1. Yeoh Hyperelastic Material

The Yeoh model was developed in 1993,¹ which is a hyperelastic material model that only depends on the first strain invariant. Its strain energy density function is

\[ W = \sum_{i=1}^{n} C_i (I_1 - 3)^i \]

where \( I_1 \) is the strain invariant and \( C_i \) are the hyperelastic constants that have the units of force per unit area. BM was assumed to be incompressible. The hyperelastic constants \( C_i \) can be derived from the uniaxial tensile test data.

2. Convergence Study

2.1 Mesh Density Study

We performed a mesh convergence study to find the appropriate mesh density for the FE model. Three models with 13,670 (coarse model), 35,312 (medium model) and 158,300 (fine model) elements were constructed (Figure S1A). The element size in the transmural direction for the sclera, choroid, LC and retina was varied. However, we used only one element for BM through its thickness in all 3 models in order to achieve a reasonable aspect ratio for these thin elements.

The mean effective strains in the LC and prelamina (preLC) in these three models are shown in Figure S1B. The differences of the output measurements
between the coarsest and finest model were within 5% (Figure S1B). Therefore, the model with a medium mesh density could be considered as converged. However, as the computational cost of the finest model was still reasonable (~20 minutes on a 18 cores server and ~7 Gb of memory), we decided to use the finest model.

![3 finite element models with varied mesh densities (coarse, medium, and fine).](image)

![LC and preLC strains as functions of the number of finite elements.](image)

**Figure S1.** (A) 3 finite element models with varied mesh densities (coarse, medium, and fine). (B) LC and preLC strains as functions of the number of finite elements.

We also constructed another model in which we optimized the geometry and element shapes around the point of BM opening (Figure S2). This study was performed to understand whether the stress concentration near the point of BM opening was due to badly shaped or sharp elements near the point of BM opening. Simulation results demonstrated that the high stress region near BM opening was not caused by imperfect element quality.
**Figure S2. Upper row:** illustrations of two models with different element shape near the point of Bruch’s membrane opening. Note that the poor-quality wedge elements that have a very small minimum interior angle have been modified to increase their quality. **Lower row:** strain distributions in these two models.

### 2.2 Mesh Type Study

Note that we modelled BM with a one-element layer to avoid extremely low quality elements. As the dimension of BM along the thickness direction is much smaller than along the other two perpendicular directions, increasing the number of elements along the thickness direction could reduce the element quality dramatically. A simple alternative is to use hyperelastic shell elements. Such elements have 4 or 8 nodes to represent a surface but they can be described with a specified thickness value. To this end, we constructed a new model in which BM was simulated with 4-noded hyperelastic shell elements (**Figure S3**). Using such an approach, mean LC
and prelamina effective strains were 0.0415 and 0.0622 in the baseline model (as opposed to 0.0414 and 0.063 when BM was modelled with hexahedral elements). Since the difference was less than 1.2%, we believe that using a one-element layer approach (with hexahedrons) is acceptable to model BM.

**Figure S3.** Finite element mesh of a model using shell elements for BM. Here, BM is represented by a surface between the choroid and the retina and can only be seen as a line between those 2 tissues. However, a thickness value can still be specified for BM (here: 5 microns).

### 3. Varying BM Stiffness

In this study, we quantified the stiffness of BMCC, but not that of BM as BM could not be fully isolated. From our data, the elastic modulus of BM can be roughly estimated using a rule of mixture as:

$$E_{bm} = \frac{T}{T_{bm}} E_{bmcc} - \frac{T_c}{T_{bm}} E_c$$

where $E_{bm}$, $E_{bmcc}$ and $E_c$ are the elastic modulus of Bruch’s membrane, BMCC and of the choroid, respectively. $T_{bm}$, $T$, and $T_c$ are the thicknesses of Bruch’s membrane, BMCC, and of the choroid, respectively.

Assuming that the elastic modulus of the choroid is 0.6 MPa,\(^2\) that BM thickness in humans can vary between 1 and 10 microns,\(^3,4\) and that the full thickness of our BMCC samples was 21 microns (as measured from 10 samples
using OCT in this study), then using the above equation, one can estimate the elastic modulus of BM between 2.7 and 21.6 MPa (or 1.7 to 13.5 times the elastic modulus of BMCC measured in this study). Note that this is only a simple estimate based on the tangent modulus of BMCC obtained at 0% strain.

For our study, we varied the stiffness of BM within this range to investigate the effect of BM stiffness on ONH deformations using finite element modelling. For completeness, we also included a baseline case for which the stiffness of BM was the same as that of BMCC.

4. Biomechanical Properties of the Optic Nerve

We performed uniaxial tensile tests on 10 porcine optic nerves (ONs). Briefly, for each ON, the dura mater was gently dissected away using forceps. Each ON specimen was then mounted between the two grips of a uniaxial tensile tester (Instron-5848; Instron, Inc., Noorwood, MA, USA). The length (grip-to-grip distance) and diameter of each sample were then measured using a Vernier caliper (resolution: 0.01 mm). A preload of 0.01N was applied to the specimen and zero displacement was defined after this load. The obtained stress-stretch curves for all 10 samples are shown in Figure S5. Specimens were (mean ± SD) 14.60 ± 3.97 mm long and 3.80 ± 0.25 mm in diameter. Extracted Yeoh parameters were $c_1 = 0.08 \pm 0.196$ MPa and $c_2 = 0.482 \pm 0.727$ MPa (assuming a circular cross-section for all samples). The average tangent modulus of the ON at 10% strain was $1.18 \pm 2.03$ MPa, which is on the same order of magnitude as that obtained by Shin et al. using bovine tissues.\textsuperscript{5}
Figure S5. Uniaxial tensile test results for 10 porcine optic nerves. The averaged stress–stretch response was fitted to a second order Yeoh model as indicated black bold line. Nominal stress is defined as the measured force divided by the original circular cross-sectional area of the sample.

Figure S4 shows a large variation in the measured responses of optic nerves to uniaxial tensile loading. It is known that the stiffness of biological tissues varies significantly across individuals and over time. Large variations of scleral stiffness have been shown in previous studies using human specimen. In this experiment, pigs were all around 6 months old when sacrificed. The slaughterhouse performed ante-mortem inspections to screen out suspected diseased pigs that are not suitable for human consumption. However, we cannot exclude the possibility that some pigs had developed certain conditions that could affect the mechanical properties of their optic nerves.
Reference