LASER VISION CORRECTION
AND THE ADVENT OF
TOPOGRAPHY GUIDED TREATMENTS

Michael George, M.D.
The Evolution of Refractive Surgery

- Initially, the goal was “reduce or eliminate our patients’ dependence on glasses”

- Drawbacks and limitations were expected, and had to be tolerated:
  - **Glare** (worst at night)
  - **Halos** (worst at night)
  - **Loss of contrast sensitivity**
  - **Light sensitivity**
  - **Dry Eyes**

- Potential sources of the origin of these problems were explored, and improvements to laser design were made → eventually diminishing side effects
The Evolution of Refractive Surgery

• What improvements were made to the initial lasers?

• Laser vision correction is accomplished by changing the corneal shape.
  • More specifically, by changing the curvature of the anterior stroma within the visual axis

Myopia
Light rays are focused anterior to the retina

Myopic LASIK
Anterior Cornea Flattened
The Evolution of Refractive Surgery

- Initial Conventional Ablations had **Small Optical Zones**

  - Flattened the cornea centrally within the visual axis
  - Central Rays Focused on retina …20/20 vision!?
  - Rays peripheral to optical zone Retain myopic focus
Spherical Aberration

- Spherical aberration:
  - The increased refraction of light rays when they strike a refractive surface near its edge, in comparison with those that strike nearer the center.

- **Zero Spherical Aberration:**
  - All incoming rays are focused on the focal point.

- **Positive Spherical Aberration:**
  - Peripheral incoming rays are focused anterior to the focal point (sic).
Early Refractive Surgery Drawbacks

- Early myopic LASIK with small optical zones left patients with:
  - The clarity of 20/20 vision (from the central cornea)
  - The glare and halos of significant uncorrected myopia (from the peripheral cornea)

- Uncorrected Spherical Aberration was a primary contributor to these symptoms

- The higher the correction, the more severe the spherical aberration & symptoms
Post 2001 LASIK...

- More sophisticated techniques introduced to maintain prolate shape:
  - Larger Optical Zones (wider area of treatment)
  - Peripheral flattening
  - Central to peripheral blending (sometimes customized with patient’s Ks)
Post 2001 LASIK

- Improvements to **treatment algorithms** yielded less and less spherical aberration

- Goal to maintain prolate corneal shape

- Improvements made to **treatment times**
  - Long treatment times (minutes) results in bed dehydration
    - The more dry stromal tissue becomes, the more it gets vaporized by laser energy
  - Longer treatments $\rightarrow$ more dehydration $\rightarrow$ more treatment effect $\rightarrow$ unpredictable results
Further LASIK Improvements:

- **Eye Tracking** (prevent decentered ablation)
  - Pupil Tracking
  - Iris Registration  (axis of astigmatism)

- **Latency Times** (time between eye tracking and laser spot placement)

- **Maintaining Stable Laser Optics** (constant pulse power output)

- Type of Laser Beam Used: **Homogenous vs Gaussian**
Beam - Homogenous vs Gaussian

Homogenous  Gaussian

Gaussian Beam = More Uniform spot overlap & smoother surfaces
And now…. TOPOGRAPHY GUIDED LASIK!!
Topography Guided LASIK

- Has been called a “Paradigm Shift” in refractive laser treatment
- We are always aiming for “Perfection” -- 20/20 vision? 20/15 vision? Better?
- Why can some people achieve 20/15 vision in glasses and others cannot?

- Major contributing factor → Higher Order Aberrations

- Traditional LASIK only treats: Myopia, Hyperopia, and Astigmatism and tries to control for Spherical Aberration
Zernike Polynomials

PISTON

VERTICAL PRISM  HORIZONTAL PRISM

ASTIGMATISM  DEFOCUS  ASTIGMATISM

TREFOIL  COMA (vertical)  COMA (horizontal)  TREFOIL

QUADRAFOIL  SECONDARY ASTIGMATISM  SPHERICAL ABERRATION  SECONDARY ASTIGMATISM  QUADRAFOIL
Current LASIK Technologies defined

• **Wavefront Optimized**: Patient’s refraction alone is used to program the ablation, based on pre-existing database. *Does not address pre-existing higher order aberrations*. Treatment centered over pupil.

• **Wavefront Guided**: Information from a wavefront sensing aberrometer is used by the treatment laser to program the ablation. Treatments applied to the cornea are based on the total contribution of all elements in the eye (both cornea and lens aberrations). Treatment centered over pupil.

• **Topography Guided**: Designed to address corneal issues exclusively to create a custom pattern of laser spot application to regularize the corneal surface. Treatment centered over corneal apex.
Should we normalize the cornea? Or normalize the eye?

