Inverse Finite Element Modelling of Posterior Human Sclera

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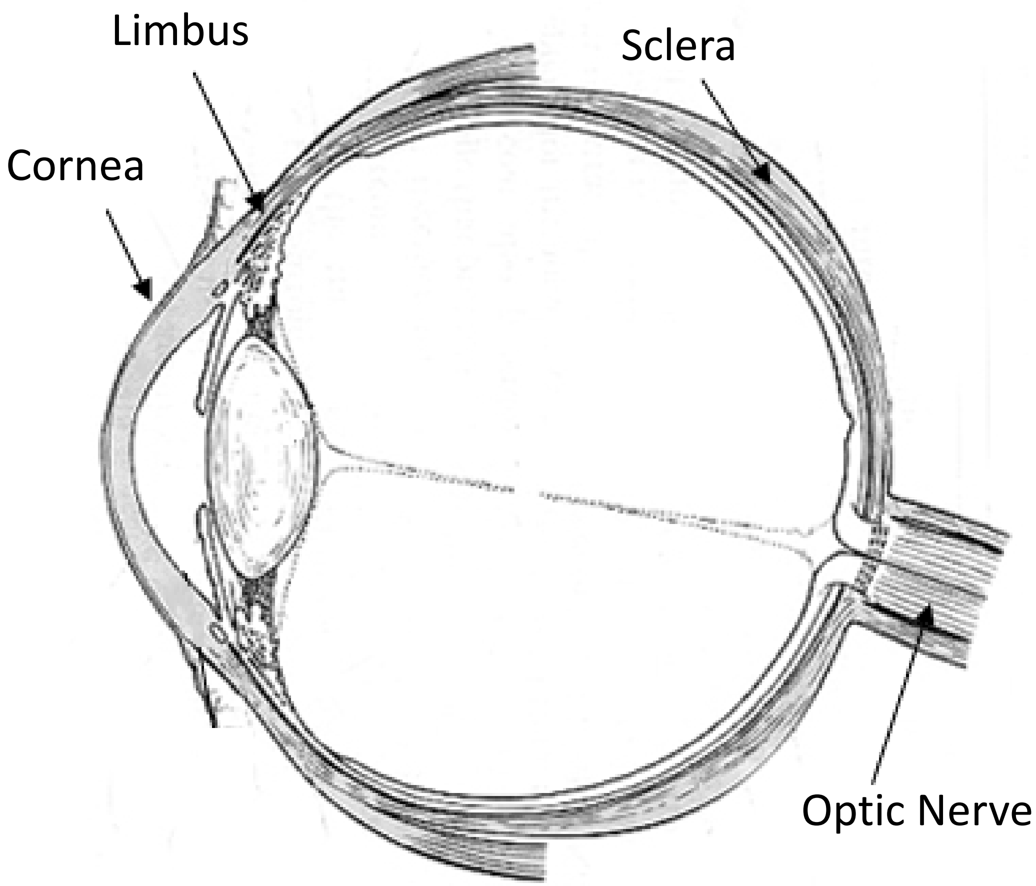
The Human Eye



Motivational Background

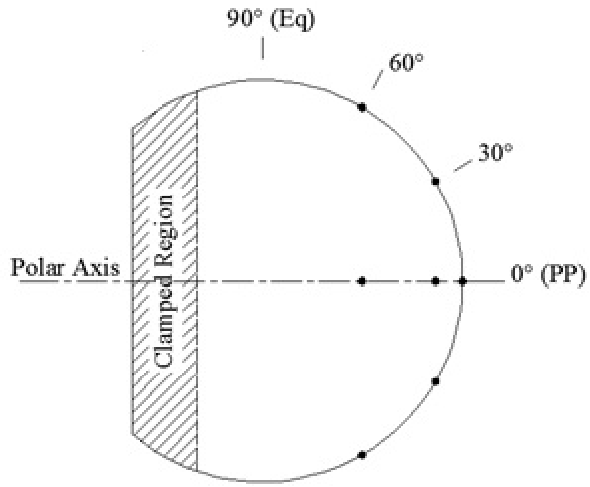
- Laser surgery – 1 in 7 patients require follow up treatment (Hjortdal et al., 2005)
- Glaucoma – the silent thief of sight
- FE modelling tends to exclude sclera or use uniform stiffness and thickness
- Scleral mechanics can have a significant effect on optic nerve head (Sigal and Ethier, 2009)

