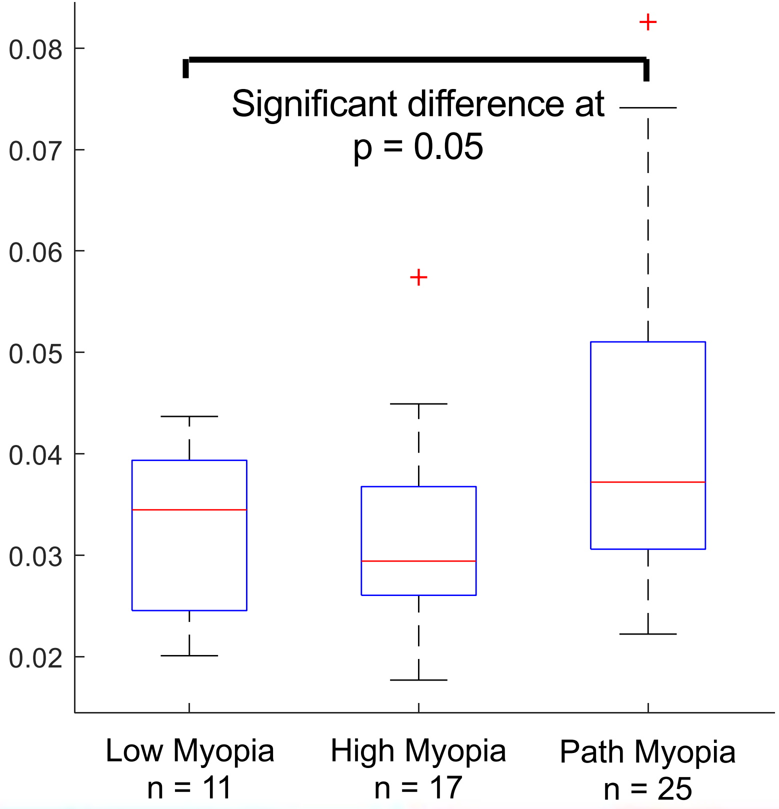
*displacement exaggerated by 5 times

Strain Visualization – IOP Elevation



Singapore National Eye Centre
SingHealth
SINGAPORE EYE RESEARCH INSTITUTE

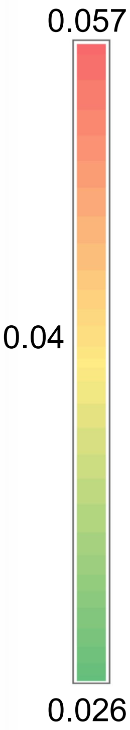
PM eyes have higher effective strain than LM

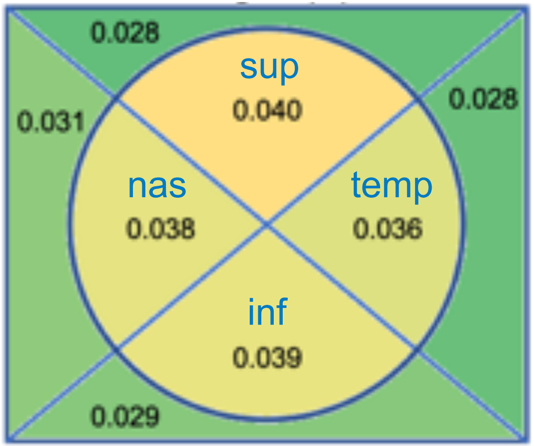


	Low Myopia	High Myopia	Pathologic Myopia
average effective strain	0.0320	0.0322	0.0427

Singapore National Eye Centre SingHealth
SINGAPORE EYE RESEARCH INSTITUTE

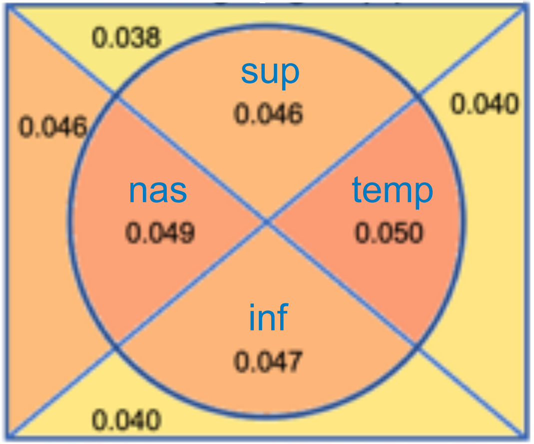
Average effective strain (by myopia level and region)

