Measurements of Multifocal Intraocular Lenses Using a Fluid-Filled Model Eye

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This presentation is the result of work done with the assistance of AMO/VISX Inc.
Wavefront measurement of eye with multifocal IOLs implanted

- An increasing number of eyes with multifocal intraocular lenses implanted
  - Diffractive bifocals
  - Refractive multifocals
- Correction of post-implantation refractive error with laser refractive treatments
- Wavefront measurements of these eyes and use of the wavefront information for treatment planning

What will a wavefront refractor find?
The diffractive bifocal - the optical situation - from the point of view of a Shack-Hartmann sensor

- Inner most lenslets sample 1 zone
- Next lenslets sample 2 zones
- Outer lenslets sample multiple zones

Inner 12 zones of a diffractive bifocal IOL

S-H lenslet array with a 0.4 mm pitch
Points spreads of S-H lenslets

- Wavefront from single zone
- Wavefront from three zones with a 1/2 wave phase jump
- Wavefront from three zones with a 1/2 wave phase jump

S-H lenslet

S-H sensor at 1 focal length from a lenslet
Points spreads of S-H lenslets

The effect of measuring a wavefront at a wavelength different from the design wavelength

Wavefront from two zones with a 1/2 wave phase jump

S-H sensor at 1 focal length from a lenslet

Doubled spots have equal amplitude

Wavefront from two zones with less than a 1/2 wave phase jump

Doubled spots have unequal amplitude
Effect on S-H spots of a annular zone multifocal design

- Rapid changes in power at annular zone transitions can occur within a single lenslet
- When the spatial variation of the wavefront is comparable to a lenslet size the spot will suffer from higher order aberrations
Experimental verification of this effect

- A diffractive bifocal or refractive multifocal IOL is placed in a fluid filled model eye.
- The length of the model is adjusted to make the eye emmetropic for the distance focus of the IOL.
- The eye is reconfigured so that it may be measured as a normal eye with a wavefront refractor.
- The wavefront of the model with the IOL is measured.
- The S-H spot pattern and the normal wavefront results are examined.
Fluid filled test eye - transmission configuration

- Test eye main body
- Pupil/IOL holder disk
- PMMA corneal shell with aspheric anterior surface
- IOL held in pupil disk by its haptics
- Fluid with the index of refraction of the aqueous humor
- Threaded central body to allow eye length to be changed
- Volume change reservoir
- Microscope slide glass window
- Removable rear window holder
- Rear body with threads for attached to microscope objective or wavefront refractor holder
Fluid filled test eye - wave front refractor configuration

- Test eye main body
- Pupil/IOL holder disk
- PMMA corneal shell with aspheric anterior surface
- IOL held in pupil disk by its haptics
- Fluid with the index of refraction of the aqueous humor
- Threaded central body to allow eye length to be changed
- Volume change reservoir
- Artificial retinal surface - dark gray matte paint
- Removable artificial retina
- Rear body with threads for attached to microscope objective or wavefront refractor holder
Fluid filled test eye

- Reservoir
- Rear body
- Main body
- Corneal shell
- Rear window holder
- Central body
- Main body
Experimental setup - transmission mode to set eye length

- Microscope objective
- 100 mm Badal lens
- 10 micron pinhole
- Tungsten/halogen lamp
- Fluid filled test eye
- CCD camera
Experimental setup - measurement with wavefront eye refractor

- Wavefront eye refractor headrest
- Wavefront eye refractor objective
- Threaded test eye holder
- Fluid filled test eye
Shack-Hartmann spots patterns showing spot doubling

- ZM900, +25 D diffractive IOL, +4 Add, ‘Technis’ design i.e. aspheric surface to correct spherical aberration
Corneal shell design parameters

\[ r_{\text{front}} = 7.80 \text{ mm}, \ k = -0.10 \]

material - PMMA

\[ r_{\text{back}} = 7.22 \text{ mm}, \ k = 0.0 \]

central thickness = 0.5 mm
Measurement results

ZM900

<table>
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<tr>
<th>Patient</th>
<th>Vis V</th>
<th>Diagnosis</th>
<th>High Order Aberrations</th>
<th>Astigmatism</th>
<th>Quality</th>
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<td>66%</td>
<td>High Order: 7.5%</td>
<td>+0.50 DC x 5.75 Rx</td>
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<tr>
<td>OD</td>
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<td>66%</td>
<td>High Order: 8.4%</td>
<td>+0.50 DC x 5.75 Rx</td>
<td>Excellent</td>
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Custom Vue IVUS

Quality: Good

Custom Vue IVUS

Quality: Excellent
Shack-Hartmann spot patterns - refractive multifocal IOL

- NXG1 +25 D refractive multifocal IOL, +4 Add, annular alternating distance/near design

Centered on pupil

Vertically de-centered 0.5 mm

Change in centration causes change in spot pattern
Measurement results

NXG1
Summary- diffractive IOL

- Diffractive bifocal IOLs cause S-H spots to double
- In the presence of spot doubling, one wavefront eye refractor (WaveScan) found the correct distance refractive error value and reasonable higher order aberration values
- The presence of a diffractive IOL in the eye can be detected by the presence of S-H spot doubling
- Clinically, the use of wavefront eye refractor finding may be used, with caution, to plan a post IOL implant refractive correction
Summary- refractive IOL

- Refractive multifocal IOL cause S-H spot pattern distortion
- In the presence of spot distortion, one wavefront eye refractor (WaveScan) does not find the correct distance refractive error value and nor does it find reasonable higher order aberration values
- The presence of a refractive IOL in the eye can be detected by the presence of S-H spot distortion
- Clinically, it would be better to use subjective refraction findings to plan a post IOL implant refractive correction
Thank you