Smart Contact Lenses: The Future is Now

Jerome A. Legerton, OD, MS, MBA, FAAO

"Everyone who's ever taken a shower has an idea. It's the person who gets out of the shower, dries off and does something about it who makes a difference."

--Nolan Bushnell, American engineer and entrepreneur

My Journey

• 26 years in Private Practice
• 19 years in product development
• 38 issued US Patents; 53 pending applications
  - 3 Alcon (PBH-WJ-Ciba). Multifocal contact lenses
  - 2 AMO (VISX). Presbyopia laser surgery
  - 13 Paragon Vision Sciences: Paragon CRT®, Refractive Error Regulation, NormalEye®; 15.5 mini-scleral lenses
  - 11 Synergeyes®; Family of lenses and processes
  - 2 Preventive Ophthalmics, Inc. DxDAMD™ Early detection AMD
  - 1 Innovega, Inc. iOptik™ wearable computer
  - 5 VICOH, LLC; Family of contact lens designs
  - 1 Eye Care for Humanity; low cost spectacle eyewear

"It's not that I'm so smart, it's just that I stay with problems longer."

--Albert Einstein

Let’s look into the future

What will photonics, electronics and information technology bring to the field of contact lenses and ophthalmic optics?

“Only those who will risk going too far can possibly find out how far one can go.”

--T.S. Eliot, American-British writer

Disclosures:

Interests in products mentioned in this presentation:
• Innovega Inc.
• Paragon Vision Sciences, Inc.
• Carl Zeiss Vision, Inc.
• VICOH, LLC

A Study of Trends Will Make You a Futurist

What trends will impact the contact lens and ophthalmic lens industry?
• Increase in incidence and prevalence of myopia
• Increased urbanization along with indoor life style
• Graying demographics of developed nations
• Miniaturization allowing for electronic components in lenses
• Precision metrology and manufacturing allowing for enhanced control of optical path
• Consumer appetite for mobile information and entertainment
• Peripheral or implanted sensors and sending units to monitor human anatomy and physiology
The Futurists
- Vernor Vinge, PhD: Rainbow’s End
- The Terminator
- Mission Impossible

MEMS and Nanotechnology
- Micro-Electro Mechanical Systems
  - Every year components get smaller [Bell’s Law]
    - Now have batteries, antennas, LEDs, mechanical and electronic sensors
    - Small enough and low cost enough to be put in a contact lens
- Nano-technology
  - Components for modulated drug delivery
  - Light filtering
    - Spectral and polarizing
- Micro-optical elements
  - Diamond turning and molding to sub-micron accuracy

Bell’s Law
- "The eye is the light of the body"
  - Close to the central nervous system
  - Transparent
  - Tear film communicates body chemistry
  - Aqueous communicates
  - Crystalline lens communicates
  - IOP changes corneal geometry
- Drug delivery enigma – need for slow delivery over time
- Control of optical path – central and off axis focus
- Control of illumination – role of central and off axis light
- Advantages of eye-borne optics – field of view and low bulk

Why Contact Lenses?
- "TriggerFish"
  - STMicroelectronics and Sensimed
    - Nano-sensors fabricated in silicon-based MEMS technology
    - Measure the shape change of eye with pressure
    - Couple with drug delivery (future)

Intraocular 1.5 mm³ IOP Monitor
- Continuous IOP monitoring
- Wireless communication
- Energy-autonomy
- Device components
  - Solar cell
  - Wireless transceiver
  - Cap to digital converter
  - Processor and memory
  - Power delivery
  - Thin-film Li battery
  - MEMS capacitive sensor
  - Biocompatible housing
Power Sources

University of California Davis
- Conductive silver wires used to measure pressure changes

Another IOP Sensing Contact Lens

Contact lenses detect blood sugar changes

University of Western Ontario in Hamilton (Jin Zhang)
- Hydrogel contact lenses with nano-particles
- React with glucose molecules found in tears
- Chemical reaction changes color

Microsoft and University of Washington
- Electronic contact lens that can non-invasively monitor and wirelessly report blood sugar levels;
- Employs a single LED

First Phase Animal Testing

Auburn University
- Imprinted contact lens
- Successful in sustained drug delivery

Smart Drug Delivery Contact Lenses

Ocugenics Drug Delivery Contact Lens Technology

- Drug delivery contact lens technology with collagen mesh in polymer
- Collagen mesh has desired characteristics for delayed drug delivery

Pharmaceutical Assisted Refractive Therapy

- Corneoplasty
  - Yolia Health: KMDI™ and TVT ™ (True Vision Therapy)
  - Euclid
  - Others ???