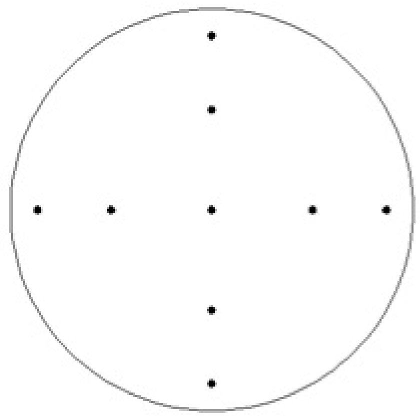
Research Problem

- Determine material parameters capable of predicting sclera mechanical response to increasing intraocular pressure
- Material test method similar to in vivo conditions
- How to extract material parameters from RAW data

Methodology

- Sclera Inflation
- Non-contact monitoring:
  - Laser displacement sensor
  - Two digital cameras
  - Pressure transducer
- Particle Image Velocimetry
- Inverse Finite Element



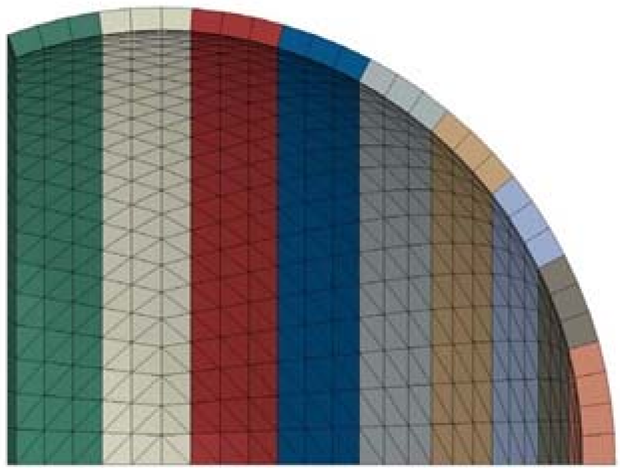


Numerical Model

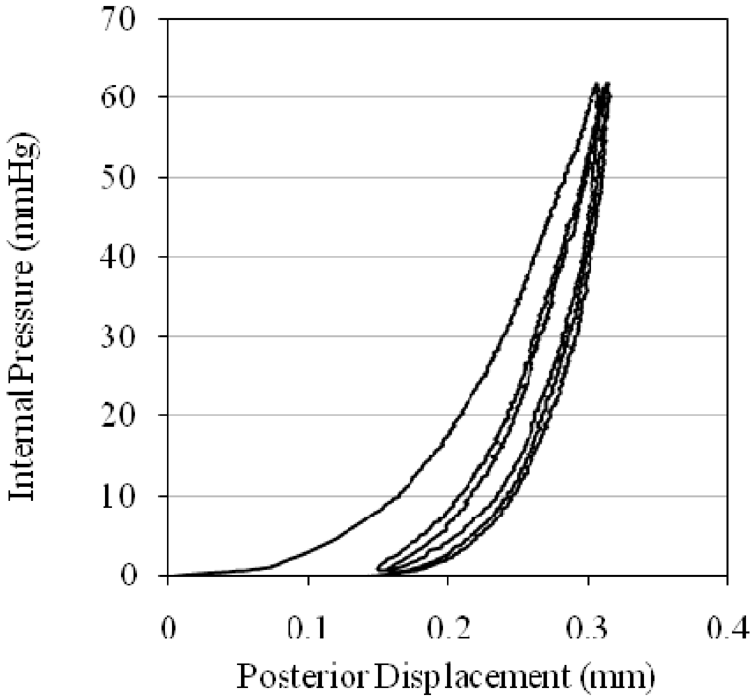
- Ogden hyperelastic material model

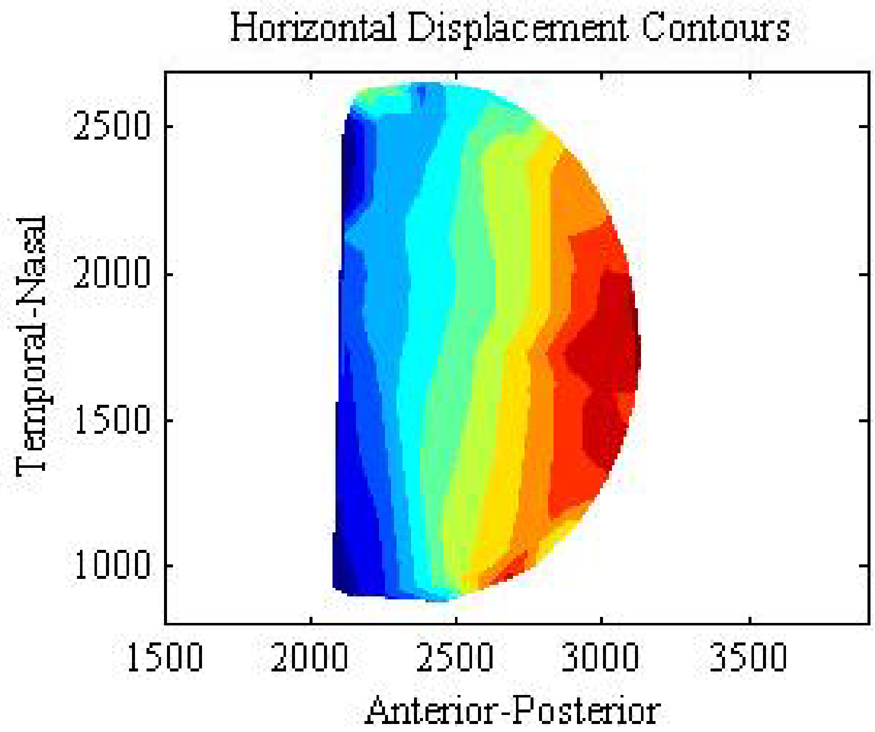
$$W = \sum_{i}^{N=1} \frac{2\mu_i}{\alpha_i^2} \left(\bar{\lambda}_x^{\alpha_i} + \bar{\lambda}_y^{\alpha_i} + \bar{\lambda}_z^{\alpha_i} - 3 \right) + \sum_{i}^{N=1} \frac{1}{D_i} (J-1)^2$$

- FE model divided into 9 ring groups
- Each group has a unique set of material parameters
- Parameters optimised to fit



