

FINITE ELEMENT MODELS OF HUMAN CRYSTALLINE LENS FOR THE INVESTIGATION OF PRESBYOPIA

Kehao Wang, Demetrios T. Venetsanos, Jian Wang, Barbara K. Piersionek

Kingston University, UK

Introduction

The human crystalline lens is a crucial ocular component contributing to about one third of the focusing power of eye. The lens shape can be adjusted to satisfy the visual demand over a range of different distances, a process termed accommodation, and is mediated by the ciliary muscle which applies forces to the lens capsule through a ring of fibrous strands collectively called the zonule. The zonule is attached to the lens capsule at its peripheral region and is divided into three sections: anterior, equatorial and posterior [1]. The accommodative ability gradually decreases with age and leads to a loss of focussing at near which is termed presbyopia.

To date, theories describing the accommodative mechanism are controversial; explanations of this age-related accommodative decline are inconclusive. *In-vivo* studies only reveal the central lens region as the periphery is blocked by the iris; *in-vitro* studies are limited by variations in measurement techniques. Therefore the *in-silico* approach, Finite Element Analysis (FEA), serves as an efficient tool in seeking relations between *in-vivo* and *in-vitro* data.

Methods

Axisymmetric models were developed at age 16 and 35 years old, based on geometries measured by recent interferometric analysis of *in-vitro* human lenses [2]. The degrees of freedom of the zonular anchorage points on the capsule were coupled with surrounding nodes to maintain smooth curvatures of lens surfaces during deformation. The three zonular fibres were provided with abilities to move into different directions, as represented in figure 1. An exhaustive search of 1815 combinations of anterior (θ_a), equatorial (θ_e) and posterior (θ_p) zonular angles was performed and the resulted Central Optical Power (COP) was calculated based on shape parameters of the deformed lens [3]. The changes were compared with *in-vivo* data [4]. All models were developed using intrinsic APDL programming language in ANSYS 16.0 and the exhaustive search was controlled by MatLab 2015b.

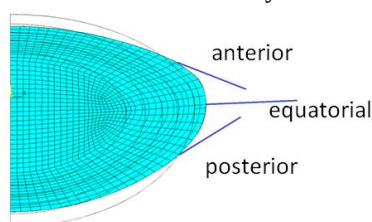


Figure 1: The anterior, equatorial and posterior zonular fibres pointing into different directions.

Results

The 16-year-old lens model fitted better to the *in-vivo* data and provided higher COPs than the 35-year-old lens model (Figure 2). Changing equatorial zonular angle did not make significant influence to the lens external deformations and COP; the anterior and posterior parts demonstrated major effects. The zonular angle combination providing the optimum fitting to *in-vivo* measurements are different from that resulting the maximum optical performances (Table 1).

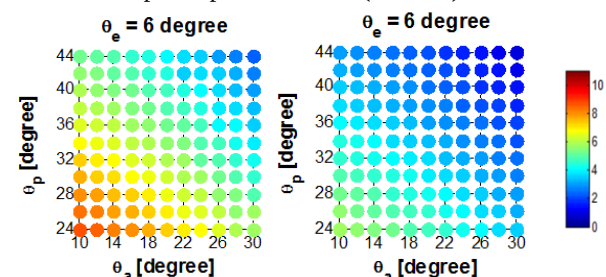


Figure 2. The magnitude of COP (dioptries) resulted by 16 (left) and 35(right) years old models, when (θ_e) was fixed to 6 degrees.

	Anterior angle	Equatorial angle	Posterior angle
Optimal fitting	14°	-6°	38°
Max. COP	10°	-14°	24°

Table 1: Comparisons of zonular angle combinations for the 16-year-old lens model.

Discussion

To our knowledge the models developed in the present work are the most physiologically accurate ones to date as the geometries were from intact lenses and the lens smooth surface curvatures were kept during FE simulations. Our results showed that the conditions best mimicking the *in-vivo* measurement can be found by altering the zonular angles. Considering the fact that the older lens model demonstrated lower COP than the younger one and the difference in zonular angles providing the optimal fitting and maximum COPs, the change in zonular angle with age can be one of the reasons for the development of presbyopia.

References

1. Streeten BW, Invest Ophthalmol Vis Sci, 16: 364-375, 1977.
2. Bahrami M. et al, Exp Eye Res, 124:93-99, 2014.
3. Wang K. et al, Sci Rep, 6, 2016.
4. Dubbelman M. et al, Vision Res, 45: 117-132, 2005.

