3785 Measurement of Lens Stiffness Using a Spinning Lens Test

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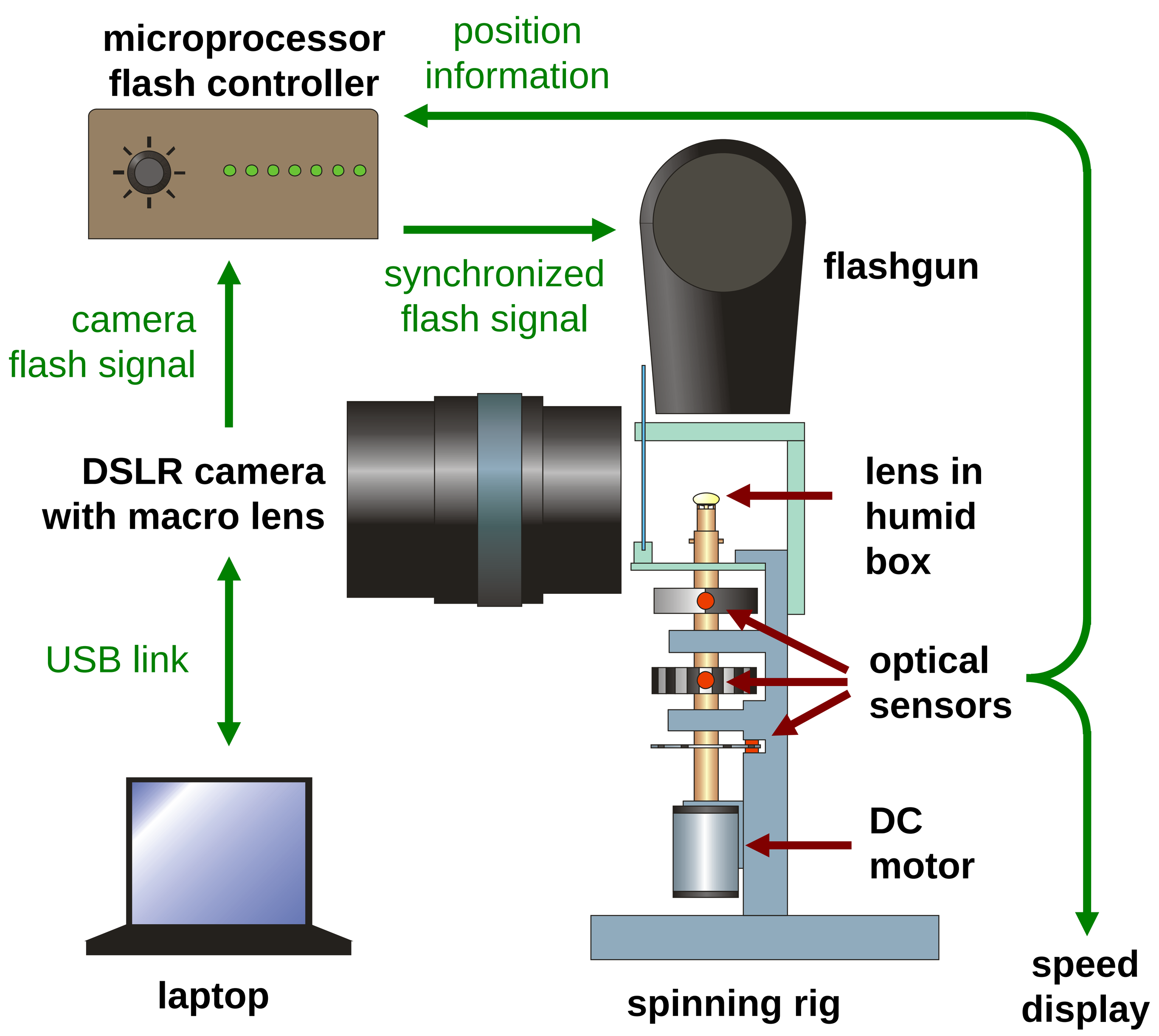
Purpose

To collect new data on the stiffness of the human lens using an improved form of the spinning lens test originally developed by Fisher (1971), and to investigate the causes of differences between Fisher's original stiffness calculations and the results of recent indentation tests (Heys *et al.* 2004; Weeber *et al.* 2007).

Methods

(a) Experimental

- Ten intact human lenses from the Bristol Eye Bank were tested in the rig illustrated below.
- Lenses were spun at 700, 1000 and in some cases 1400 rpm.
- Photographs were taken at eight angular orientations before, during and after each spin.
- For seven of these lenses, the capsule was carefully removed and the test was repeated.
- The lenses were not frozen and were tested within four days of death.



