VioBio Lab ARVO Itinerary Planner and Abstract Book

2014 ARVO Annual Meeting
May 03 - 08, 2014

To make changes to your itinerary or view the full meeting schedule, visit http://arvo2014.abstractcentral.com/itin.jsp
### Saturday, May 03, 2014

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### Sunday, May 04, 2014

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<tr>
<td>1:30 PM-3:15 PM</td>
<td>Exhibit/Poster Hall SA, <strong>Spatial and temporal vision</strong></td>
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<tr>
<td>1:30 PM-3:15 PM</td>
<td><strong>781 - D0024. Visual testing of segmented bifocal corrections with a compact simultaneous vision simulator</strong> C. Dorronsoro; A. Radhakrishnan; P. de Gracia; L. Sawides; J. Alonso-Sanz; D. Cortés; S. Marcos</td>
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### Monday, May 05, 2014

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### Tuesday, May 06, 2014

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<tr>
<td>8:30 AM-10:15 AM</td>
<td>Exhibit/Poster Hall SA, <strong>Refractive Error</strong></td>
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<td>8:30 AM-10:15 AM</td>
<td><strong>2718 - A0100. Evaluation of a low-cost wavefront aberrometer for measuring refractive errors</strong> E. Lage; F.A. Vera-Diaz; S.R. Dave; D. Lim; C. Dorronsoro; S. Marcos; F. Thorn; N.J. Durr</td>
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<td>3:45 PM-5:30 PM</td>
<td>Exhibit/Poster Hall SA, <strong>Corneal biomechanics and keratoprosthesis</strong></td>
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<td>3:45 PM-5:30 PM</td>
<td><strong>3700 - A0214. Finite element modeling for the dynamic biomechanical characterization of the in-vivo cornea</strong> S. Kling; N. Bekesi; C. Dorronsoro; S. Marcos</td>
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<td>3:45 PM-5:30 PM</td>
<td><strong>3714 - A0228. The Effects of Cross-linking on the Static and Dynamic Corneal Viscoelastic Properties</strong> N. Bekesi; A. de la Hoz; S. Kling; S. Marcos</td>
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<td>3:45 PM-5:30 PM</td>
<td>Exhibit/Poster Hall SA, <strong>IOL and Accomodation</strong></td>
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<td>3:45 PM-5:30 PM</td>
<td><strong>3783 - B0043. Imaging crystalline lens microscopic structures of intact in vitro mammal lenses using confocal microscopy</strong> J. Birkenfeld; J. Lamela; S. Ortiz; S. Marcos</td>
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<td>3:45 PM-5:30 PM</td>
<td>3784 - B0044. OCT 3-D surface topography of isolated human crystalline lenses</td>
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<td>M. Sun; J. Birkenfeld; A. de Castro; S. Ortiz; P. Perez; M. Velasco; S. Marcos</td>
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3:45 PM-5:30 PM

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<td>3:45 PM-5:30 PM</td>
<td>3788 - B0048. Crystalline lens gradient refractive index and posterior surface shape from multiple orientations OCT imaging: towards a reconstruction in vivo?</td>
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<td>A. de Castro; J. Birkenfeld; B.M. Maceo; M. Ruggeri; E.A. Arrieta; J.A. Parel; F. Manns; S. Marcos</td>
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Wednesday, May 07, 2014

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<tr>
<td>11:00 AM-12:45 PM, S 330EF, Building an Optical Instrument from Cells - Minisymposium</td>
<td>4594. OCT-based reconstruction of the crystalline lens Gradient Refractive index: changes with age and accommodation S. Marcos</td>
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<tr>
<td>12:00 PM-1:45 PM, S 230EF, Vision with Adaptive Optics</td>
<td>5970. Internal code for blur: Interocular effects A. Radhakrishnan; C. Dorronsoro; L. Sawides; M. Webster; E. Peli; S. Marcos</td>
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12:15-12:30 PM

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<tr>
<td>12:15-12:30 PM</td>
<td>5974. Longitudinal Chromatic Aberration of the human eye in the visible and near infrared from Hartmann-Shack wavefront sensing, double-pass and psychophysics</td>
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<td>M. Vinas; C. Dorronsoro; L. Sawides; D. Cortés; D. Pascual; A. Radhakrishnan; S. Marcos</td>
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Purpose: To evaluate optical quality and visual perception with bifocal simultaneous vision corrections with different pupil segmentation patterns (PSPs).

