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LETTER TO THE EDITOR

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Comment on the publication "Three-dimensional ultrasound, biomicroscopy environmental and conventional scanning electron microscopy investigations of the human zonula ciliaris for numerical modelling of accommodation" by O. Stachs et al.

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Dear Editor

Stachs et al. constructed three-dimensional images of the architecture of the zonules from two-dimensional UBM images of postmortem human eyes. They compared these images with scanning electron microscopic images of the zonules [20].

The authors used a line between the scleral spur and the base of the ciliary muscle as the basis for a coordinate system to construct the three-dimensional images [20, 21]. Unfortunately, this line is not a sufficient coordinate reference from which to construct a three-dimensional image. The authors did not provide references on the globe or use landmarks sufficient to insure that the three-dimensional UBM images were not affected by perspective distortion. It has been demonstrated that small misalignments of the UBM probe with respect to the eye, which induce as little as a three-pixel shift between compared images, can cause significant perspective distortion [18, 19]. Moreover, since the lens equator is not visible in all images of the UBM, the path of the zonules and the location of their attachment to the lens capsule were inferred by the authors and have not been confirmed by them [20]. Consequently, it is premature for the authors to conclude that the zonular architecture is different from that which has been demonstrated with scanning electron microscopy [5, 22].

Then, using the finite element method (FEM), the authors determined the effect of the position of the lens zonules on the change in central optical power of the lens associated with zonular traction [20]. The authors did not select the most appropriate properties for the model employed in their FEM study, but simply relied on the FEM model performed by Burd et al. [2]. Had they used the correct FEM mesh elements, geometric and material properties in their model, a converged FEM solution would provide a reliable method for analyzing the mechanics of this biological system [1, 11, 13]. Burd et al. have recently re-evaluated the material properties of the lens cortex and nucleus, and acknowledge that the values used in their FEM analysis are inappropriate for modeling the human lens [3].

Burd et al. modeled the lens of a 29y/o in which the cortex was 6 times *harder* than its nucleus [2]. Brillouin light scattering [23], a non-invasive technique, and dynamometric measurements of in vitro *fresh* human lenses [14] and routine clinical observation during in vivo cataract extraction by phacoemulsification demonstrate that the hardness of the nucleus of lenses older than 25 years is either the same or *greater* than its cortex [8].The most appropriate material properties for the lens cortex and nucleus are based on the following:

The mean shear modulus, G, of the young lens is 50 Pa [7] and the bulk modulus, K, of the lens cortex is 2.8 GPa and the lens nucleus is 3.7 GPa [23]. From the relationship between G, K and the elastic modulus, E, the lens Poisson's ratio, v, is [16]:

$$\nu = \frac{3K - 2G}{6K + 2G} \cong 0.49999999$$

From the following relationship [16]:

$$E = \frac{9KG}{3K + G}$$

the elastic modulus of the lens cotex and nucleus is 150 Pa.

In addition, Burd et al. [2] did not consider the fact that the cortex is readily separated from the capsule [15] and should have incorporated contact elements to simulate the capsule-cortex interface. Burd et al. [2] used triangular elements to model the capsule, which are not as reliable as quadrilateral elements [9, 10] and a discontinuous function, consisting of a polynomial, a straight line and a circular end cap, to model the lens profile. It would be more appropriate to use a continuous function to model the lens such as given by Chien et al. [4].

With attention to these needed modifications, the authors should be able to obtain an FEM converged solution of zonular traction, such that the force and lens equatorial displacements required to induce 10 diopters of accommodation, can occur within the physiological force capacity of the ciliary muscle [6, 12, 24] and the space limitations of the equatorial circumlenticular space [17].

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