Experimental Results



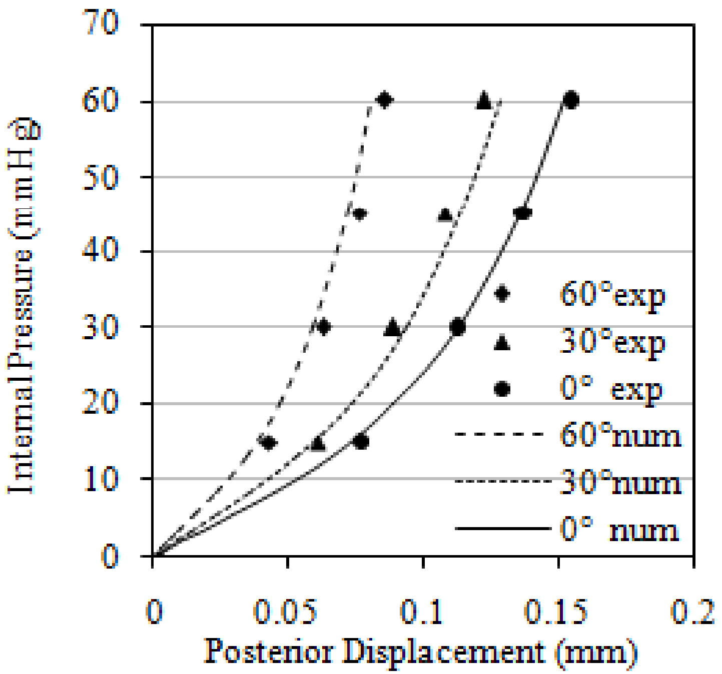


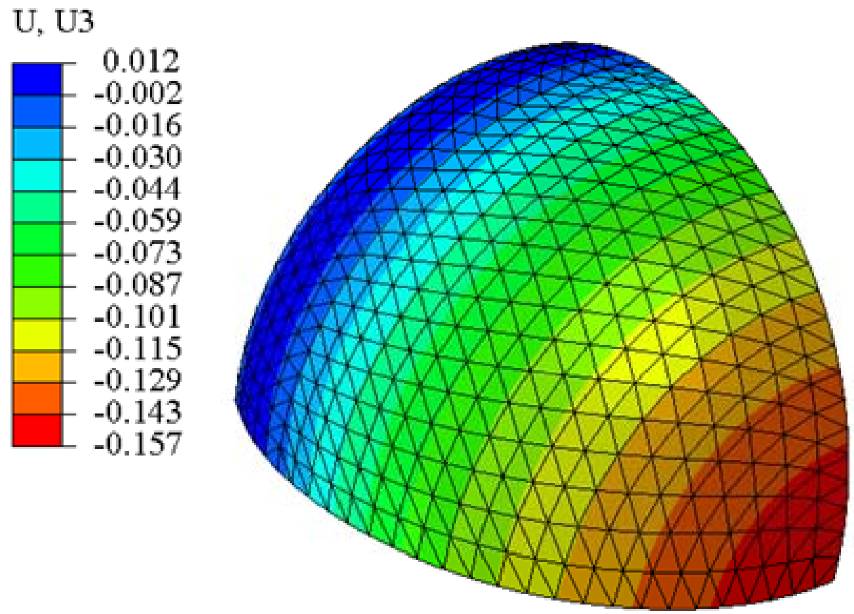
Experimental Results

- Comparison of displacements in both planes showed similar behaviour

Position from PP	Transverse Plane	Standard Deviation	Saggital Plane	Standard Deviation
0°	100%		100%	
30°	81%	7.74%	84%	8.05%
60°	59%	9.39%	62%	9.78%

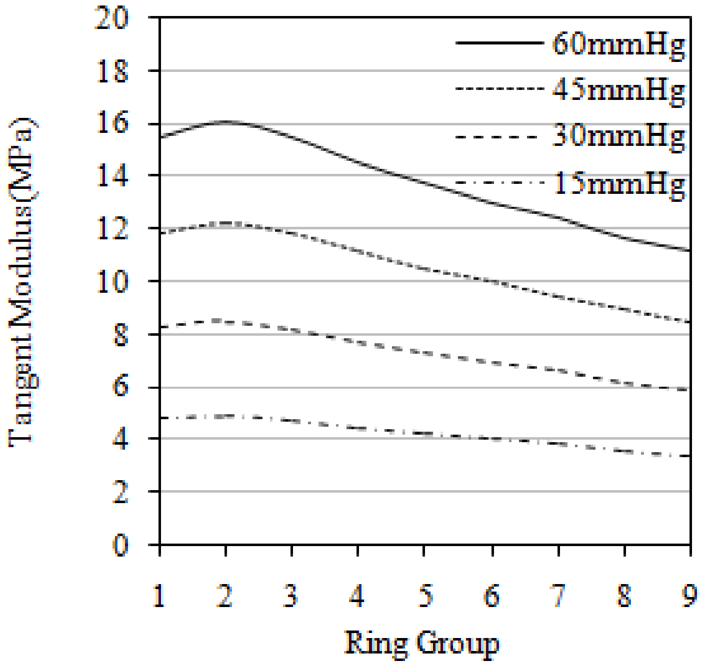