Methods: Fourteen different PSPs with balanced far and near areas (+3.0 D add), arranged in different angular/radial distributions, were evaluated in optical simulations and in visual experiments. The visual experiments were performed on a modified simultaneous vision simulator that introduced PSPs by means of adjustable polarization patterns projected through two focusing channels. Subjects had to score their perceived quality (PQ) over successive face images (0.75 deg) degraded with different PSPs. 105 pairs (all combinations of 14) were presented randomly under cycloplegia (6-mm artificial pupil) for far, near and intermediate vision, and repeated 3 times for each of the 5 subjects. Optical aberrations were measured using custom Hartmann-Shack aberrometry. Through focus optical quality (OQ, in terms of Strehl Ratio) was calculated using Fourier optics for each PSP and each eye.

Results: The different PSPs on a simulated diffraction-limited eye did not produce relevant differences (<3%) in OQ. However, the presence of real aberrations induced strong differences in OQ across PSPs (factors 2 to 10, depending on the subject). All subjects showed significant differences in PQ (p<0.05) with most (56% on average) of the PSPs, typically changing between far and near. Although OQ and PQ across PSPs were not highly correlated (r: 0.3-0.76; with p<0.05 in 2 subjects), in 4/5 subjects the PSP producing the best OQ also produced the highest PQ, both for far and near. In one subject, the best scored PSP was not predicted from optics, indicating neural effects weighting the visual response. Asymmetries in the wave aberration were generally related to higher scores in angularly segmented patterns (with a strong orientation bias).

Conclusions: Significant perceptual differences were found across the different far/near pupillary distributions of bifocal corrections, which varied across subjects and distances. The visual responses can be predicted to a large extent from the differences in the ocular aberrations. However, a two-channel simultaneous vision simulator, considering both optical aberrations and potential neural effects, allows subjective validation of the bifocal patterns producing the best visual quality in each patient.
Evaluation of a low-cost wavefront aberrometer for measuring refractive errors

E. Lage; 1 F. A. Vera-Diaz; 2 S. R. Dave; 1 D. Lim; 1 C. Dorronsoro; 3 S. Marcos; 2 F. Thorn; 2 N. J. Durr 1

2. New England College of Optometry, Boston, MA, United States.

Purpose: To evaluate the performance of a low-cost wavefront aberrometer in measuring refractive errors.

Methods: A double-blind study was conducted to evaluate accuracy of a prototype low-cost wavefront aberrometer in obtaining a refractive prescription. The prototype was compared with a Grand Seiko WR-5100K open-field autorefractor and binocular subjective refraction. The prototype is a handheld, lightweight, open-view, and easy-to-use device that quickly provides a refractive prescription without requiring pupil dilation. The prototype includes a Hartmann-Shack lenslet array with a low-cost CMOS image sensor for wavefront sensing, and an 850 nm laser diode for illumination (maximum corneal power of 250 μW). All the functional components of the device are off-the-shelf parts that cost less than $1,000 in total. The subjects held and looked through the prototype while a 30-second video of spot diagrams was captured. The spot diagrams were processed using a custom algorithm to calculate Zernike coefficients and estimate a prescription. Refractions were obtained for 43 subjects (mean age 26.2 ± 9.5 years) with each method. Eight of these subjects were used for validation and development of the prototype algorithm, and the remaining 35 were used for the double-blind test.

Results: For the 35 subjects, the range of spherical equivalent (SE) refractive error measured by subjective refraction was -6.50 to +3.63 D. The correlations between the SE measured objectively and subjectively were R = 0.96 for the prototype and R = 0.97 for the autorefractor. The average SE error of the prototype compared to subjective refraction was 0.54 ± 0.54 D, versus 0.40 ± 0.46 D for the autorefractor. The average errors of the J0 and J45 power vectors were 0.16 ± 0.22 D and 0.11 ± 0.11 D for the prototype and 0.13 ± 0.09 D and 0.08 ± 0.07 D for the autorefractor compared to subjective refraction.

