Presbyopic Correction Through Negative Spherical Aberration

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Presbyopic Correction Through Negative Spherical Aberration

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The symptoms of moderate presbyopia can be alleviated by introducing controlled amounts of negative spherical aberration. The treatment trades best-focus image for greater depth of focus.
Refresher: What is “Spherical Aberration (SA)”?

Zero
Paraxial power = Peripheral power

Positive
Paraxial power < Peripheral power

Negative
Paraxial power > Peripheral power
Presbyopia can be mitigated by increasing the eye’s depth of focus

Problem
Accommodation loss creates a fixed-focus system with symptoms of blurry images for most of the object distances.

Solution
Introduce a controlled amount of negative spherical aberration to achieve longer depth of focus.
Methods
Optical simulations were used to design and test long depth of focus in a model eye

The model eye was optimized to achieve the best focus of the object at infinity

Pupil Diameter = 6mm

<table>
<thead>
<tr>
<th>Anterior Cornea parameters</th>
<th>Radius (mm)</th>
<th>Conic Const</th>
<th>2nd order coef</th>
<th>4th order coef</th>
<th>6th order coef</th>
<th>8th order coef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic model</td>
<td>7.8</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Aspheric model</td>
<td>7.71</td>
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<td>-0.000816</td>
<td>0.000825</td>
<td>-0.000231</td>
<td>0.000019</td>
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</tbody>
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Results
**Through-focus spot diagrams** show that image quality is more consistent with negative SA.

Spot diagram is analogous to PSF.

Model eye was optimized for the best focus of an object at infinity.
The *Encircled Energy* of an eye with negative SA changes less for far and near objects than the eye with zero SA.
For both far and near objects, the PSF of an eye with negative SA changes less than an eye with zero SA.

Geometric polychromatic point spread function was calculated using 3 wavelengths – 450, 550, and 650 nm.
MTF of an eye with negative SA shows less variability for far and near objects.
Conclusions

Simulations with a model eye show that reduction in image quality (contrast and sharpness) is slower with negative spherical aberration than when no spherical aberration is present.

Controlled amounts of spherical aberration can mitigate moderate presbyopia by trading best-focus image quality for longer depth-of-focus.