• Regarding Topography Guided LASIK:
  • Cases will exist where normalizing the cornea normalizes the eye
    • I.E. primary problem is irregularities in cornea
  • Cases will exist where normalizing the cornea leaves the eye with uncorrected irregularities!!
    • I.E. Lenticular astigmatism that neutralizes corneal astigmatism

• Regarding Wavefront Guided LASIK:
  • Cases will exist where normalizing the eye normalizes the cornea
    • I.E. when the cornea is the primary location of irregularities
  • Cases will exist where normalizing the eye creates unnecessary irregularities in the cornea
    • I.E. subclinical nuclear or cortical lens changes
    • I.E. congenital or acquired lens imperfections
    • I.E. state of accommodation measurement errors
    • I.E. state of pupillary dilation measurement errors
  • Do we want to treat the cornea based on a lens whose optical properties may (will) not be stable as you age? This may generate the need for secondary refinement procedures immediately or eventually.
<table>
<thead>
<tr>
<th>TOPO Guided (Refractive Suite) vs WF Guided (VisX) Measurements</th>
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</thead>
<tbody>
<tr>
<td>• Cornea More Stable (both short and long term)</td>
</tr>
<tr>
<td>• More Reproducible (more accurate)</td>
</tr>
<tr>
<td>• Not Pupil Dependent</td>
</tr>
<tr>
<td>• Measures Cornea then Treats Cornea</td>
</tr>
<tr>
<td>• Not Sensitive to Centroid Shift</td>
</tr>
<tr>
<td>• Greatly Enables Better Blending &amp; Transition Zones</td>
</tr>
<tr>
<td>• 22,000 Points Measured</td>
</tr>
<tr>
<td>• Global Preference YES</td>
</tr>
<tr>
<td>• Natural Lens Less Stable (both short and long term)</td>
</tr>
<tr>
<td>• Less Reproducible</td>
</tr>
<tr>
<td>• Pupil Dependent</td>
</tr>
<tr>
<td>• State of Accommodation Dependent</td>
</tr>
<tr>
<td>• Measures WF (entire system) then Treats Cornea</td>
</tr>
<tr>
<td>• Sensitive to Centroid Shift</td>
</tr>
<tr>
<td>• Difficulty Blending with on the Cornea / Problems</td>
</tr>
<tr>
<td>• Treating Lenticular Problems on the Cornea</td>
</tr>
<tr>
<td>• 240 Points Measured</td>
</tr>
<tr>
<td>• Global Preference NO</td>
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</table>
Topography Guided LASIK – Still must consider entire optical system

- Consider the following example:
  - LASIK Candidate → **28 year old female with a manifest refraction is -3.75 sphere**
  - Topography shows 0.5 diopters of cyl at 90 degrees!
    Do we topographic lasik and treat the cyl? Topo and treat the sphere only?
  - We do an OPD scan to determine LASIK candidacy and find:
Topolyzer (Alcon) Keratometer Measures Cornea @ 22,000 Points

- Assists in Determining Candidacy for TOPO Guided
- Best to Correct only Long Term Stable Target – The Cornea
- WaveLight Wavefront Analyzer (Alcon) measures only 168 sites
- WaveScan (Abbott Medical Optics, Santa Ana, Calif.) measures only 240 points.
Not ALL Racecars Are The Same!
Not All Excimer Lasers Are The Same!
First In Texas

WaveLight Refractive Suite

- FS200 kHz Femtosecond
- EX 500 Hz Excimer
FS 200 kHz (Femtosecond Laser)
200,000 pulses per second!

- Flap in 6 seconds
- Auto Pt. Interface Calibration
- Auto Flap Centration
- Adjustable Vacuum

- Flap Fully Adjustable
  - Diameter, Thickness and Shape
  - Hinge Size, Position
  - Side Cut Angle

- Improved OBL Control

- Lamellar or Full Thickness Corneal Transplants
- Intra-Corneal Ring Segments
- Limbal Relaxing Incisions
WaveLight EX 500 Excimer Laser

- Pulses Delivered at 500 Hz (consistent energy)
- Average Treatment Time under 10 seconds
- Less chair time for Patient
  - Least Risk to Hydration Factors
  - Less Patient Fatigue, Movement and Anxiety
  - Less Time for an Untoward Event During Surgery
## Excimer LASER Comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>WaveLight EX 500</th>
<th>VISX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking Rate/ sec</td>
<td>1050/ sec</td>
<td>60 / sec ?</td>
</tr>
<tr>
<td>Treatment Rate/ sec</td>
<td>500/ sec</td>
<td>6-20/ sec (variable)</td>
</tr>
<tr>
<td>Latency Adjustment * (very important)</td>
<td>500 x /sec</td>
<td>?</td>
</tr>
<tr>
<td>Seconds/Diopter Myopia</td>
<td>1.9 sec</td>
<td>6 sec</td>
</tr>
<tr>
<td>Seconds/ Diopter Hyperopia</td>
<td>3.5 sec</td>
<td>24 sec Estimate</td>
</tr>
<tr>
<td>Type of Beam</td>
<td>Gaussian (Blended)</td>
<td>Homogenous (Flat Top)</td>
</tr>
<tr>
<td>Iris Registration</td>
<td>Yes All Treatments</td>
<td>Myopes and Mixed Astigmatism Only</td>
</tr>
<tr>
<td>Angle kappa Adjustment</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>
Eye Tracking @ 1050 x / second
Latency Correction @ 500 X / second (2ms)