Conclusions: The prototype wavefront aberrometer performed similarly to a high-end open-field commercial autorefractor in objective refraction when using subjective refraction as the gold standard. The prototype performed worst on subjects with anisometropia (n=2), likely due to cross-coupled accommodation. Future improvements in the prototype algorithm can improve its accuracy in measuring refractive errors. An easy-to-use and low-cost autorefractor, such as the one evaluated here, may be beneficial for improving eye care in low-resource settings.
Purpose: Mechanical properties give important information on the health of biological tissues. Recently new non-contact imaging techniques have been proposed to measure the dynamic response of the cornea to vibration and air-puff. In this study, we built a finite element (FE) model to relate the measured geometrical deformation to the inherent corneal biomechanical parameters.

Methods: A 2D-axisymmetric viscoelastic FE-model was built including cornea, limbus, sclera and the humors. All ocular tissues were pre-loaded with the intraocular pressure (IOP) before two different simulations were performed: (1) Transient analysis of corneal deformation following an air-puff of 115 mmHg and (2) modal analysis in the range of 50-510 Hz of the corneal vibration response. The model was optimized to reproduce experimental data of human and porcine corneas. Deformation parameters and resonance modes that were most sensitive to the inherent corneal mechanical parameters were identified.

Results: A typical indentation (Aind=0.91 mm) of a 558μm-cornea following an air-puff resulted in an elasticity modulus of 0.75 MPa for the anterior and 0.65 MPa for the posterior cornea. Increased corneal stiffness decreased the indentation by 1.88 mm/MPa. Harmonics of the fundamental corneal resonance mode (FRes=54.8 Hz) were observed at 131, 232, 328, 433 and 500 Hz shifting to higher frequencies for stiffer corneas (1.19-7.18 Hz/Pa). Within the physiologic range, corneal deformation following an air-puff depends significantly on corneal stiffness (ΔAind= 0.38 mm), thickness (ΔAind= 0.20 mm) and IOP (ΔAind= 0.23 mm), while the vibration resonance frequencies depend predominantly on corneal stiffness (ΔFRes=14.8 to 89.0 Hz) and density (ΔFRes=0 to -91.8 Hz).

Conclusions: Dynamic optical non-contact imaging in combination with finite element modeling will allow an in-vivo analysis of corneal biomechanical property changes in disease and after treatment. The simulations allowed retrieving inherent corneal biomechanical parameters. While IOP and geometrical parameters played a major role in the corneal deformation with air-puff, the vibration modes did not critically depend on these parameters.
Purpose: To characterize the quasi-static and the dynamic viscoelastic properties of the cornea, and their changes produced by UV corneal collagen cross-linking (CXL).

Methods: The viscoelastic behavior of the cornea was studied experimentally on freshly enucleated porcine eyes, in 3 conditions: untreated; after 30 min riboflavin-dextran instillation, and after CXL. The quasi-static viscoelasticity was studied by inflation creep tests, where the intraocular pressure (IOP) was increased from 15 to 30 mmHg, and kept constant for 10 min. The experiment was automatically controlled, and corneal images captured using Scheimpflug imaging (Pentacam, Oculus). Changes in corneal geometry versus IOP and time were analyzed. The dynamic viscoelastic properties were assessed from corneal deformation using air-puff high speed Scheimpflug imaging (Corvis, Oculus). The viscoelastic material properties (in a generalized Maxwell model) were determined by reverse modeling using Finite Element Analysis in ANSYS. Dehydration due to the application of riboflavin-dextran was also considered in the modeling. The parametric model of the eye globe was built, and both the static and the dynamic test configuration were simulated on the same model with the same material properties, with different loads: the IOP time curve for the static condition, the IOP and the air puff dynamic pressure distribution for the dynamic one. The parameters of the viscoelastic material model were changed to fit the experimental corneal deformations of the inflation and air-puff experiments.

