Differences in Wavefront Refraction and Higher Order Aberration Measurements between Three Different Aberrometers

Ronald R. Krueger, M.D.
Jerome C. Ramos-Esteban, M.D.
Karolinne Maia Rocha, M.D.
Sonya Bamba, M.D.
Commercial Disclosures

• Ronald R. Krueger, M.D.
  - Consultant Alcon
• Jerome Ramos-Esteban, M.D.
  - None
• Karolinne Maia Rocha, M.D.
  - None
• Sonya Bamba, M.D.
  - None
Purpose

• To evaluate differences in wavefront refraction (WFR) and higher order aberration measurements (HOA) in normal subjects between three commercially available aberrometers under room light illumination before and after cycloplegia
Methods

• 10 healthy volunteers, divided into 2 groups (n=5)

• Group 1:
  - Young presbyopes (age 45 to 55)
  - Mean SE -1.45 D

• Group 2:
  - Pre-presbyopes (age 20 to 40)
  - Mean SE -1.75 D
HOA Assessment

• Testing conditions:
  - Room light illumination
  - Measurements before/after Tropicamide 1%

• Evaluated parameters:
  - Pupil diameter (PD)
  - Wavefront Refraction (WFR)
  - Higher order aberrations (HOA)

• Wavefront information determined for two predetermined PD of 5.0 and 6.5 mm
Aberrometers

LADARWave 4000 (ALCON)

WaveScan (VISX/AMO)

Maxwell Ocular Wavefront (Ziemer/Imagine Eyes)
Technical Specifications

<table>
<thead>
<tr>
<th></th>
<th>WaveScan</th>
<th>LADAR</th>
<th>Maxwell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle</td>
<td>HS</td>
<td>HS</td>
<td>HS</td>
</tr>
<tr>
<td>Pupil Diameter (mm)</td>
<td>5 - 6</td>
<td>2.5 -10</td>
<td>2 -10</td>
</tr>
<tr>
<td>Dynamic Range (D)</td>
<td>+6 to -8</td>
<td>+15 to -15</td>
<td>-15 to +20</td>
</tr>
<tr>
<td>Laser Wavelenght (nm)</td>
<td>785</td>
<td>820</td>
<td>780</td>
</tr>
<tr>
<td>HOA</td>
<td>6(^{th}) order</td>
<td>8(^{th}) order</td>
<td>6(^{th}) order</td>
</tr>
<tr>
<td>HOA PD Adjustable(^*)</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Corneal Aberrations</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

*Zernicke Tool Software used to obtain HOA information at pupil diameters (5.0 and 6.5 mm) for WaveScan
Statistical Analysis

• The average of three consecutive measurements was used for statistical analysis

• Descriptive statistics were used to summarize numerical data

• Differences in PD, WFR, and HOA measurements between aberrometers were assessed using paired T-test
Experimental Design

10 healthy Volunteers

Group 1
Young Presbyopes
n=5

Group 2
Pre-Presbyopes
n=5

Pupil diameter
Wavefront Refraction
HOA

Before and after Tropicamide 1%
### Patient Demographics

<table>
<thead>
<tr>
<th>GROUP</th>
<th>MEAN AGE</th>
<th>SD</th>
<th>M</th>
<th>F</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>48.4</td>
<td>5.13</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>26.4</td>
<td>5.32</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>
Undilated Pupil Diameter
Presbyopes

<table>
<thead>
<tr>
<th></th>
<th>Maxwell</th>
<th>LADAR</th>
<th>WaveScan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm)</td>
<td>5.41</td>
<td>5.59</td>
<td>5.85</td>
</tr>
<tr>
<td>SD</td>
<td>0.93</td>
<td>0.80</td>
<td>1.02</td>
</tr>
</tbody>
</table>

WaveScan PD measurement > 0.26 mm over LADAR  p=0.19
0.44 mm over Maxwell  p=0.015
Undilated Pupil Diameter
Pre-presbyopes