- Multi-Spatial Tracking – X, Y, and Z axes
- Halo Ring – Illumination / Infrared / Vacuum
Eye Tracking @ 1050 x /second
Latency Correction @ 500 X /second (2ms)
NeuroTracking: Optokinesis

- Optokinesis is a Neuronal Response of the Eye to Spacial Clues of an Image. It Forces the Eye to Stabilize the Retinal Image to Achieve Perfect Vertical and Horizontal Orientation

- The So-called Vestibular Ocular Reflex (VOR) Automatically Rotates the Eye Back to Compensate for Possible Head Rotation

Images with different degrees of spacial clues that trigger an optokinetic response (Pensell, Sverkersten, Ygge)

Square shape created by the yellow illumination lights of the ALLEGRETTO WAVE as seen by the patient and reflection of square shape on pupil
Real Time Pachymetry

- 1st Fully Integrated in US
- Safety - Confirm the Accuracy of Predetermined Measurements
- Flap Thickness
- Residual Stromal Bed

Prior Lasers Pachymetry Was not Integrated, Cumbersome and Often Problematic....
Consistent Energy → Checked at 3 Points
Completely Sealed Laser Beam Path
Nitrogen Preserves Quality & Longevity of Optics
### LASIK Treatment Parameters

<table>
<thead>
<tr>
<th>WAVELIGHT Wavefront Optimized</th>
<th></th>
<th>WAVELIGHT Wavefront Optimized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia</td>
<td>Up to -12 Diopters (SE)</td>
<td>Hyperopia</td>
</tr>
<tr>
<td>Cylinder</td>
<td>Up to -6 Diopters</td>
<td>Cylinder</td>
</tr>
</tbody>
</table>

### Topography Guided Treatments (Also corrects HOA)

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<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Sphere (only Myopia FDA approved)</td>
<td>Up to -8.00 Diopters</td>
</tr>
<tr>
<td>Cylinder (only myopia FDA approved)</td>
<td>Up to -3.00 Diopters</td>
</tr>
<tr>
<td>Spherical Equivalent</td>
<td>Up to -9.00 Diopters</td>
</tr>
</tbody>
</table>
Topography Guided LASIK Case #1

- Irregular corneal topography (steeper superiorly)
- Topography guided LASIK planned & performed to regularize cornea
- Treatment done on virgin eye (per FDA approval criteria)
Topography Guided LASIK Case #1

Before

After
Topography Guided LASIK Case #2

- Past (corneal) ocular history:
  - 6/13/2008 – Intralase Allegretto (near aim -1.25)
  - 11/2/2012 – Intralase Enhancement (near aim -2.00)
  - 11/9/2012 – Debridement of Interface (ingrowth)
  - 11/16/2012 – Debridement of Interface (ingrowth)
  - 11/27/2012 – Debridement of Interface (ingrowth)
  - 1/5/2013 – Debridement of Interface (ingrowth)
  - 2/19/2013 – Debridement of Interface (ingrowth)(2 stitch)
  - 5/27/2016 – PRK EX500 Topo

- Disclaimer: Although done frequently outside the United States, Topo treatment on non-virgin eyes is not FDA approved, is considered off label, and because it requires significant additional knowledge it is not recommended by the manufacturers.

- Pentacam - Significant anterior corneal (Axial / Sag) irregularity
Topography Guided LASIK Case #2

6/7/2016

Surgery
5/27/2016
Topography Guided LASIK Case #2 – Comparison

Pre-Op Axial

Post-Op Axial

Change Map
# Topography Guided LASIK Case #2 – HOA changes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z6</td>
<td>Trefoil (U)</td>
<td>0.40</td>
<td>0.21</td>
</tr>
<tr>
<td>Z7</td>
<td>Coma (V)</td>
<td>0.47</td>
<td>0.48</td>
</tr>
<tr>
<td>Z8</td>
<td>Coma (H)</td>
<td>0.62</td>
<td>0.08</td>
</tr>
<tr>
<td>Z9</td>
<td>Trefoil (I)</td>
<td>0.53</td>
<td>0.20</td>
</tr>
<tr>
<td>Z12</td>
<td>Sph. Aber</td>
<td>0.50</td>
<td>0.37</td>
</tr>
<tr>
<td>Total HOA</td>
<td>All</td>
<td>1.25</td>
<td>0.82</td>
</tr>
</tbody>
</table>
Vertex & Line of Sight Are Inferior Nasal To Pupil Center / Very Large Angle kappa
Vertex & Line of Sight Are Inferior Nasal To Pupil Center / Very Large Angle kappa
Best Outcome of Any Studies To Date Especially in Lines of Gained Acuity