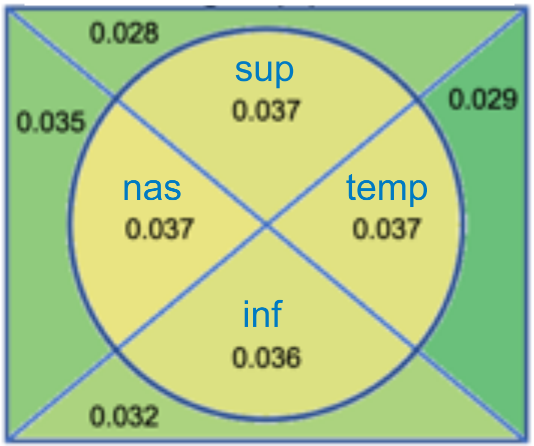




Low myopia

Pathologic myopia



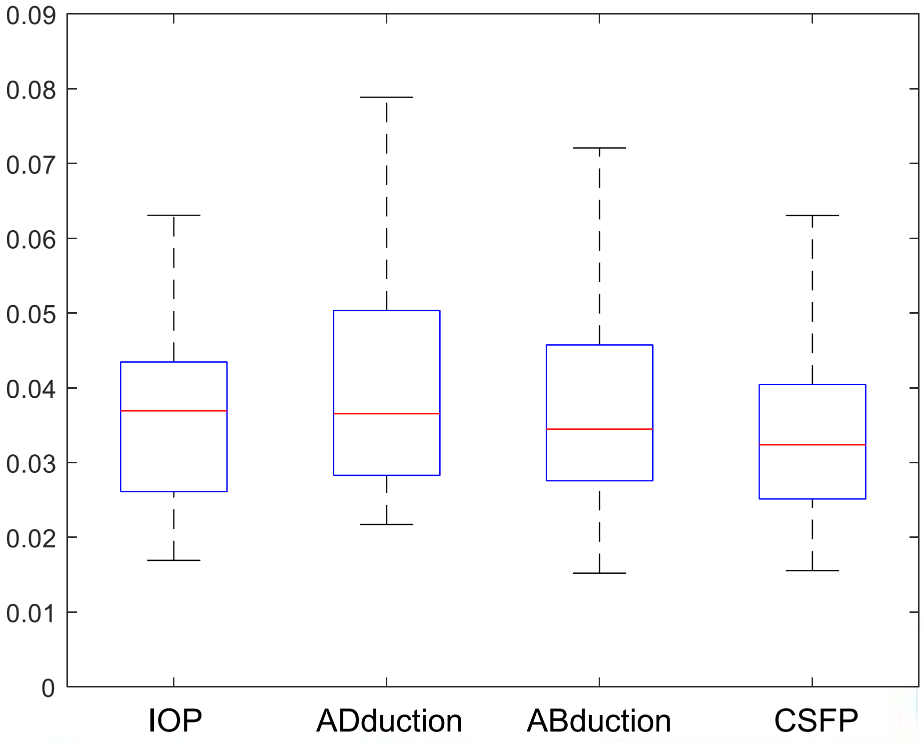


High myopia

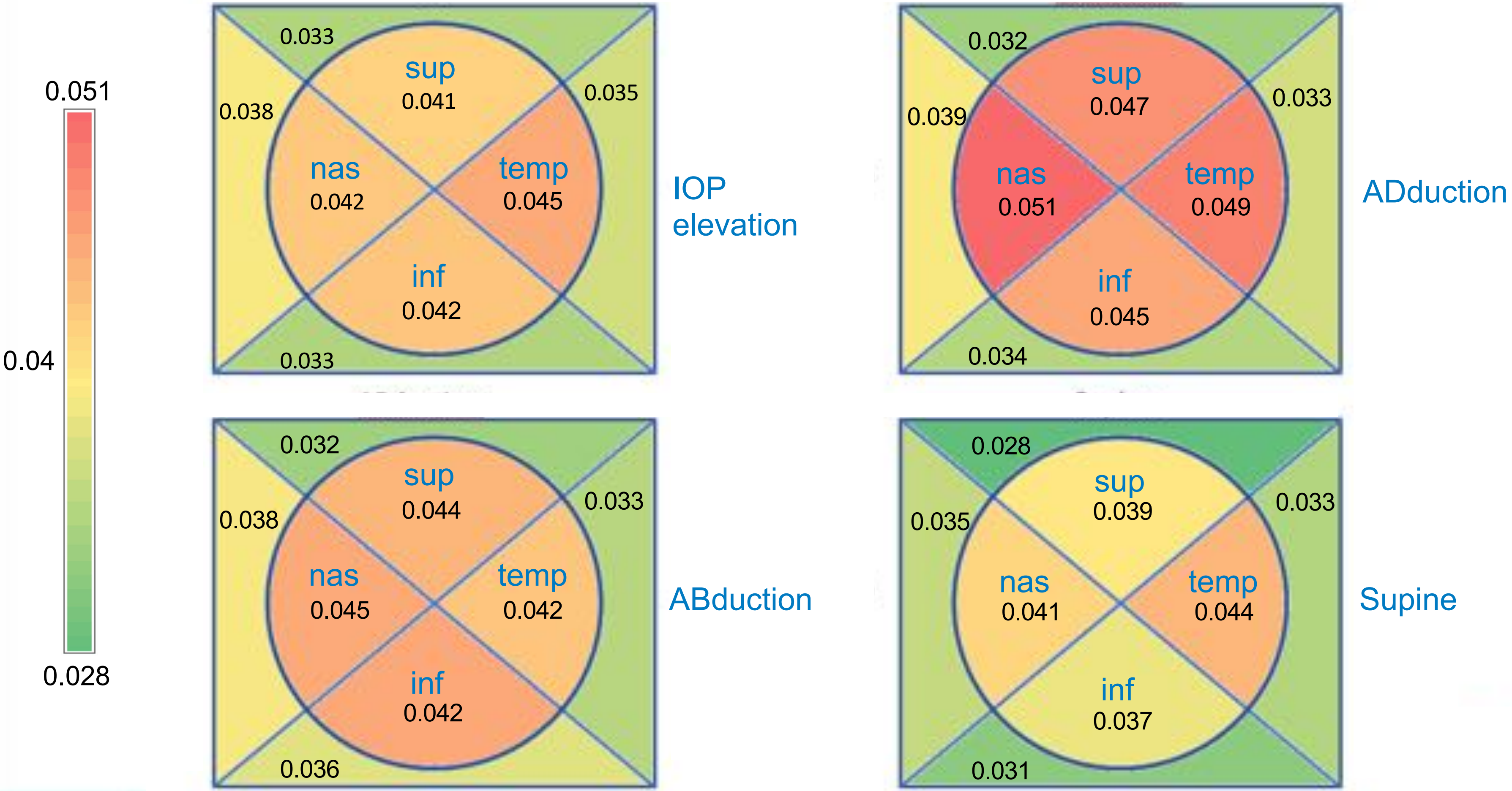
Central region = best-fit circle to Bruchs membrane opening

Adduction results in the highest strain

	IOP	Adduction	Abduction	Supine
average effective strain	0.0381	0.0400	0.0392	0.0373