Digital Media

Consumers are hungry for anytime-anywhere rich media.

Contact lenses will deliver the iPod audio experience as a mobile iMax multi-media experience.

Michio Kaku

Physics of the Future: How Science will Change Daily Life by 2100

“The Internet will be in your contact lens”

“It will recognize people’s faces, display their biographies, and even translate their words into subtitles”.

Pain: Media Bottleneck

- Screen too small for rich content
- Narrow Field of View
- Unattractive Styling
- Excessive Bulk

Limitation of Personal Displays

Mobile Entertainment Screens

Small to be “pocketable” – Too small to enjoy

Virtual and Augmented Reality Contact Lenses

University of Washington (Babak Parviz)

- Incorporating micro-circuitry for augmented reality applications.
- Rich content requires substantial pixel density
- Diffraction is expected to limit the scope of the application.
Semprius Micro-display Lens

- 32x32 display using OLED pixels
- Solution to the power issue - thin film micro-solar cells

The Era of Intra-lens Components

- Micro-Electro-Mechanical Systems
- Light-emitting
- Power sources
- Sensors
- Processors
- Antenna
- Oxygen generators
- Micro-optical components
  - Lenslets
  - Filters
  - Reflectors/deflectors
  - Diffusers
- Nano-structures
  - Drug delivery
  - Anti-microbial products and systems

Delivering Wearable Digital Media

The Problem:

- Eyewear Digital Systems Today
  - High bulk
  - Not stylish
  - Small field of view
- Rich Media will require
  - Further miniaturization
  - Optics that enable greater than 60° FOV
  - Performance in bright ambient lighting

Solution: Contact Lens Enabled Wearable Displays

Passive Optics: Innovega Inc. iOptik Contact lens

Inc. Magazine
April, 2012
Centerfold

Eliminating Optics in Eyewear Breaks the FOV/Bulk Trade-off

- BULK
- Field Of View (Degrees)
- iOptik
- Google
- Vuzix
- TOVVisor
- eMagin
- NVIS
- Rockwell Collins
- iOptik™ Contact Lens

Built on the Paragon NormalEyes 15.5 mini-scleral Platform

Outer lens provides normal vision for real world

Center lens streams HD/3D Digital Media from eyewear

Paragon Vision Sciences is the development partner
How iOptik™ Display Works

- Passes real world and rejects display light
- Passes display light and rejects real-world
- Enables wearer to view near-eye media without altering normal vision

Gas Permeable Nano-polarizer Contact Lens

Off-axis projection to transparent holographic film on spectacle lens

Technology in Development

- Off axis projection
  - LCOS
  - Laser Pico-projector (Microvision)
- Film in spectacle lens
  - Holographic volumetric film
  - Transflective film (Microvision)
  - Speckle free
- Eye trackers

iOptik HMD System

- Optics embedded in contact lens enable focus of imagery on spectacle lens
- LCOS module projects image onto holographic reflector spectacle lens
- Wearer can see unobstructed surrounding environment and projected image simultaneously
- Contact lens optics provide high spatial resolution in direction of gaze, lower resolution in peripheral vision
- Retro-reflective embedded in contact lens enables high-speed pupil tracking without imaging

Contact Lens Enabled AR Wearable Display Elements

Eyewear Configuration

Projected image outline on spectacle lenses
Initial Projector Optical Design

- Complex aspheric projection optics required to achieve off-axis, short working distance projection
- Latest design has reasonable size and weight, and image resolution at the pixel level over the foveal image region

Perspective Views of Spectacle Lenses and Projector

- Orientation between each spectacle lens and its corresponding projector module must remain constant
- Nose-piece will be adjustable z and y axis to center lenses to eyes
- PD adjustments in projector modules
- Different eyewear sizes required to support diversity of head width and PD

Eyewear Configuration

- 100% stereoscopic overlap

100% stereoscopic overlap

Anthropometric Model

- Head Form Overview
- Head Form Overview

Head Metrics

<table>
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<tr>
<th></th>
<th>Head Size</th>
<th>Eye Locations</th>
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<tr>
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<td>Width</td>
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<td>212.0</td>
</tr>
<tr>
<td>Average</td>
<td>267.8</td>
<td>167.8</td>
</tr>
</tbody>
</table>