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<th>LADAR</th>
<th>WaveScan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm)</td>
<td>5.42</td>
<td>5.66</td>
<td>5.95</td>
</tr>
<tr>
<td>SD</td>
<td>0.77</td>
<td>0.37</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Wavescan PD measurement > 0.29 mm over LADAR  $p=0.23$
0.53 mm over Maxwell  $p=0.025$
### Mean Undilated Wavefront Refraction

**Presbyopes**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Sphere (D)</td>
<td>-0.97 (0.5)</td>
<td>-1.37 (1.7)</td>
<td>-0.71 (1.6)</td>
</tr>
<tr>
<td>Cylinder (D)</td>
<td>-0.91 (0.5)</td>
<td>-0.75 (0.6)</td>
<td>-0.81 (0.6)</td>
</tr>
<tr>
<td>Axis (Degrees)</td>
<td>81 (75)</td>
<td>89 (67)</td>
<td>121 (64)</td>
</tr>
</tbody>
</table>

**Note:**

- LADAR Sphere measurement > 0.4 D over Maxwell, p=0.039
- 0.6 D WaveScan, p=0.003
Mean Dilated (6.5 mm) Wavefront Refraction Presbyopes

<table>
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<tr>
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<th>WaveScan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sphere (D)</strong></td>
<td>-1.15 (1.7)</td>
<td>-1.54 (2.6)</td>
<td>-1.52 (1.7)</td>
<td>-0.99 (1.8)</td>
</tr>
<tr>
<td><strong>Cylinder (D)</strong></td>
<td>-0.2 (0.3)</td>
<td>-0.46 (0.2)</td>
<td>-0.43 (0.3)</td>
<td>-0.39 (0.6)</td>
</tr>
<tr>
<td><strong>Axis (Degrees)</strong></td>
<td>72 (98)</td>
<td>71 (74)</td>
<td>73 (67)</td>
<td>110 (69)</td>
</tr>
</tbody>
</table>
Mean Dilated (5.0 mm) Wavefront Refraction Presbyopes

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<tr>
<td>Sphere (D)</td>
<td>-1.15 (1.6)</td>
<td>-1.32 (2.4)</td>
<td>-1.21 (2.1)</td>
<td>-0.80 (1.6)</td>
</tr>
<tr>
<td>Cylinder (D)</td>
<td>-0.20 (0.3)</td>
<td>-0.42 (0.3)</td>
<td>-0.5 (0.3)</td>
<td>-0.40 (0.3)</td>
</tr>
<tr>
<td>Axis (Degrees)</td>
<td>72 (98)</td>
<td>74 (71)</td>
<td>72 (72)</td>
<td>113 (72)</td>
</tr>
</tbody>
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CR SE 0.47 D > WaveScan WFR SE p=0.03
Mean Undilated Wavefront Refraction
Pre-presbyopes

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<tr>
<td>Sphere (D)</td>
<td>-1.49 (1.8)</td>
<td>-1.84 (1.9)</td>
<td>-1.54 (1.7)</td>
</tr>
<tr>
<td>Cylinder (D)</td>
<td>-0.46 (0.2)</td>
<td>-0.51 (0.2)</td>
<td>-0.55 (0.2)</td>
</tr>
<tr>
<td>Axis (Degrees)</td>
<td>124.8 (56)</td>
<td>90 (68)</td>
<td>120 (52)</td>
</tr>
</tbody>
</table>

WaveScan cylinder measurement > 0.09 D over Maxwell * p=0.04
Mean Dilated (6.5 mm) Wavefront Refraction Pre-presbyopes

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<tr>
<td><strong>Sphere (D)</strong></td>
<td>-1.45 (1.6)</td>
<td>-1.31 (1.8)</td>
<td>-1.71 (1.9)</td>
<td>-1.46 (1.8)</td>
</tr>
<tr>
<td><strong>Cylinder (D)</strong></td>
<td>-0.4 (0.1)</td>
<td>-0.49 (0.2)</td>
<td>-0.44 (0.2)</td>
<td>-0.41 (0.1)</td>
</tr>
<tr>
<td><strong>Axis (Degrees)</strong></td>
<td>130 (51)</td>
<td>94 (64)</td>
<td>126 (56)</td>
<td>121 (51)</td>
</tr>
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</table>
**Mean Dilated (5.0 mm) Wavefront Refraction Pre-presbyopes**