Results: The resulting elasticity of the virgin cornea was 2.6 MPa with a relative modulus of 0.3 for the dynamic (0.001 s) and 0.15 for the quasi-static (100 s) loads. Applying riboflavin-dextran solution increased both the elastic modulus (x 2.15) and the static viscoelasticity (x 2.3), and decreased the dynamic viscoelastic parameter (x 0.4). Cross-linking increased the elasticity by a factor of 4.75, decreased the dynamic viscoelastic contribution (x 0.57), and increased the quasi-static viscoelastic relative modulus (x 1.67), compared to the virgin cornea.

Conclusions: Riboflavin-dextran and cross-linking change both the elastic and static and dynamic viscoelastic properties of the cornea. The description of the corneal material properties in different time regimes is important for the understanding and modeling of corneal treatments such as CXL.
Final ID: 3776 - B0036

Lens Spherical Aberrations in Cynomolgus Monkeys: Comparison of Laser Ray Tracing Measurements and Reconstructed GRIN Model Predictions

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2. Department of Biomedical Engineering, University of Miami, Biomedical Optics and Laser Laboratory, Coral Gables, FL, United States.
3. Consejo Superior de Investigaciones Científicas, Instituto de Óptica, Madrid, Spain.
4. Vision Cooperative Research Centre, Brien Holden Vision Institute, UNSW, Sydney, NSW, Australia.

**Purpose:** To compare the spherical aberration of cynomolgus monkey lenses measured with a laser ray tracing (LRT) system and the spherical aberration estimated from numerical ray-trace through a model of the lens with the measured lens shape and a reconstructed gradient refractive index (GRIN).

**Methods:** Measurements: LRT measurements were performed on 5 cynomolgus monkey lenses from 4 donors (4.4-7.3 years, PMT= 25.2±13.6 hours). The tissue was mounted in a lens stretcher (Ehrmann et al, Clin Exp Optom, 2008) and measured in the unstretched (accommodated) and fully stretched (relaxed) state. The LRT delivered 51 equally-spaced parallel meridional rays over a 6mm diameter zone. The height of each individual ray was measured at 12 positions along the optical axis using a camera. The measured ray heights were plotted as a function of entrance ray height and fit with a 3rd order polynomial. The focus of the lens was determined from the fits and the Zernike spherical aberration coefficients were extracted.

Model: The shape and GRIN of the 5 individual lenses were reconstructed from cross-sectional Optical Coherence Tomography images and measurements of the lens power (De Castro et al, IOVS, 2013) in the same stretching conditions. A numerical ray trace was performed through the reconstructed GRIN lens for a 6-mm pupil diameter (101 rays, ray spacing 30µm) to estimate the spot diagrams at the same axial positions as the LRT measurements. The spherical aberration was estimated from a calculation of the wavefront in the exit pupil plane of the reconstructed GRIN lens. The predicted and measured spot diagrams and spherical aberration were compared.

**Results:** The Zernike spherical aberration coefficients obtained with the LRT were -6.11±0.29µm in the unstretched position and -2.78±0.47µm in the stretched position. The Zernike spherical aberration coefficients estimated with the GRIN reconstruction were -5.84±1.10µm in the unstretched position and -2.34±0.64µm in the stretched position. There was a close match of measured and simulated spot diagrams.

**Conclusions:** The agreement between experimental data and the model predictions validates the method for reconstructing the GRIN from OCT images of crystalline lenses. Both experiment and model show that Zernike spherical aberration coefficients become more negative with simulated accommodation for cynomolgus monkey lenses.
Purpose: To image microscopic structures of the intact in vitro mammal crystalline lens using confocal microscopy.

Methods: Rabbit eyes were obtained from a local slaughterhouse and transported at a temperature around 4°C. The cornea was removed from the eye 2-24h post-mortem, and the eye was placed in a cuvette and used immediately for imaging. Measurements were done with a custom made optical microscope, which can operate alternately or simultaneously as a confocal microscope or a multiphoton microscope. The microscope is equipped with two lasers, one diode laser at 488 nm and a Ti: Sapphire femtosecond laser tunable over a range of wavelengths between 670 nm and 1040 nm, and two detection channels. Images were obtained with an air objective (MPLAN, 50x, NA 0.75, Olympus). The anterior pole of the lens was imaged, and volumes of images were obtained around the lens apex. All measurements were done on intact lenses with the capsule still attached to the lens zonulae.

