Unanswered Technical Challenges that Still need to be Overcome

NIDEK perspective

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Challenges to Excimer-Refractive Surgery over the Years

1983 – does it work?
1986 – it works!

Myopic Astigmatism
Mixed Astigmatism
Hyperopia
Topolink

Wavefront LASIK
Aberrometry
fs LASIK
LASIK
LASEK
Custom Lasik
Whats next?
Today's Customized Refractive Surgery is Technically Challenging the…

...Diagnostic Device
...Surgical Procedure
...Laser Ablation
OPD-Scan Aberrometer Principle

- Eye
- Pupil
- Lens
- Iris
- Chopper Wheel (Rotating Drum)
- Projection Lens
- Infrared LED
- Photo Diode Array
- Slit Illumination
- OPD-Scan Aberrometer
By rotation of the photo diode array 1440 local refractions are measured within a 6 mm Pupil and directly displayed on the OPD map in diopters. Neither Zernike nor Fourier interpolation is used at this stage!
Challenges: Spatial Resolution and Reconstruction Method

- There is no Aberrometer on the marked yet which comes any close to the spatial resolution of an average Topographer (current maximum is OPD-Scan 1440 data points compared to >8000 in topography)

- Most Aberrometers display data using Zernike or Fourier series which causes loss of fidelity.
Challenges: Corneal & Internal WF

Differentiation between Corneal and Internal Aberrations

- Important to know the origin of aberrations (cornea or lens?)
- In order to get meaningful internal eye aberration data Aberrometer and Topographer need to be integrated, using the same measurement axis.
Example: Measuring Lenticular Aberrations

- history of trauma with small sectoral cataract and zonular dialysis superiorly
- baseline refr.
- +5.00 -4.50 x 160
- UCVA 20/400 corrects to 20/40

- Postoperative Internal OPD shows the internal cylinder decrease to 0.75
- → phaco and IOL with capsular tension ring
- spherical IOL +21.5 D PC
Cornea dK: -1.25
Internal cyl: -4.52
Entire Eye cyl: -4.50

Cornea dK: -1.58
Internal cyl: +0.62
Entire Eye cyl: -0.75

preOP

with IOL

IOL
Today's Customized Refractive Surgery is Technically Challenging the... 

...Diagnostic Device

...Surgical Procedure

...Laser Ablation
## H70 Efficacy Comparison

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>H70 ALL EYES 3 Months</th>
<th>B&amp;L Technolas 3 Months</th>
<th>Alcon Ladarvision 6 Months</th>
<th>VISX Star 3 Months</th>
<th>Wavelight Allegretto 3 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of Treatment</td>
<td>0.5-6.0 D sph ≤ 3.0 D cyl</td>
<td>1.0-4.0 D sph ≤ 2.0 D cyl</td>
<td>&lt; 6.0 D sph ≤ -6.0 D cyl</td>
<td>0.50-5.0 D sph ≤ 3.0 D cyl</td>
<td>≤ 6.0 D sph ≤ 5.0 D cyl</td>
</tr>
<tr>
<td>MRSE within: attempted vs achieved</td>
<td>± 0.50 D 93/118 (78.8%)</td>
<td>222/343 (64.7%)</td>
<td>168/267 (62.9%)</td>
<td>106/150 (70.7%)</td>
<td>196/276 (71.0%)</td>
</tr>
<tr>
<td></td>
<td>± 1.00 D 109/118 (92.4%)</td>
<td>314/343 (91.5%)</td>
<td>235/267 (88.0%)</td>
<td>142/150 (94.7%)</td>
<td>259/276 (93.8%)</td>
</tr>
<tr>
<td></td>
<td>±2.00 D 117/118 (99.2%)</td>
<td>340/343 (99.1%)</td>
<td>264/267 (98.9%)</td>
<td>N/A</td>
<td>275/276 (99.6%)</td>
</tr>
</tbody>
</table>

MRSE within (attempted vs achieved)
Challenges: Surgical Procedure

20-30 microns of StDev in flap thickness when using mechanical microkeratomes

- Higher residual bed thickness limits correction range
- Femtosecond LASIK important

3-Standard Deviation Intervals

- Flap Thickness intervals for different devices:
  - Amadeus
  - SKBM
  - Hansatome
  - Moria M2
  - Moria CB
  - Nidek MK2000
Challenges: Online Measurement

- Online Pachymetry
- Online Topography and Aberrometry
  - Yes, desirable; but...
  - may be limited by intra-operative stromal edema
  - technology becomes more complex requiring more service
  - processing time still an issue with today's hardware
Today's Customized Refractive Surgery is Technically Challenging the...

