Improved retinal shape detection using high-resolution MRI compared to partial coherence interferometry

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Target audience: MRI clinicians and researchers in ocular and vision science

Purpose: The current study compares PCI (partial coherence interferometry) and MRI quantitative assessment of the retinal shape of the eye, with the data ultimately being useful for various surgical interventions.

Methods: The on- and off-axis axial lengths of 16 left eyes of healthy volunteers were measured using a Lenstar LS900 (Haag-Streit AG) partial coherence interferometer. The measurements were performed along the 0º meridian and within a -30º to +30º field angle range with an angular step of 10º. To enable the off-axis measurements, a wide-angle LED gazing system was fabricated and fixed to the interferometer head (Figure 1). With the addition of the measured anterior corneal geometry on-axis, an algorithm was created to geometrically reconstruct the retinal shape. Concurrently, the volunteers left eye was scanned with a custom-made 3-channel receive eye-coil combined with a volume transmit coil (Nova Medical) in a Philips Achieva 7T whole body MR scanner (Figure 2). Eye-motion artefacts were minimized using a cued-blinking protocol and the MR images were acquired using a 3D inversion recovery turbo gradient echo technique (inversion delay 1200ms).[1] The total MRI examination takes less than 15 minutes. The resulting MR-images were processed using an automatic segmentation algorithm that detects the retinal contour with sub-pixel accuracy.

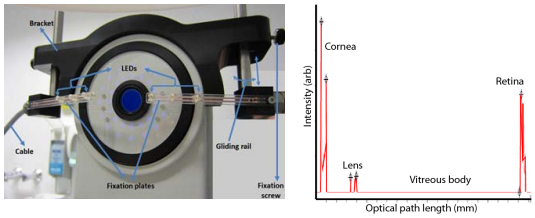

Figure 1. (Left) Lenstar LS900 with a wide-angle LED gazing system. (Right) PCI A-scan description of the interfaces between different eye components.

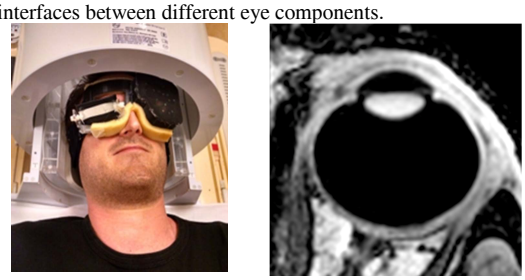

Figure 2. (Left) Dedicated eye-coil used for the MRI measurements. By using a cued-blinking protocol motion-free images of the eye (Right) are made.

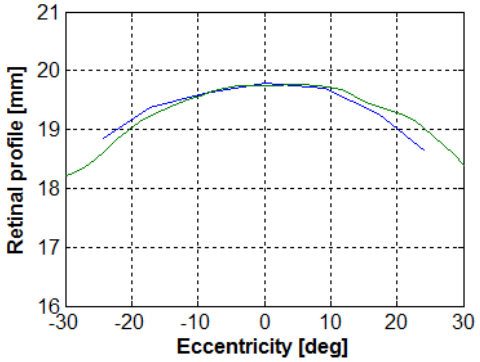

Figure 3. Retinal contours for one volunteer: PCI (blue) and MRI (green), measured from the centre of the lens.

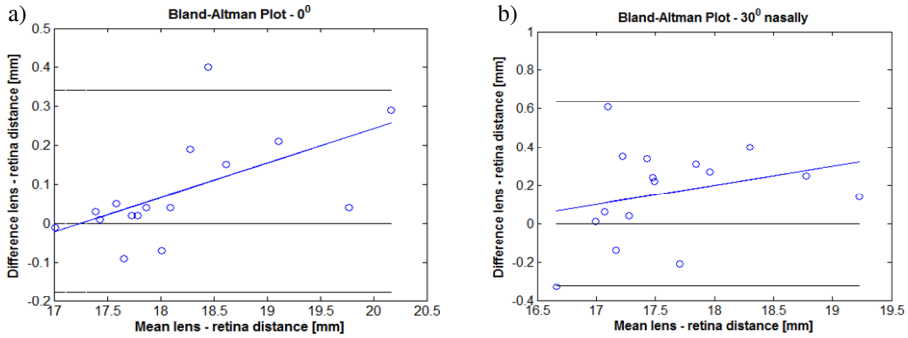

Figure 4. Bland Altman plots: the retinal shape between MRI and PCI correlate highly at 0º (a), but the correlation decreases the further you go off-axis (b).

Results: The on-axis axial length measured by the PCI varied between 22.6 and 26.0 mm with an average of 23.7 mm. When compared along the optical axis (Figure 4a), there is a strong correlation (R^2 = 0.99) between the PCI and MRI distances with a systematic error of 0.083 mm and a reproducibility of 0.13 mm. The 95% confidence interval limits (within which all but one volunteer data are situated) are between -0.18 and 0.34 mm. For -30º field of view, the systematic error increases to 0.16 mm and the reproducibility is 0.24 mm. The 95% confidence interval is also poorer between -0.32 and 0.64 mm (Figure 4b).

Conclusions: The high correlation between on-axis PCI and MRI measurements shows that MRI is very accurate with respect to the "gold standard". Off-axis PCI is known to be inaccurate due to optical refraction, with the error increasing with angle, while MRI measurements are angle-invariant. As expected the off-axis measurements show increased differences with angle due to larger errors in the PCI, meaning that MRI can be treated as the gold-standard for full three-dimensional retinal shape characterization.

References 1. Beenakker et al. NMR Biomed 26: 1864 (2013); 2. Atchison et al. Opt. Vis. Sci. 88: E601 (2011)