Projector Placement Imposed
February to June

Spectacle Lens Reflector Function
- Passes surrounding environment light unmodified
- Reflects display light towards pupil
- Expands reflected beams at each pixel to fill the pupil at all gaze angles

Transflective Diffuser
- Micro lens array sandwiched between two transparent substrates
- MLA elements receive narrow band reflective coating
- Refractive index of optical adhesive laminating substrates together matches index of MLA
- Transmitted light passes through constant index of refraction without distortion
- Projected light is reflected with diverging angles due to curved nature of reflective coating
- Uses specular reflection resulting in no speckle

Transflective Diffuser Demonstration
- Sample MLA has poor surface quality
- 100 um pitch (desired pitch is 25 um)
  - Results in low resolution image “spots”
- Demonstrates clear transmission simultaneous with diffuse projected image reflection

25 Micron Transflective Reflector Configuration

Transflective Film Performance
Pupil Tracking

- Retro-reflector is embedded into each contact lens
- Scleral contact lenses are rotationally and laterally stable on eye
- IR LED illuminates eyes with low power IR
- Photo-sensor detects position of retro-reflector
  - A calibration step is required to initially register the virtual image to the real world.
  - Low latency tracking with no image processing required

Pupil Tracking Geometry

Unknowns (10 Total):
- 2 axis left eye rotation
- 2 axis right eye rotation
- 3 axis eyewear rotation
- 3 axis eyewear translation

Knowns (6 Total):
- Azimuth, elevation, and distance to eye from left eye sensor pair
- Azimuth, elevation, and distance to eye from left eye sensor pair

Physical constraints
- Eyes track together in vertical direction (eliminates One unknown)
- Assume eyewear pitch rotation is centered at ears and is therefore largely a Y translation at eyes
- Assume tight eyewear fit does not allow yaw rotation or X translation.

Warfighter Embodiment

- 720P
- 90° FOV
- Full Color
- 3-D stereoscopic
- Variable transparency (5% to 80%)
- HDMI tethered connection to smart phone or laptop
- Lithium ion battery mounted in head strap recharged via USB connection

Consumer Embodiment

- 720P
- 90° FOV
- Full Color
- 3-D stereoscopic
- Variable transparency (5% to 80%)
- HDMI tethered connection to smart phone or laptop
- Lithium ion battery mounted in head strap recharged via USB connection

Mobile “Display Accessory”

- Audio
- Micro HDMI Connector
- Holographic Lens
- LCOS Projector
- Smart Phone
- Micro HDMI or USB/MHL Connector
Transparent Optics

Media Interface blends Media with Surroundings

Emerging Application: Augmented Reality

Good AR requires transparency and large fields of view

High Resolution and Contrast in All Lighting Conditions

Bright Daylight
Without Contact Lens
Night
With Contact Lens

Inovega

First iOptik Clinical Testing

Naval Medical Center San Diego, July 2012

Your Future Patients

Serious Gamers
- First-person photo-real immersive 3D gaming
- More than 20% of 15-40 year old, “serious gamers” already wear contact lenses

Medical Applications
- Medical and Surgical Visualization and Training
- Low Vision

Defense Training & Simulation
- Presently a $1B per year business (US alone)

Defense and Intelligence Field Operations
- Next Generation Night Vision
- Situation awareness
- Remote weapon sight

Ultimately most anyone who wants to wear their media and computers

Analog: How many of you are wearing a wristwatch?

First Adopter Platforms

Mini-Scleral Platform (Paragon NormalEyes™ 15.5)
- Filters easier to encapsulate in rigid substrate
- Lens stability
- Rotationally
- Translationally
- Eye protection factor
- Foreign body migration
- Water environment
- Ballistic protection

Hybrid or Composite Platform
- Same rigid substrate advantages
- Easier to fit
- Comfort and convenience
The Un Met Medical Need
Low Vision Market “Pain”

Graying of Europe, Japan and the United States
- Age-related Macular Degeneration (AMD)
- Greater span of impact on individuals who are otherwise active and healthy
- Prevalence of DIGITAL media and information
- Stimulates greater need for image augmentation for low-vision patients

Low Vision
- Relative distance and angular magnification limited
- Field of view,
- Control of brightness, wavelength and contrast.
- No useful means of field expansion or night vision enhancement for patients with field losses and reduced low light acuity
- Need for useful augmented reality eyewear for the low partially sighted patients