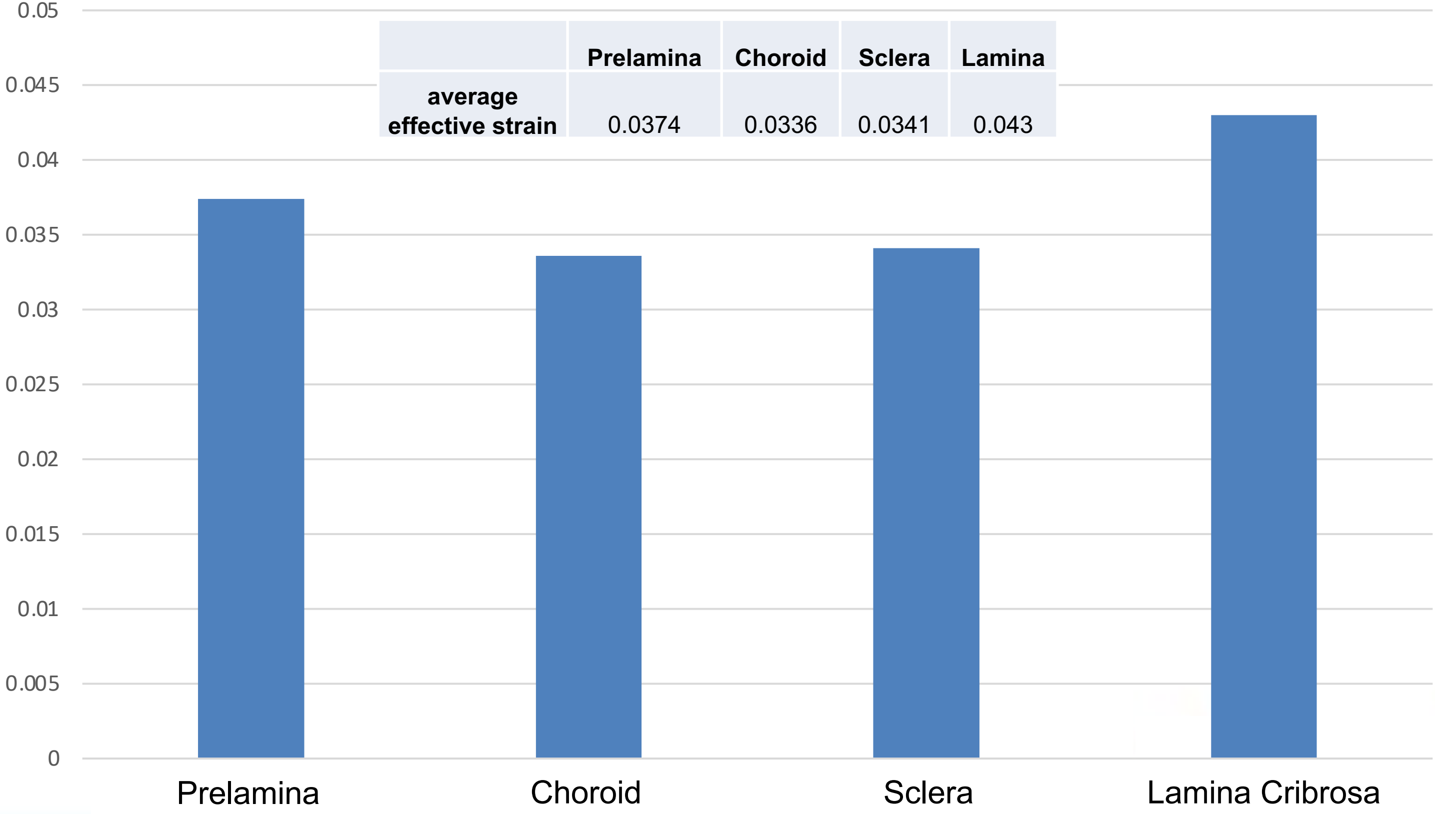


Average effective strain (by load and region)

