Validation of a Novel Hartmann-Moiré
Wavefront Sensor with Large Dynamic Range

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Introduction I: Review of Hartmann Shack Wavefront Sensor

- Validation of a Clinical Hartmann Shack Wavefront Sensor, Cheng et al, 2003

- Large-dynamic-range Shack-Hartmann wavefront sensor for highly aberrated eyes, Yoon et al, 2006
- Characterizing the Wave Aberration in Eyes with Keratoconus or Penetrating Keratoplasty Using a High–Dynamic Range Wavefront Sensor, Pantanelli et al, 2007
An aberrometer (i.e. HM) with large dynamic range for all aberrations within a single exposure is a very intriguing tool for general clinical studies.
Introduction: Review of Diffraction Aberrometer
(for example: Ophthonix)

- Distortion in grid encode with wavefront slope
- Near field diffraction pattern (Talbot self imaging effect)
- Checker-board grid aperture (can be made holographically)
- Retinal point source

Diagram:
- Distortion in grid
- Encode with wavefront slope
- Near field diffraction pattern (Talbot self imaging effect)
- Checker-board grid aperture (can be made holographically)
- Retinal point source
Distortion in diffraction pattern encodes wavefront slope.

The Moiré effect amplifies the movement of the “spots” so that the image plane distance from the first element can be shortened, and thus increasing the dynamic range without sacrificing sensitivity.
Method: Experimental Set Up

Testing Scheme

Test Cases:

Topcon Trial Lens Set
- Sphere -20 D to +18 D (77 lenses)
- Cylinder -8 D to +8 D (16 lenses)
Results: Sphere Test Cases Report I

Comparison of Measurement and Tested Trial Lens

Comparison from -20 D to +18 D range:
Correlation coefficient \( r > 0.999 \)

From –0.75D to +0.75D, The increments of tested lens was 0.125D
Results: Sphere Test Cases Report II

Over from -20 D to +18 D range

Mean absolute difference: 0.0304 D
Maximum absolute difference: 0.1123 D
Results: Sphere Test Cases Report III

Over from -20 D to +18 D range
Max standard deviation was smaller than .007 D

Good repeatability
Comparison from -8 D to +8 D range
- Correlation coefficient $r > 0.999$

Clinical HSWS

Large dynamic range for all aberrations (i.e. astigmatism)
Over from -8 D to +8 D range
- Mean absolute difference: 0.0654 D
- Maximum absolute difference: 0.17 D
Result: Sensitivity Test Report

**Dynamic range**: The ability to measure the large aberration;

**Sensitivity**: The ability to distinguish small change of aberration;

**Sensitivity over large dynamic range**: the ability to distinguish small change even in the presence of large aberration;

Comparison between measured change and introduced change
Correlation coefficient $r_1, r_2, r_3 > 0.999$

Good sensitivity over large dynamic range
Conclusions:

• The Hartmann-Moiré wavefront sensor measures defocus and astigmatism accurately and robustly over a large dynamic range required for clinically abnormal, highly aberrated eyes.

• For defocus, the sensor was validated (R>0.999) over a 38D range (-20 to +18). For a 4mm pupil, 20D is equivalent to 12 microns RMS.

• For astigmatism, the sensor was validated (R>0.999) over a 16D range (-8 to +8). For 4mm pupil, 8D is equivalent to 6.5 microns RMS.

• The sensor was accurate to within 0.12 D of spherical power and 0.17 D of cylindrical power over its full dynamic range.

• The instrument maintained high sensitivity to small changes over its full dynamic range.

• Since the test apparatus contained no focusing mechanism, these large dynamic ranges were a property of the wavefront sensor itself.

• Our measurements underestimated the true dynamic range of the sensor. Other factors (e.g. lens thickness & alignment, displacement of principal planes, calibration and availability of test cases) limited our investigation.

• Dynamic range of the sensor is unlikely to be a major limiting factor for a double-pass aberrometer.
The End: Acknowledgement

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Thank you for your attention......