Results: A z-scan through the lens allowed identifying distinct regions of the intact crystalline lens: the lens capsule, a thin epithelium layer, and the lens fibers. The lens capsule was seen as a striated structure with an estimated thickness of 10 μm. The structures were oriented, and usually parallel to each other, with an average inter distance of 1.6 μm square. The lens epithelium appeared as a thin cell layer below the lens capsule, with cells of approximately 9 μm in diameter. The lens fibers appeared as elongated, tightly packed fibers with an estimated thickness of 2-3 μm, and a predominant orientation, with all fibers located parallel to each other within the imaged volume.

Conclusions: The potential of confocal light microscopy (CLM) in the anterior pole of the eye lenses was demonstrated by performing an in vitro study of in eye intact rabbit lenses. This method is suitable for quantifying the lens structures in the intact crystalline lens, holding promise for applications in vivo and for microscopic analysis of the lens under accommodative forces.
OCT 3-D surface topography of isolated human crystalline lenses

M. Sun; J. Birkenfeld; A. de Castro; S. Ortiz; P. Perez; M. Velasco; S. Marcos;

1. Visual Optics and Bio-photonics Lab, Instituto de Optica, CSIC, Madrid, Spain.

Purpose: To measure surface topography of isolated human crystalline lenses, and evaluate the relationship between anterior and posterior lens shapes and their changes with age.

Methods: Custom spectral optical coherence tomography (sOCT) was used for 3D imaging of isolated crystalline lenses in 2 orientations (anterior surface/posterior surface up) with 12 x 12 mm range, 0.17/0.007 mm lateral/axial resolution. 23 crystalline lenses from 18 human donor eyes (19 to 71 yr) were extracted <48 h post-mortem and imaged in a DMEM-filled cuvette. Custom algorithms were used for surface segmentation and distortion correction. Anterior and posterior surface elevations were fitted by conics (radius of curvature R and asphericity Q), and (after subtraction of the reference spheres) fitted by 7th order Zernike polynomials in 6-mm pupils. Deviations from a sphere are accounted by the corresponding Zernike terms, Root Mean Square (RMS) and variance. The age-dependence and anterior/posterior correlations of these parameters were evaluated by linear regressions.

Results: Anterior and posterior surfaces of isolated lens became significantly flatter with age (R vs age: slopes=0.12 & -0.023 mm/yr; r=0.71 & -0.54; p=0.0002 & 0.0076, respectively), and Q less negative. Astigmatism was the predominant surface aberration (>90% of the surface variance), but did not vary significantly with age. Anterior and posterior surface tetrafoil RMS decreased significantly with age (slopes: -0.01 & -0.08 um/yr; r=-0.48 & -0.52; p=0.02 & 0.01, respectively). Anterior high order astigmatism increased significantly (p=0.04) and posterior trefoil, coma and 6th and higher RMS decreased significantly (p<0.05) with age. In general, there was a high correlation between anterior and posterior lens shapes, for R (r=-0.54, p=0.0076), Q (r=0.67, p=0.0004), astigmatism Z22 (r=0.47, p=0.02) and tetrafoil Z44 (r=0.85, p<0.0001), with slopes <0.51.

Conclusions: The human crystalline lens shows non-spherically symmetric surfaces. The increased steepness and negative asphericity in isolated young lenses is consistent with maximum accommodation. Astigmatism predominates, with anterior and posterior aligned axes. The change in tetrafoil with age may be associated to lens fibers branching. Although zonular tensions may cause topographic differences in the in vivo crystalline lens, this is the first comprehensive topographic study of the human lens.
Crystalline lens gradient refractive index and posterior surface shape from multiple orientations OCT imaging: towards a reconstruction in vivo?

A. de Castro; J. Birkenfeld; B. M. Maceo; M. Ruggeri; E. A. Arrieta; J. A. Parel; F. Manns; S. Marcos;

1. Instituto de Óptica, Consejo Superior de Investigaciones Científicas CSIC, Madrid, Spain.
2. Ophthalmic Biophysics Center, Bascom Palmer Eye Institute, Miami, FL, United States.
3. Biomedical Engineering, University of Miami, Biomedical Optics and Laser Laboratory, Miami, FL, United States.
4. Vision Cooperative Research Centre, Sydney, NSW, Australia.