Numerical Results

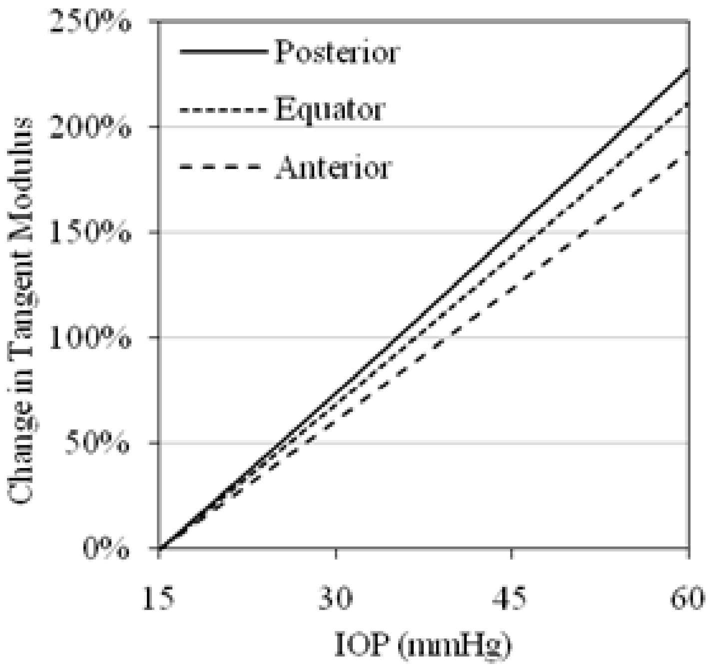




60 mmHg

Numerical Results





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Conclusions

- On average, sclera behaves similarly in the transverse and sagittal planes, but variation is evident
- Inverse relationship between stiffness and thickness
- Highest percentage increase in stiffness in the posterior region with increasing pressure