Spherical Aberration and Peripheral Through-focus Image Quality

Geunyoung Yoon, PhD
Flaum Eye Institute, The Institute of Optics, Biomedical Engineering, Center for Visual Science
University of Rochester

Myopia Progression Hypotheses

- Genetics
  - Parents with Myopia
  - Amount of Dopamine (which can inhibit eye growth)
- Environment
  - Time spent outdoors
  - Amount of near work and intensive schooling
  - Impact of wavelength and light intensity on eye growth
- Accommodative lag during close work
  - Leads to hyperopic defocus and a blurred retinal image
- Peripheral defocus
  - Result of a prolate eye shape…triggers axial growth
  - Hyperopic defocus in the peripheral retina

Peripheral Refraction in Children

Spherical equivalent cycloplegic autorefraction 30° nasal
822 children aged 5 to 14 years

<table>
<thead>
<tr>
<th>Refractive Category</th>
<th>Primary Guess Spherical Equivalent</th>
<th>Peripheral Sphere</th>
<th>Peripheral Cylinder</th>
<th>Peripheral Spherical Equivalent</th>
<th>Relative Peripheral Refraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopes</td>
<td>-2.84 ± 2.09</td>
<td>-0.61 ± 1.09</td>
<td>2.31 ± 0.82</td>
<td>-2.06 ± 1.82</td>
<td>-2.84 ± 1.09</td>
</tr>
<tr>
<td>Emmetropes</td>
<td>+0.44 ± 0.45</td>
<td>+0.17 ± 0.64</td>
<td>0.08 ± 0.35</td>
<td>+0.03 ± 0.70</td>
<td>+0.44 ± 0.70</td>
</tr>
<tr>
<td>Hyperopes</td>
<td>+1.81 ± 0.79</td>
<td>+0.24 ± 0.09</td>
<td>2.19 ± 0.08</td>
<td>+0.72 ± 1.09</td>
<td>+1.09 ± 1.09</td>
</tr>
</tbody>
</table>

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Flaum Eye Institute, The Institute of Optics, Biomedical Engineering, Center for Visual Science
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Peripheral Defocus

Influence of form deprivation on refractive development and axial elongation
Foveal refractive development can be mediated by the peripheral visual field. An intact fovea is not necessarily needed for emmetropization to occur.

Myopia Control Solutions

- Under-correction of myopia
- Atropine/Pirenzipine
- UV Light Exposure/Time Spent Outdoors
- Tints/Filters
  - May include gradient tints to reduce transmission of red wavelengths
- Accommodative Lag
  - Bifocal and multifocal lenses to reduce accommodative error
  - Esophoria reduction with prisms
- Peripheral Defocus
  - Refractive, Diffractive, Fresnel, PALs, Bifocal or Multifocal
  - Ortho-K (Orthokeratology)
Study Goal

To understand the potential benefits that can be achieved by using primary and secondary spherical aberration as a peripheral optical treatment strategy.

Work in Progress Hypothesis:
Spherical aberrations provide a myopic shift and extended depth of focus in the peripheral retina, desensitizing the system to a hyperopic shift of refractive error.

Impact of SA on Visual Performance

- **No aberration**: No defocus is applied.
- **+SA**: Positive spherical aberration applies a myopic shift.
- **-SA**: Negative spherical aberration applies a hyperopic shift.

SA degrades image quality.
SA shifts subjective refraction.
SA increases depth of focus.

Interactions between SA and defocus

Optical Eye Model: Zemax™


- The study cohort comprised 121 emmetropic and myopic participants aged 25 ± 5 years (age range 18-36 years).
- A-scan ultrasound biometry and MRI measurements

<table>
<thead>
<tr>
<th>Medium</th>
<th>Refractive index @ 555nm</th>
<th>Radius of curvature (mm)</th>
<th>Asphericity</th>
<th>Distance to midsurface (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornea</td>
<td>1.376</td>
<td>7.77 + 0.022 * SR - 0.15</td>
<td></td>
<td>0.55</td>
</tr>
<tr>
<td>Aqueous</td>
<td>1.3374</td>
<td>6.4</td>
<td>-0.275</td>
<td>3.15</td>
</tr>
<tr>
<td>Anterior Lens</td>
<td>1.418 + 0.0100737Z 2 - 0.0020399(X 2 + Y 2)</td>
<td>11.48</td>
<td>-5</td>
<td>1.44</td>
</tr>
<tr>
<td>Posterior Lens</td>
<td>1.418 + 0.0100737Z 2 - 0.0020399(X 2 + Y 2)</td>
<td>11.48</td>
<td>-5</td>
<td>1.44</td>
</tr>
<tr>
<td>Vitreous</td>
<td>1.336</td>
<td>-5</td>
<td>-2</td>
<td>16.28</td>
</tr>
<tr>
<td>Retina</td>
<td>RX = -12.91 – 0.094 * SR</td>
<td>FY = -12.72 + 0.004 * SR</td>
<td>QX = 0.27 + 0.026 * SR</td>
<td>QY = 0.25 + 0.017 * SR</td>
</tr>
</tbody>
</table>

Optical Eye Model: Zemax™

- Foveal retinal image quality was optimized
- Zernike primary and secondary spherical aberration was induced onto the anterior cornea
  - ±0.10, ±0.25, ±0.50, ±0.75, ±1.00µm over a 6mm diameter
- Wavefront is calculated for an elliptical pupil with a 6mm long axis at 0, 10 and 20 deg
- Through-focus peripheral image quality was calculated using area under MTF

Interactions between SA and defocus

Visual Performance Measurement

- Native aberration corrected
- Aberrations from eye model induced
- 0, 10, 20 degrees temporal retina
- High contrast visual acuity
- 6mm circular pupil
SAs induces a myopic shift and extends depth of focus.

**Take Home Message**

Spherical aberrations provide benefits of shifting refractive error to myopic direction and extended depth of focus at the peripheral retina.

The combined effects may be effective in controlling myopia progression compared to the effect of peripheral myopic defocus alone.