Innovega Solution
- iOptik™ offers full field, high resolution, variable image amplification for all visual stimuli.
- Video and text and real time camera and sensor feed
- Field expansion through digital manipulation of camera captured data
- Night vision display to increase and equalize the brightness of displayed images
- Augmented reality to “bold border” objects to assist orientation and mobility of very low partial sighted patients

Improving Quality of Life for Low-Vision Patients
- Electronic image amplification offers a higher contrast ratio in a full field of view without optical distortion and the need to control ambient illumination
- Camera driven system provides real time “telescopic” image amplification in a full field of view
- Camera driven or digital feed reading system provides real time “microscopic” image amplification at a normal working distance
- Night vision sensor provides wide field amplification in scotopic or mesopic illumination for retinitis pigmentosa
- Simultaneous display of off blind field for hemianopia
- All digital data become available to the low vision patient as an alternative to current computer monitor and iPad systems.

Benefits of iOptik™ System for Low Vision
- Utilizes available high-definition digital processing and HD displays.
- Illumination, contrast, position and wavelength adjustment algorithm further enhance vision.
- 60 to 120 degree fields provide display of text and live or produced video feed in a magnified and augmented view which far surpasses optical magnification (more view or text presented in a line)
- Use of contact lens and light weight eyewear provides comfort, mobility and freedom for all day vision enhancement.
- Live camera feed allows for normal distances for holding text and objects along with visual access to the distance world that is not possible with telescopic lenses
- Transparent displays provide the potential for augmented reality for low form vision patients
- Night vision infrared or temperature sensors can provide useful images for orientation and mobility

Advantage of Field of View

1x in 31°

5x in 31°

5x in 93°

Competitive Head Mounted Displays
- All require mounting optics in eyewear to focus display directly or by total internal reflection optics
- Resultant limited field of view (approximate maximum 40 degrees)
- Thickness of display and optical system plus vertex distance results in front surface minimum 25 mm from eye
- Pupillary distance sensitivity and SKU or adjustment requirement
- Poor performance in high ambient light levels

Dr. Rejean Munger, Chief Scientist for eSight, Inc. and a senior scientist at the University of Ottawa Eye Institute
“...making electronic vision aids lighter and less obstructive will mean more people will wear them and for longer periods.”
Jordy Head Mounted Display

The current Gold Standard for electronic low vision aids.

Low Vision Market Size

- NIH has identified Low Vision as a major public health problem.
  - "With the aging of the population, the number of Americans with major eye diseases is increasing, and vision loss is becoming a major public health problem. By the year 2020, the number of people who are blind or have low vision is projected to increase substantially." (Archives of Ophthalmology, Volume 122, April 2004)
- 3.3 million (2004) in US; Forecast 5.5 million by 2020
- 124 million globally currently (World Health Organization)

Prior to 1980 and the widespread use of Intracocular Lenses for cataract surgery, more than 10% of all contact lens patients were over the age of 65.

UCSD Telescopic Contact Lens

UCSD Telescopic Contact Lens

Paragon Vision Sciences is the development partner

HANDS FREE ZOOM

Reflective Optics Telescope

- Thickness: 1.5mm
- Diameter: 8.7mm

Materials: HiRL (outer), HDS 100 inner

HFZ Telescopic Contact Lens

Concentric Folded Optics

Switching between telephoto and normal vision

Polarization and shutter eyewear

Passive polarization filters integrated into contact
Switching via external polarization modulator in head-mounted glasses
50% maximum transmission

Normal vision: Transparent center
Telescopic vision: Transparent edge

Input scene image file: 80° field of view
Telescopic Vision
Simulated retinal image
Annular pupil: 2.8x mag
Smart Lenses for Presbyopia

Why Have Simultaneous Vision Provided Limited Results?

- They are pretty good in GP lenses, However;
  - GP are time consuming
  - GP have discomfort and foreign body limitations
- Simultaneous Vision has limited success in hydrogels
  - Why?

Cause of Visual Compromise in Simultaneous Vision Hydrogels

Visual Compromise
- Uncorrected cylinder
- Failure to center over the visual axis
- Lens to lens variance due to wide manufacturing tolerances
- On eye lens distortion
- Need for pupil size dependent design

Let's Look at Some of Today's Offerings with Power Mapping

Power Maps of Consecutive Lenses

Better but poor lens to lens reproducibility

Center Distance Multifocal (CDM)

Irregular center add geometry in final product – they didn’t intend this outcome

Pretty rough for optics; we wouldn’t accept this in a spectacle lens
Ingredients for Success with Simultaneous Vision

- Correct all low order aberrations (Sphere and cylinder)
- Center the optics over the visual axis
- Size the near segment based on pupil size and pupil reactivity
- Manufacture optics equivalent to GP lenses
- Maintain good surface wetting

We Will Damage PSF with a Simultaneous Vision Lens

So we must maintain optical integrity so much the more in every other way

- Correct all sphere and cylinder
- Center over the visual axis
- Produce excellent optics

What will it take to beat monovision?