...Diagnostic Device

...Surgical Procedure

...Laser Ablation
Challenges: Ablation Speed

- Faster Ablation might reduce hydration influence

- But: Power = Energy/Time! → Heat

- How high can we go in repetition rate?
Challenges: Hit the Target

1. Registration – What to track?

2. X-Y-Z & Torsion – How to track?

3. Centration Philosophy – Where to aim for?
Challenges: Registration

Improve current registration techniques

- Iris / Pupil based registration techniques are sensitive to changing illumination conditions during the ablation
- This may introduce systematic centration errors
Challenges: Tracking

Ideally we should have a full x-y-z and online torsional tracking with latency short enough for the used laser repetition rate.
Challenges: Centration Philosophy

Center on Vertex normal!

(OZ ≥ Scotopic Pupil Diameter)

Shift to visual axis by entering Offset values at the laser

Reflexes, Centers & Intercepts

RIGHT EYE

- Geometrical corneal center
- Entrance pupil center
- Vertex-normal light reflex
Challenges: Energy Compensation
Differences between Attended vs. Achieved Ablation

- There is no ‘one size fits all’ compensation matrix
- Radial energy fall off is not symmetrical
- Needs to be different for OS and OD
- Needs to be different for steep and flat eyes
Factors Influencing Loss of Peripheral Ablation Efficacy

- \( \downarrow \) cross-sectional area (oval)
- \( \downarrow \) transmission, \( \uparrow \) reflectance
- \( \downarrow \) effective fluence, \( \downarrow \) ablation
- biomechanics
- healing -- epithelium
Nidek
Compensation + Custom

- Conventional
- CATz – Topography based Custom
- OPDCAT – WF based Custom
- OPA – Optimized Prolate Ablation
Post OP
Conventional
-5.50 D
6.5 / 7.5 mm

Post OP
CATZ
-5.25 D
5.5 / 9.0 mm
Delta Q by Surgery Type

Delta Kseq [D]

Delta Qseq (8 rings)

- More Oblate

- More Prolate

H70
Kermani Hyp
Alaa Myo OZ>6.5
Alaa OATZ
OPA
myoPAC
hypPAC
Summary

- Custom ablation has been rising the bar.
- It all starts with good diagnostic data.
- The weakest link in the chain from the measurement to the ablation defines our outcomes.
- An iterative Ablation Profile design procedure should be used to make sure we get what we intended.
Thank You!
Challenges: Target Shape

Have we defined the ideal target shape yet?

- Which is the idea target Q-value?
- What amount of spherical aberration is desirable?
- How much does the ideal target shape change with age?

SA Increase with Age

$SA = AGE \times 0.394 - 15.675$
$r^2 = 0.634; p < 0.001$
Challenges: Presbyopia

- Central near zone?
- Peripheral near zone?
- Q-Value/Spherical Abberation based?

- Presbyopia is not a corneal problem
- Multifocality = Abarrations!
Challenges: Reference Axis

- Choosing the best Reference Axis
  - Different concepts among different aberrometers
  - Time to move away from pupil center?!
• Case # 367058  Left Eye
• 22 YO Patient post PRK
• few years ago elsewhere
• presented with UCVA 20/70
• BCVA 20/20
• with -0.75 -3.25 x 170

• Had Toric Artisan 13 August 03

• Post operative
• UCVA 20/20
• MR -0.75 -0.75 x 180 BCVA 20/15
• Corneal Astigmatism
• 3.77 preop and
• 4.29 postop
• Corneal thickness was 420 (reason why LASIK was not done)

• Internal OPD shows the cyl induced by toric Artisan
Measuring Lenticular Aberrations - Example #3

- CASE # 43582
- Had DLKP LEFT EYE
- OPD exam 1: shows early post DLKP
  - with high Corneal CYL (8.78) and low Internal Astig (1.24)
- OPD exam 2: after suture adjustment:
  - Corneal Astigmatism decreased to 2.1
  - Internal OPD decreased to 0.36 (possibly because the internal corneal surface is responsible for a part of the cyl)
- OPD exam 3: Post removal of sutures
  - Corneal Astigmatism returned to 6.42
  - Internal OPD cyl to 1.32
- OPD exam 4: Post Toric Artisan
  - Corneal Astig still high (6.12)
  - internal Cyl increased to 5.50 opposite direction to negate the Corneal CYl
  - MR was -0.25 -1.25 x 60
  - UCVA 20/25
  - BCVA 20/20
  - Note:
    - MR before T-Artisan implantation - 8.75 -8.75 x 075
    - Power of Artisan -8.5 sph -7.00 cyl
    - this is supposed to leave about 1.50 Cyl uncorrected (this is the highest cyl power possible to manufacture with this lens)
Early Post DLKP

Post DLKP with Sutures
After Suture Removal

Post OP toric ARTISAN

DK: -6.63
DK: -6.98
Cyl: -1.12
Cyl: +6.95
Cyl: -7.50
Cyl: -2.25
After Suture Removal

dK: -7.21
cyl: +1.26

cyl: -5.75

Post OP toric ARTISAN

dK: -6.82

cyl: +5.44

cyl: -1.00