Purpose: The gradient index (GRIN) plays a key role in the crystalline lens optical properties, yet most current estimations are in vitro. We provide computational and experimental evidence to extend a method previously applied in vitro and reconstruct both the GRIN and posterior lens surface using optical coherence tomography (OCT) images obtained from multiple projections.

Methods: Optical path difference (OPD) between anterior and posterior surface of a simulated 4-variable (nucleus/surface refractive indices \(n_N/n_S\); axial/meridional decay \(p_a/p_m\)) GRIN lens were calculated for different angles of the entry rays (0 and 30 deg in air). Gaussian error (\(\sigma=10 \mu m\)) was added to the data to simulate experimental error. A global search algorithm was used to search the GRIN variables and the posterior surface shape that best matched the OPD data. The reconstruction error using different projections was compared. As a demonstration, four in vitro cynomolgus monkey lenses were imaged using the probe of a commercial OCT system (ENVISU R4400, Bioptigen, Inc.) mounted on a rotational stage at different angles from -45 to 45 deg (5-deg steps). The anterior surface was used for registration purposes. The OPD of the rays passing through the lens was used to reconstruct the GRIN variables and the posterior surface shape, as described. The lens was flipped up and imaged for a direct measurement of the posterior lens surface.

Results: While on axis OCT images alone provided a poor reconstruction of the GRIN variables and the posterior surface shape, using input data from multiple angles (0 and 30 deg) allowed high accuracy in the estimated parameters on the simulations: mean errors of 0.007 and 0.004 for \(n_S\) and \(n_N\), and near 1 for axial and meridional exponential decay; and 0.3 mm and 0.1 for posterior surface shape \(R\) and \(Q\), respectively. Mean GRIN estimates from experimental data in the monkey lenses were: \(n_S =1.371; n_N =1.422; p_a =5.4; p_m =7.7\). The experimental accuracy in the estimation of the posterior surface shape was 0.55 mm for \(R\) and 1.0 for \(Q\).

Conclusions: Simultaneous reconstruction of lens GRIN and the posterior surface shape is possible from multiple projection OCT imaging, suggesting that in vivo GRIN reconstruction may be possible using optimization methods.
OCT-based reconstruction of the crystalline lens Gradient Refractive index: changes with age and accommodation

S. Marcos; 1

1. Instituto de Optica, Instituto de Optica, CSIC, Madrid, Spain.

Presentation Description: The optical properties of the crystalline lens are largely determined by its shape and its gradient index (GRIN) distribution. Knowledge of their change of these properties with accommodation and age will give us important insights into the mechanism of accommodation and presbyopia. Quantitative Optical Coherence Tomography (OCT) allowed measurements of the 3-D shape the lens in vivo and in vitro. In addition, an OCT-based method, combined with global search algorithms allowed reconstruction of the crystalline lens GRIN in vitro. Studies were performed in porcine lenses, human lenses of different ages and non-human primate lenses under simulated accommodation in a stretcher system. Experimental measurements of shape and GRIN in the same lenses allowed the first direct analysis of their relative contribution to the crystalline lens spherical aberration, as a function of aging and accommodation.
Purpose: To assess the relationship between the internal code for blur and the differences in ocular optical quality between eyes.

Methods: A custom adaptive optics system with a psychophysical channel was used to measure the ocular aberrations and to perform blur adaptation tests under fully-corrected aberrations. Blur magnitude was characterized by the Strehl Ratio (SR), and blur orientation by the point spread function’s (PSF) major axis. Interocular differences were defined as 30% discrepancy in SR (blur) and/or 20-deg axis (orientation) between eyes. Subjects showed either same blur magnitude and orientation in both eyes (n=4); same blur magnitude but different orientation (n=2); or different blur magnitude and orientation between eyes (n=4). All tests were monocular, and performed in both eyes. Best perceived focus (BPF) was measured using a QUEST 2AFC psychophysical paradigm, in which subjects were presented with 128 images blurred with different SR and the best perceived image identified. Additionally, the directional internal code for blur (ICB) for each subject and eye was obtained using a pattern classification technique (Sawides PLOS One 2013) in which 500 pairs of images with similar magnitude of blur (same SR) but different blur orientations are presented, the subjects selecting the best image from the pair. The ICB was obtained by averaging and weighting of the positive responses, and its orientation determined. The BPF and ICB were compared between eyes and correlated with the ocular PSFs.

