**Custom Contact Lenses For Vision Improvement**

Are They Feasible In A Disposable World?

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**What is Wavefront Aberration?**
Sources of Retinal Image Blur

- Diffraction
- Aberrations
- Light Scatter

Point Spread Function vs. Pupil Size

**Perfect Eye**

Point Spread Function vs. Pupil Size

**Typical Eye**
What is the Wavefront?

- Ideal wavefront: plane wavefront
- Defocused wavefront: parallel beam

What is Wavefront Aberration?

- Parallel beam: plane wavefront
- Aberrated beam: irregular wavefront

Wavefront Aberration of a Surface

3 Dimensional View
2 Dimensional View

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How Do We Measure Wavefront Aberrations of the Eye?

Shack-Hartmann Wavefront Sensing

Shack-Hartmann Wavefront Sensor

Perfect Eye

Aberrated Eye
Deconstruction of a Wavefront

Hartmann-Shack Image → Reconstructed Wavefront

Defocus Astigmatism Coma Triangular Astigmatism Spherical Aberration

Zernike Modes

radial order 2nd

3rd

4th

5th

Zernike Co-Efficients

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Is There a Need for Contact Lenses Which Correct Higher Order Wavefront Aberrations?
PSF Convolution
3mm Pupil
6mm Pupil
Wavefront
PSF
Convolution
Normal Population Distribution
Zernike Co-efficient Distribution - Normal Population
Zernike Co-efficient Magnitude (um)
Mean
Mean±SD
Min-Max
Z311
Z310
Z331
Z330
Z400
Z420
Z421
Z440
Z441
Z510
Z511
Z530
Z531
Z550
Z551
Pupil = 6.0mm
n = 838
HORMS vs Refractive Error
Relationship Between Refractive Sphere and Higher Order Wavefront Aberration of the Eye
Refractive Sphere (D)
HORMS (um)
Pupil Size = 6.0mm
n = 838
53%
Designing Contact Lenses - Which Higher Order Wavefront Aberrations Should We Correct?

Designing Custom Contact Lenses

Wavefront "Optimized":
- Partial HOA correction
- Usually Defocus and Spherical Aberration
  - Rotationally symmetrical aberrations
  - e.g. Purevision, Choice AB, Frequency55, Biomedics55, Premier

Wavefront Guided:
- Full wavefront correction
- 2nd thru 5th or 6th HOAs
  - Symmetrical and non-rotationally symmetrical aberrations
  - e.g. Ophthonix IZon, Technovision LaseLens, QuarterLambda, SynergEyes W

Population Spherical Aberration

![Histogram of Normal Population Spherical Aberration (Z_4)](image)
Aspheric Contact Lens Optics

Simplest custom contact lens design
- Corrects rotationally symmetric SA
- Based on population average
- Easily manufactured with lathe technology

The Ideal Aspheric Design

-6.00D -5.00D -4.00D -3.00D -2.00D -1.00D Spherical Aberration

SPHERICAL ANTERIOR

SF<1

0.15µm ASPHERIC ANTERIOR

SF=1

LEVEL OF SPHERICAL ABERRATION TO THEORETICALLY OFFSET POPULATION AVERAGE (ASSUMING PERFECT LENS CENTRATION) -0.20µm
Visual Impact Beyond SA

Custom Correction of Wavefront Aberration with Contact Lenses
- What Type of Lens Should We Use?

Customized Contact Lenses
- Effect of Rotation & Movement

Gurao et. al. VSIA, 2000
Optimally Fit RGP Lenses

Soft Lens Fitting Theory

Soft Toric Lens Design

- Orientation Mechanism Necessary
Custom Correction of Wavefront Aberration with Soft Contact Lenses
- How to Manufacture?

Manufacturing Techniques

Custom Lathing:
- 3-axis lathe
- Sub-micron accuracy
- Hydration phase
- No polishing
- Cost effective

Custom Molding:
- Personalized molds necessary
- Lathed or Ablated
- Plastic or Metal
- High Dk materials
Manufacturing Techniques

Combined Molding/Lathing:
- Mold posterior surface
- Lathe anterior surface

Direct Ablation:
- Anterior surface ablation of dry polymer
- High Order ablation on Low Order blank
- Small spot size Excimer
- Slow
- Expensive

Measured Aberration of Customized Contact Lens

Design vs Measurement

Residual HO rms = 0.25 μm

WFG CLs: The Business Model

- Wavefront Sensor Measures Aberration in Clinician's Office
- Correcting Lens Design is Computed Remotely Via Internet
- Lens is Custom Packaged and Delivered to Doctor or Patient
- CNC Lathe Creates Non-Symmetric Customized Lenses

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Custom Correction of Wavefront Aberration with Soft Contact Lenses

- Can We Improve Vision?

Correction of the eye's aberration using phase plate and measurement of visual performance

Reduction of RMS Error
Reduction of HOA: Feasibility

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<th>JP</th>
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Improvement in VA

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Correction of 3 keratoconic eyes with Customized Soft Contact Lenses

- 45% water content hydrogels
- Standard B&L Optima Toric design - lathe cut
- Sphero-cylindrical over-refraction, 4 alternative forced choice acuity task

Custom Correction of Wavefront Aberration with Soft Contact Lenses

- Issues to Resolve?
Issues to Resolve

- Lens Centration
- Adaptation of the Visual System

Line of Sight vs Visual Axis

Methods
Lens Centration

Pupil Center Relative to Corneal Center

Visual Axis Relative to Pupil Center

Acquisition: Trial Lens

Issues to Resolve

- Lens Centration
- Adaptation of the Visual System
Correction of Keratoconics
(Sabesan & Yoon, 2009)

- Comparison of keratonic to normal eyes
- Real-time adaptive optics to correct HO aberrations
- 4 alternative forced choice acuity test

Conclusion

Technically Feasible for a Large Percentage of the Population Needing Vision Correction

To Be Maximally Effective It Requires Custom Correction of Individual Non-Rotationally Symmetric Wavefront Aberrations Up to and Including 5th Order Zernike.

Can Be Delivered Within the Paradigm of Disposable Lenses

Consistent Orientation and Centration of Lens Necessary

May Require Adaptation of the Visual System to Recognize Full Benefit