One Year Post Op

15.7 %  20/10 or better
34.4 %  20/12 or better
68.8 %  20/16 or better
92.7 %  20/20 or better

29.6% Gained 1 or More Lines of UCVA Compared to Their Corrected Acuity Pre Op
Tylock Eye Care and Laser Center
Results TOPO GUIDED PO Day #1

n = 52 Eyes

30 eyes 20 /15 58%
20 eyes 20/20 38%
2 eyes 20/25 4%
Summary  TOPO GUIDED Treatments
(Available in the US in 2016)

• 30% of patients gained 1 or more Lines of Vision. This Study Excelled in Gaining Extra Lines of Vision For Patients – As Well as Achieving Acuities Beyond 20/20

• Almost 70% of Eyes Achieved 20/16 or Better

• Correcting Higher Order Aberrations is the Next Step Toward Our GOAL of Perfect Vision Correction. Of the patients who had one eye done in the study correcting HOA’s compared with their fellow eye correction with WFO only they preferred the study eye that had their HOA’s corrected.

• The WaveLight EX 500 is Inherently a Much Superior Excimer Laser Compared to the Visx S4 and Best Suited in Providing Patients with the Best Possible Acuity and Quality of Vision

• Corneal TOPO Guided is Preferred over Wavefront Guided because the Natural Crystalline Lens of the Eye has More Variation in the Short and Long Term. The Cornea is more Stable over the Short and Long Term.
Thank You!!
Phakic IOLs

- Advantages
  - Reversible
  - Preserves accommodation / much less risk of retinal detachment than RLE
  - Preserves natural corneal shape / no risk of ectasia
  - Can be used in patients with ocular surface disease
  - Utilizes familiar surgical techniques
Phakic IOLs

• Complications
  • Cataracts (surgical learning curve – much less of an issue with newest icls)
  • Endothelial cell loss
  • Glaucoma (pigment dispersion and pupil block)
  • Iris atrophy (pupil ovalization)
  • Traumatic dislocation (artisan / verisyse)
Phakic IOLs vs Eximer laser refractive surgery

- No significant difference between percentage of eyes with UCVA of 20/20 or better at 12 months postoperatively
- Phakic IOL Surgery is safer than eximer laser for moderate to high myopia: significantly less final loss of BCVA
- Phakic IOL surgery is better contrast sensitivity than eximer laser correction for moderate to high myopia.
- Phakic IOL surgery also scores more highly on patient satisfaction preference questionnaires
Implantable Collamer lens: visian ICL (Staar Surgical)

- Indications:
  - 21 to 45
  - Anterior chamber depth >2.8mm
  - To correct Myopia from -3D to -20 D with up to -2.5D astigmatism
  - Full available range is +21 to -23D with up to 6D of cylinder
• Peripheral iridotomy required
• The Visian has been approved since 2005, and surgical implantation vaults the lens over the lens capsule to minimize the risk of cataract formation.
3 year outcomes (526 eyes of 294 patients)

- 59.3% of UCDVA >= 20/20
- 94.7% of UCDVA >= 20/40
- 88.2% within 1D of predicted refractive outcome
- 3 year endothelial cell loss < 10%
- 2 clinically significant surgically induced anterior sub capsular cataract
- 97.1% of patients reported they would choose ICL again

Verisyse /Artisan (Ophtec)

- Anterior chamber iris claw fixated pIOL
- Corrects -5D to -20D with 2.5D astigmatism
- Greater long term concern over endothelial cell loss when compared to ICL but no change in IOP
- The Verisyse has been approved since 2004, and the FDA study results showed almost all patients had 20/40 after 3 years, but only half had an improvement in vision, and 6% had a loss of 1 or 2 lines. Complications in the FDA study ranges from a 1.8% endothelial cell loss rate per year to iritis in the early postoperative period and implant decentration.
• “There are several advantages of posterior chamber phakic IOL over their anterior chamber counterparts,” she said, including smaller wounds, minimal induction of astigmatism, a similar technique to IOL implantation during phaco, and cosmetics—the lens is less visible as it’s mostly hidden behind the iris, Dr. Yoo said.
• The Hole ICL and Toric ICL are not yet approved, although the latter is under FDA review.
• The Hole ICL “is designed to prevent pupil block and obviates the need for peripheral iridotomy,” she said