Acknowledgments

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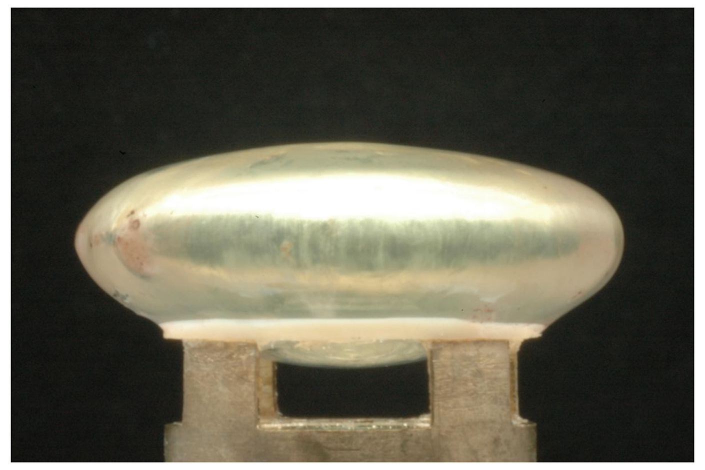
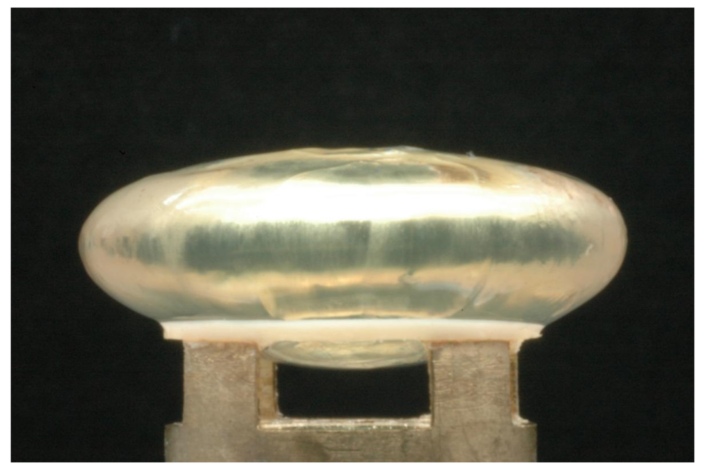
A 40-year lens spinning at 1000 rpm



intact capsule

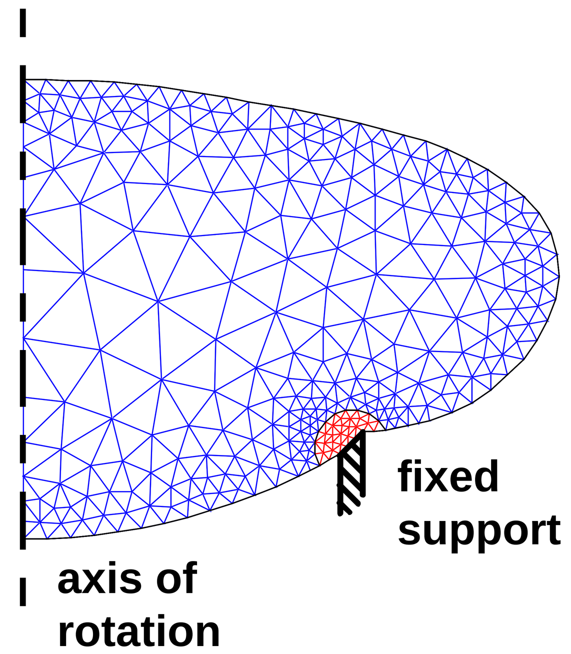


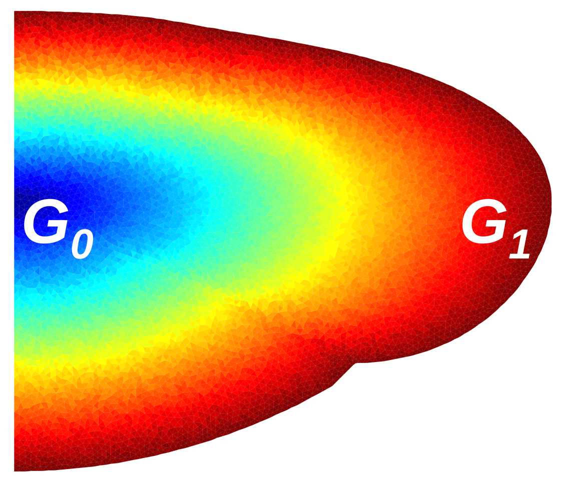
decapsulated

(b) Finite element inverse analysis

- The decapsulated lenses were analysed by using an axisymmetric hyperelastic finite element method to deduce their stiffnesses.
- The lenses were modelled as a non-homogeneous neo-Hookean continuum.
- Radial body forces corresponding to spinning at 1000 rpm were imposed, assuming an age dependent lens density.