Results: The average discrepancy in ocular image quality (SR) between eyes was 24.47%. Despite the differences in ocular SR, the BPF measured in right and left eye was similar in most subjects (8.47% average discrepancy in SR; r=0.98, p<0.0001). The BPF correlated highly with the least aberrated eye’s SR (r=0.787, p<0.0001) or the average SR of both eyes, (r=0.677, p<0.0001), and less with the more aberrated eye (r=0.52, p=0.026). In all subjects, the estimated ICB was highly correlated between left and right eyes (mean r=0.996, p<0.0001). In all subjects with different interocular PSF orientaton, ICB axis matched the PSF axis of the least aberrated eyes (within 8.78 deg on average).

Conclusions: The internal code for blur is similar between eyes despite interocular differences in magnitude and orientation of blur. In most of the subjects the internal code for blur is driven by the eye with better optical quality.
Longitudinal Chromatic Aberration of the human eye in the visible and near infrared from Hartmann-Shack wavefront sensing, double-pass and psychophysics

M. Vinas; 1; C. Dorronsoro; 1; L. Sawides; 1; D. Cortés; 1; D. Pascual; 1; A. Radhakrishnan; 1; S. Marcos; 1;
1. Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC, Madrid, Spain.

Purpose: Longitudinal Chromatic Aberration (LCA) plays an important role on polychromatic optical quality and retinal imaging at different wavelengths (λ). However, the reported LCA varies across studies, likely associated to the different measurement techniques. We present LCA obtained from Hartmann-Shack (HS) wavefront sensing, double-pass (DP), and psychophysical methods in the same subjects.

Methods: A supercontinuum laser (450-1020nm) was used as the light source in custom-develop Adaptive Optics (AO) system provided with a HS (HASO, Imagine Eyes) and a deformable mirror (MIRAO, Imagine Eyes) to measure and correct the aberrations of the system and/or eye. The system incorporates a motorized Badal system, a natural pupil monitoring system, a CCD camera capturing aerial retinal images, and a psychophysical channel with monochromatically back-illuminated stimuli. A total of 16 wavelengths were tested using 2 fiber-optic-channels: 450-650nm in the visible (VIS), and 700-1020nm in the near infrared (NIR). Measurements were performed on 5 subjects (35.60±3.3yrs; -2.75±1.9D) with dilated pupils (6-mm artificial pupil). LCA was estimated from measurements at all λ from: (1) the defocus Zernike terms from HS wave aberrations; (2) best focused images of through-focus (0.25D steps) DP aerial image series; (3) subjective Badal best focusing of monochromatic stimuli (VIS only). Measurements were corrected by the calibrated LCA of the optical system (0.05D in VIS/0.28D in NIR).

Results: The average VIS LCA (488-650nm) was 0.83±0.18D from HS, 0.84±0.08D from DP, and 1.16±0.03D (1.56 ± 0.03 D for 450-650nm) from subjective best focus. The average NIR LCA (650-950nm) was 0.39±0.18D from HS and 0.33±0.10D from DP. The average Total VIS-NIR LCA (488-950nm) was 1.30±0.23D from HS and 1.54±0.23D from DP.

Conclusions: A custom-made polychromatic AO system allowed objective and subjective measurements of LCA, in a wider range (HS and DP) than previously explored. Subjective LCA (best focus, large pupils) is significantly higher than LCA from reflectometric techniques (HS and DP, both in excellent agreement). LCA measurements under AO-corrected aberrations with this system will give insights on the origin of the systematic discrepancies of subjective/objective LCA: presence of aberrations or λ-dependency of the retinal reflective layer.