EFFECTS OF SAMPLE GEOMETRY AND LOADING CONDITIONS ON THE STRAIN DISTRIBUTION WITHIN SCLERAL SAMPLES IN BIAXIAL TESTING

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Introduction

Biaxial testing is widely used to characterize soft tissue biomechanical properties [Sacks, 2003]. However, testing methods have not been standardized, and variations in methodology can affect the results [Sun, 2005 & Waldman, 2005]. Here we investigate how sample geometry and experimental boundary conditions affect strain fields in human scleral samples, whose properties are of interest in the study of glaucoma. The results can be used, for example, to determine suitable locations on the sample for optical strain measurements.

Methods

A series of 2D finite element models (ANSYS 11.0, ANSYS Inc., Canonsburg, PA) were used to numerically simulate biaxial tests on small (6 mm x 6 mm) tissue scleral samples using hook-like attachments (tines of 300 micron diameter) to mount the sample (Figure 1A). The following parameters were investigated: the number of tines used to load the specimen, tine spacing and configuration, and specimen geometry. In the absence of more detailed data, samples were assumed to be linearly elastic and essentially incompressible. The ratio of the first (E_{11}) to second (E_{22}) principal strain during a simulated uniform biaxial test was used as a measure of the uniformity of the strain field in the sample.

Results

The “uniform strain area” (defined here as the central region where $E_{11}/E_{22} < 1.10$), enlarged as the number of tines increased (3%, 18%, 29% and 34% of total sample area for 3, 4, 5 and 6 tines per side, respectively). This area was maximized when the corner tines (red circle on Figure 1-A) had a minimal separation distance. Separate simulations were performed where the middle left side tine was translated 10% of the tine-to-tine distance vertically and 10% horizontally; the position of the remaining

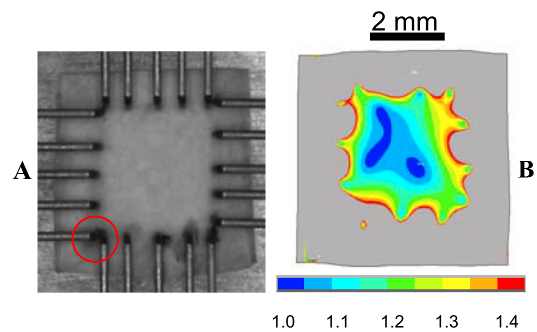

Figure 1: (A) A scleral sample mounted in the tissue tester device. (B) A contour plot of the ratio of principal strains, E_{11}/E_{22} for tine positions measured from panel A.

tines was unaltered. The uniform strain area was found to decrease 7% and 8% respectively. Furthermore, by changing the sample geometry to several non-square quadrilateral shapes, and maintaining a fixed tine configuration, the uniform strain area decreased by < 5%. Finally, in models constructed from images of real sclera (e.g. Figure 1), the central area where $E_{11}/E_{22} < 1.10$ was calculated to be $9.5 \pm 0.5\%$ of the sample area.

Discussion

Considering tine and specimen sizes and the dependence of uniform strain area on tine number, five tines per side was selected as the optimum. Tine configuration and spacing affected the strain field uniformity more than the sample geometry. Models incorporating the tine positions and geometry of real samples suggested that optical measurements of the strain should be restricted to the ~ 9.5% central sample area to ensure uniform biaxial strain.

References

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