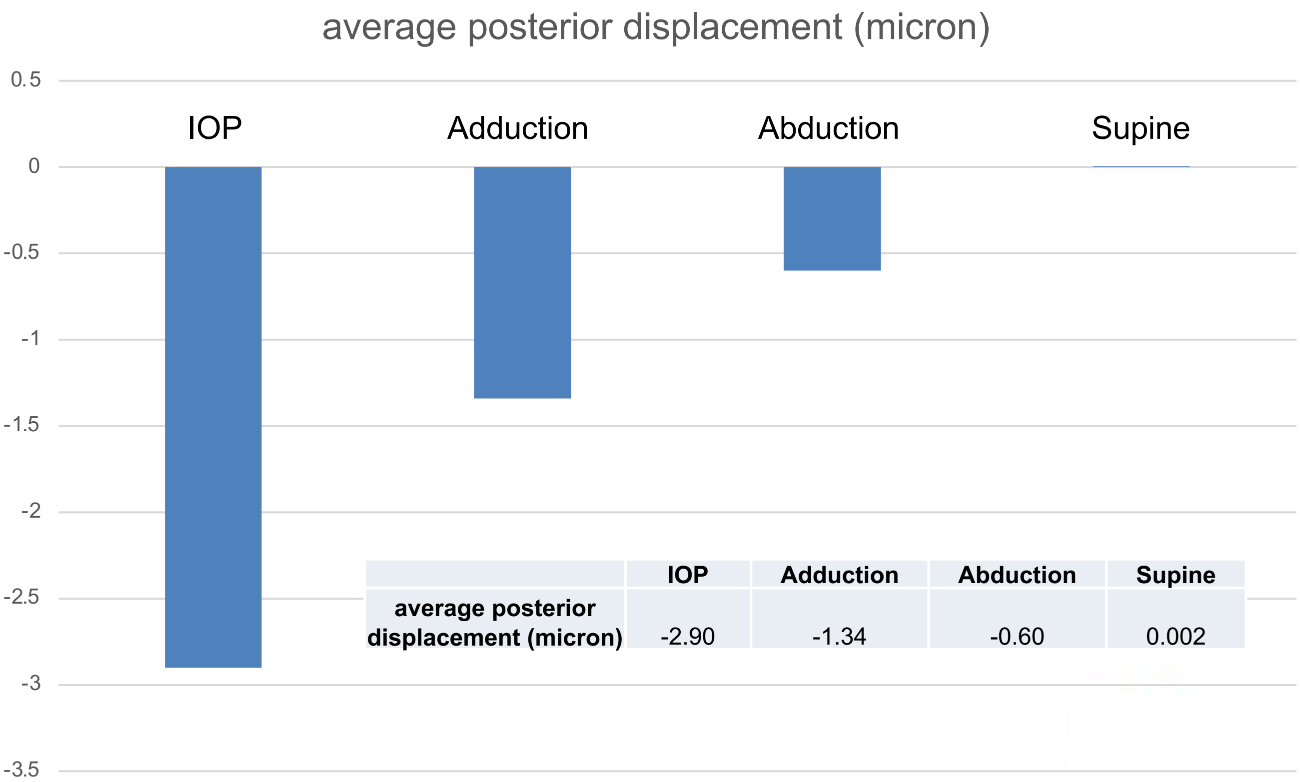


Lamina Cribrosa Experiences the Highest Effective Strain

	Prelamina	Choroid	Sclera	Lamina
average effective strain	0.0374	0.0336	0.0341	0.043



IOP Elevation Results in the Largest Posterior Displacement



	IOP	Adduction	Abduction	Supine
average posterior displacement (micron)	-2.90	-1.34	-0.60	0.002

Summary

- PM eyes experience significantly ($p < 0.05$) higher strains than LM and HM eyes
- Central regions of the ONH experience significantly higher strain than peripheral
- Nasal regions experience significantly higher strain than other regions
  - This is especially true under Adduction
- Adduction exerts highest strain on the tissue
- LC tissue tends to experience highest strain as compared to other tissue
- IOP elevation causes the ONH tissue to displace posteriorly – this is a distinct feature as compared to other type of loads
- ONH strain differs significantly between LM, HM and PM eyes and has the potential to serve as a biomarker for progression.

Acknowledgements

- Thanadet Chuangsuwanich, D. Jason Yu, Tin A. Tun, Chee Wai Wong, Xiaofei Wang, Chin Zhi Yun, Sripad Krishna Devalla, Dan Milea, Tin Aung, Michael J.A. Girard and Retina Department, Singapore National Eye Centre

- Funding Support from:
  - National Medical Research Council Clinician Scientist Award (grant CSA-INVMay0011), Singapore
  - National Eye Institute K08 Grant (K08 EY023595)
  - Singapore Ministry of Education, Academic Research Funds Tier 2 (grants R-397-000-280-112 & R-397-000-308-112)

donny.hoang@snec.com.sg