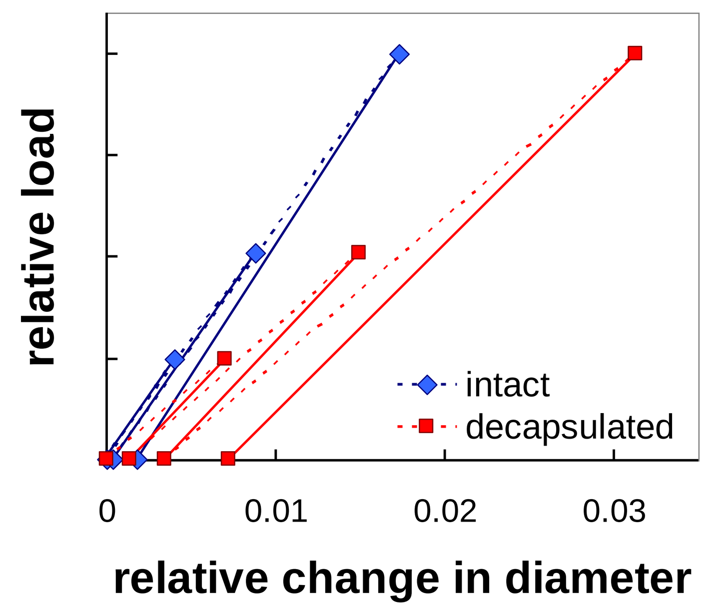
1. Compute a least-squares spline to describe the average outline from 8 static photos of a given lens
2. Construct a mesh of 15-noded triangles within the spline outline
3. Select appropriate shear modulus values varying linearly from G_0 at the centre to G_1 at the surface
4. Simulate the spinning test to find the change in diameter and thickness for G_0 and G_1
5. Do the thickness and diameter changes match the experiment? No → return to step 3; Yes → Finish

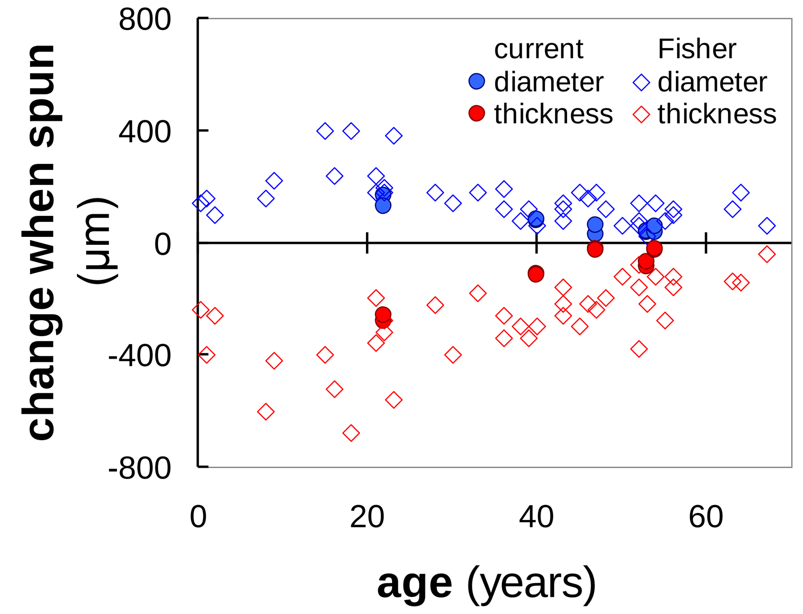




Results

The test regime for one 40-year lens, first tested intact at 700, 1000, and 1400 rpm, then again with the capsule removed.





Observed changes in diameter and thickness of intact lenses spinning at 1000 rpm compared with equivalent values from Fisher (1971).

Conclusions

- Removing the capsule caused the deformation due to spinning to increase by 30-35%.
- The current experiment produced diameter and thickness changes for intact lenses comparable with the lower values from Fisher (1971).
- The FEM simulation shows that these measurements are consistent with a large increase in central lens stiffness with age, as reported by Heys *et al.* (2004) and Weeber *et al.* (2007).

References

Fisher, R. F. (1971). "The elastic constants of the human lens." J Physiol.

Heys, K. R., S. L. Cram, *et al.* (2004). "Massive increase in the stiffness of the human lens nucleus with age: the basis for presbyopia?" Mol Vis.

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