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Modeling The Mechanism Of Compensation Of Aberrations In Real Eyes

P. Artal, J. Tabernero and A. Benito

Laboratorio de Optica, Universidad de Murcia, Murcia, Spain

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Abstract

Purpose: In most normal eyes, the aberrations of the crystalline lens partially compensate for the aberrations of the corneal, improving the overall retinal image quality. This compensation effect appears to be larger in hyperopic eyes (Artal et al., Journal of Vision, in the press). We study here the optical and geometrical sources that are responsible for this aberration compensation.

Methods: We performed series of measurements in the eyes of three small groups of young subjects: 6 hyperopes (from +4 to +1 D), 8 emmetropes and 8 myopes (from –3 to –8 D). We measured the eye aberrations using a Hartmann–Shack wavefront sensor and the corneal aberrations by combining ray–tracing techniques with corneal topography. Angle kappa, lens tilt with respect to the line of sight and lens decentration with respect to the pupil centre was also measured by using our own developed instrument based in the recording of Purkinje images. Axial length and anterior chamber depth were measured using a clinical instrument (IOL–Master, Zeiss). From the complete set of experimental data, individual (customized) eye models were developed for each eye by using Zemax optical software. The predicted aberrations of the complete eye were compared with the measured aberrations.

Results: Lens tilt was larger in average in the case of the hyperopic subjects (6.2º) than in the myopic group (4.5º). Lens decentration with respect to pupil center was small (maximum value 0.23 mm) in all eyes. The prediction of the aberrations by the individual models was in good agreement with the actual aberrations. For the particularly interesting case of coma, the correlation between prediction and measured data was high (R^2>0.7) after fitting the measured spherical aberration value. The main factors driving the coma–compensation mechanism are related to the geometry (shape factor) of the lens in combination with the eye's tilted optics (angle kappa). On the contrary, the impact of lens decentrations, lens surfaces asphericity or gradient–index distribution within the lens appeared to be negligible for the coma–compensation mechanism.

Conclusions: We explored the underlying mechanisms that produce the compensation of aberrations in the eye by using optical and geometrical data together with a powerful modeling engine. We showed that angle kappa together with lens geometry (shape factor) mostly determine the compensation coma.

Keywords: crystalline lens • optical properties