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<tbody>
<tr>
<td><strong>Sphere (D)</strong></td>
<td>-1.45 (1.6)</td>
<td>-1.07 (1.9)</td>
<td>-1.81 (1.9)</td>
<td>-1.28 (1.9)</td>
</tr>
<tr>
<td><strong>Cylinder (D)</strong></td>
<td>-0.45 (0.1)</td>
<td>-0.61 (0.1)</td>
<td>-0.43 (0.2)</td>
<td>-0.65 (0.4)</td>
</tr>
<tr>
<td><strong>Axis (Degrees)</strong></td>
<td>130 (52)</td>
<td>90.3 (70)</td>
<td>94 (69)</td>
<td>96 (73)</td>
</tr>
</tbody>
</table>

LADAR WFR SE 0.84 D > Maxwell WFR SE p=0.004
Mean Undilated HOA Presbyopes

WaveScan 0.09 μm > LADAR p=0.05
WaveScan 0.19 μm > Maxwell p=0.001
LADAR 0.08 μm > WaveScan p=0.02

- Total RMS
- Total HOA
- Defocus
- Astigm 1
- Astigm 2
- Horizontal Coma
- Vertical Coma
- Spherical Aberration

Maxwell  
LADAR  
WaveScan

Cleveland Clinic
Mean Dilated (6.5 mm) HOA
Presbyopes

- WaveScan 0.03 μm > LADAR p=0.003
- LADAR 1.11 μm > WaveScan p= 0.007
- WaveScan 0.13 μm > Maxwell p=0.03
- LADAR 0.06 μm > Maxwell p=0.01
Mean Dilated (5.0 mm) HOA
Presbyopes

WaveScan 0.07 μm > LADAR p=0.0009
WaveScan 0.07 μm > Maxwell p=0.048
Mean Undilated HOA Pre-Presbyopes

- LADAR 0.47 µm > Maxwell p=0.10
- WaveScan 0.33 µm > Maxwell p=0.01
- LADAR 0.62 µm > Maxwell p=0.03
- WaveScan 0.37 µm > Maxwell p=0.001
- Maxwell 0.07 µm > LADAR p=0.04
- LADAR 0.07 µm > WaveScan p=0.02
Mean Dilated (6.5 mm) HOA
Pre-presbyopes

- LADAR 0.96 µm > Maxwell p=0.002
- LADAR 0.76 µm > WaveScan p=0.003
Mean Dilated (5.0 mm) HOA Pre-presbyopes

- **LADAR 0.48 µm > WaveScan 0.66 µm, p=0.0002**

- **LADAR 0.12 µm > Maxwell p=0.04**

- **LADAR 0.10 µm > Maxwell p=0.03**

Graph showing various HOA measures for pre-presbyopic patients with data points for Maxwell, LADAR, and WaveScan.
Summary

• In comparison with cycloplegic refraction, the spherical magnitude of refraction (and magnitude of defocus) tends to be less with the WaveScan and more with the LADARWave in both presbyopic and pre-preserved eyes.

• The spherical magnitude of refraction (and magnitude of defocus) of the Maxwell is greater than the WaveScan in presbyopes and less than the LADARWave in pre-preserved eyes.

• Cylinder and HOA differences are variable.
Conclusions

• Diagnostic and therapeutic measurements should be performed with similar aberrometers and treatments should be laser platform specific.

Clinical Customized Ablations

CustomCornea (LADARWave)
Must typically use a “+” offset to treat less than the full Wavefront Sphere for an emmetropic outcome

CustomVue (WaveScan)
Must typically use a “-” offset to treat more than the full Wavefront Sphere for an emmetropic outcome