- Rigid-like Optics with soft lens comfort
- Correction of astigmatism
- Pupil size driven add segment
- Centering of segment over the visual axis
- Practitioners who are interested to harness the technology
- Patients who want optimized vision

“Every design will work on who it works on”

Be thankful when they work

- Partial correction of cylinders
- Temporal displacement
  And the visual axis is nasal
  Most all multifocal designs are visual axis sensitive
- Poor or inconsistently manufactured optics
- One size fits all segment diameters

Fitting tip: Use topography over multifocal lenses to check location of segment relative to the pupil center

21st Century Manufacturing Technology

Cutting File Software
Optoform 80® / Fast Tool Servo Variform Lathe
Vibration Free – No Polish

Key Ingredients in a Successful Soft Multifocal

- Non-deforming lens design
- Segment Size
  - Pupil size and reactivity determines segment size
- Segment Location
  - Measured individual lens displacement
  - Pupil shift with focal demand and illumination change
- Add Power
  - Determined like spectacle lenses from
    - Regular near point testing
    - Vocational and avocational demands
    - Precision optics deliver full add power
Lens Deformation

- All soft lenses today deform on the eye
  - Base curve 2 to 6 diopters flatter than the cornea conforms to the cornea
  - Base curve 4 mm steeper than the sclera conforms to the sclera.
- Can only happen by deformation that varies from one patient to the next.

Industry needs a non-deforming design to use as a platform for multifocal contact lenses.

Pupil Size and Reactivity

Chateau, 1996
N = 112 (224 eyes)

<table>
<thead>
<tr>
<th>TABLE 2. Mean and standard deviation values of pupil diameter</th>
<th>( L_{d} = 60 \text{ cd} m^{-2} )</th>
<th>( L_{d} = 350 \text{ cd} m^{-2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance vision</td>
<td>( \phi = 4.7 \pm 0.85 \text{ mm} )</td>
<td>( \phi = 3.7 \pm 0.60 \text{ mm} )</td>
</tr>
<tr>
<td>Near vision</td>
<td>( \phi = 3.3 \pm 0.61 \text{ mm} )</td>
<td>( \phi = 2.7 \pm 0.42 \text{ mm} )</td>
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</table>

These data report the means but not the individual variance in reactivity.

Where do Hydrogel Lenses Center Relative to the Visual Axis?

- Most ride down and out
- The visual axis is nasal
- Most all multifocals are visual axis sensitive

Measuring Lens Decentration

Topography over best fit multifocal will demonstrate displacement of near segment optics from center of pupil.

Lens Geometric Center Relative to Illumination and Focal Demand

Will an optimized Peri-Focus lens require a de-centered therapeutic optical structure?

Pupil Shift with Focal Demand

Pupil shifts superior nasal with near demand and decreased illumination.
Mean Pupil Size Decreases with Age

What does this say for one size fits all?

The Era of Visual Axis Registration
Taking contact lens correction to the next level will require registration of the lens optics with the visual axis

- The best multifocal designs are visual axis sensitive
- Peri-focus refractive therapy designs may be best if registered
- Contact lenses for “wearables” are best when registered

Measuring Pupil Size, Reactivity and Location

OD
Photopic 2.6
Mesopic 4.3
Scotopic 5.3

Photopic (x,y) 0.542, -0.213
Scotopic (x,y) 0.316, 0.035

Multifocal Lens of the Future
An optimized multifocal requires a displaced near segment and may benefit from an irregularly configured near segment

But What Do I Do Now?

- Legerton’s Three Rules
  - Every lens design will work on who it works on
  - The practitioner that puts the most lenses on patients will fit the most patients
  - You can’t fit from an empty wagon
- Create a Presbyopic Contact Lens Evaluation Procedure
- Have three to five designs to evaluate on every patient

Does it Matter?

