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Interferometic and Hartmann-Shack Measurements of Aberrations in e*x-vivo* Human Crystalline Lenses

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Abstract

Purpose: To investigate the optical properties of ex-vivo human crystalline lenses using two complementary techniques: a point-diffraction interferometer (PDI) and a Hartmann-Shack (HS) wavefront sensor. The type and amount of the measured aberrations will be compared with estimates of lens aberrations obtained in-vivo by subtracting ocular and corneal aberrations (Artal et al., J. Vis., 2001).

Methods: We built a custom dual setup combining a PDI and a HS sensor to measure aberrations of ex-vivo isolated human crystalline lenses in monochromatic light (633nm). The lenses were immersed in a chamber filled with culture medium with good optical-quality parallel plates as covers. The PDI technique is based on recording the interference pattern between a reference spherical beam generated by diffraction through a clear pinhole placed in a semitransparent plate and the beam under test. The HS sensor was built to measure the lens wavefront aberrations also in transmission as with the PDI. There was a difference between the two techniques since the laser beam enters the lens parallel in the PDI but diverging in the HS sensor. Wave aberrations were obtained with the two techniques in fully accommodated lenses of human donors of different ages. Wave aberrations were reconstructed from both techniques as Zernike polynomial expansions.

Results: The complete experimental procedure was first validated by measuring calibrated phase plates with known aberrations with the PDI and HS instruments. Both techniques provided similar results, with root mean square (RMS) difference lower than 4%. For the ex-vivo lenses, we were able to obtain valid wavefront data before degradation of the tissue occurs. The measured values of total RMS, as well as individual Zernike coefficients of the lenses, obtained with both techniques were comparable. The dominant aberration terms present in the crystalline lenses were astigmatism, coma and spherical aberration. However some 5th order terms were also non-negligible. The lenses were also measured illuminating both surfaces of the lens by flipping the chamber up-side-down.

Conclusions: We measured wave aberrations maps of ex-vivo isolated human crystalline lenses using two complementary techniques. These results could be compared with those obtained from ray-tracing modeling using geometrical and refractive index data of the lenses. This study will help us to better understand the internal aberration structure of the human eye.

Keywords: aberrations • optical properties