- If you had to take extra measurements to improve your success and productivity in fitting multifocal lenses, would you do it?
- If customization instead of one size fits all were required would you be interested?
- Are monovision and one size fits all good enough for you and your patients?
Suggested Designs

- B+L Purevision
- Alcon O2 Optix
- CooperVision D & N (Modified Monovision)
- SynergEyes M
- GP Aspheric designs

The Future

Be willing to apply the same science to fitting contact lenses for presbyopia that you apply to your success with progressive addition spectacle lenses

Optically “Smart” Contact Lenses

Optically “Smart” Lenses; Optimizing Vision

Increasing Prevalence of Aberrometers

- Wavefront guided refractive surgery
- Wavefront driven free-form spectacle lenses
- Zeiss: i.Scription®
- Combo Instruments
- Nidek (Marco): OPD®
- Zeiss: i.Profiler plus®
- Ophthonix: Z’View®
- Topcon
- Tracey
More than 1000 in US market

It is time to start using them in the customized contact lens practice

2014: Year of Wavefront Guided Contact Lenses

Two companies spun off from Optical Connection, Inc. (St. Shine)

- WaveForm (previously WaveSource)
- WaveTouch
  - http://www.wavetouchtech.com/

Will they succeed in delivering on the promise? Mass market potential or niche?
Determine refraction for various pupil sizes

- Detect the wavefront across the full pupil aperture up to 7mm
- Provides useful information about the entire optical system of the human eye
- Wavefront data for the full pupil are used to optimize contact lens correction

The influence of the Aberrations on visual Performance depends highly on pupil Size

Aberrations impact night vision more than daylight vision

“Typical” Aberrations

Spherical Aberration Population Distribution

Soft Contact Lens Spherical Aberration Comparison

The population spherical aberration mean is approximately ~0.15 microns over 6 mm²
Wavefront “Lite”
1. Measure residual aberrations on all existing contact lens wearers as part of pre-testing for comprehensive examinations
2. Place 2 or more different brands of lenses of the same power and measure for the lowest residual aberrations
   - Applies to Spheres and Torics
3. Prescribe the lens with the desired residual HOA
   Resultant prescription should be optimized for all light levels and pupil sizes.

What will it take to produce a true wavefront guided contact lens?
- Rigid Optics (with soft lens comfort)
- Precision non-rotating diagnostic lenses
- A registration system
- An aberrometer
- A manufacturing method that is accurate to 0.05 microns over 6 mm
- Practitioners who are interested to harness the technology
- Patients who want optimized vision

Wavefront “Advanced”
- Place a precision predicate lens
- Measure residual lens eye aberrations
- Measure registration of lens and pupil
  - Rotational
  - X, Y
- Order custom lenses with Higher Order Aberrations registered to non-rotational lens respective to the eye

Aberrometers
- Moving toward standardization
- Provide the data for HOA treatment with surgery, contact lenses, and spectacle lenses

Buyer Beware
- Fallacy of one size fits all
  - Giving everyone the same spherical aberration correction ignores the normal distribution
  - Corneal aberrations most always transfer to the front surface of soft lenses
  - Contact lenses rarely center over the pupil
    - Decentered spherical aberration correction becomes a new coma aberration

Remember what happens with a decentered ablation

Correcting HOA with Contact Lenses
Place precision diagnostic lens
- Determine proper Base Curve Radius
- Measure residual Low and Higher Order Aberrations with Aberrometer
- Simultaneously measure registration error
  - Translational (x, y in 0.1 mm)
  - Rotational (θ in degrees)

Wavefront guided contact lenses will be technology driven and will require very little chair time or brain straining
Predicate Wavefront Lens

Apply Diagnostic Lens

11.8 mm Cornea

Superior Decentration \((x=0, y=0.5 \text{ mm})\)

and Nasal Rotation \((\theta = + 10^\circ)\)

Must rotate optics -10 degrees and decenter inferiorly 0.5 mm to register over pupil

Higher Order Aberration Correcting Lens

Higher order correction decentered and rotated to position over Visual Axis

The Result

Wavefront guided contact lenses
- Customized
- Optimized
- Corrected for best visual acuity
- Provide clearer, sharper real world vision
- Corrected low orders to better than 0.05D
- Corrected all high orders to 0.05 microns
The Perfect Sight Opportunity

Higher Order Aberration Correction

- Most eyes with loss of BSCVA (Best Spectacle Corrected Visual Acuity) have Higher Order Aberrations (HOA)

- Most eyes with Keratoconus and Surgical mishaps have HOA even with an RGP in place

“What we need is more people who specialize in the impossible.”

--Theodore Roethke, American poet

Thank you