Unanswered Technical Questions That Need to Be Overcome: Bausch and Lomb

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Acknowledgements: University of Rochester Team
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• David Williams PhD, Center for Visual Science
• Geunyoung Yoon PhD
• Krystal Huxlin PhD
• Ian Cox PhD
• Manoj Subbaram PhD
• Mo Mohander PhD
• Jason Porter PhD
• Joe Stamm OD
The author is a consultant to:

Bausch and Lomb
What Are the Important Technical Issues to Be Solved For Refractive Laser Surgery?
Why Are Retreatments and Irregular Corneas Rx’s Only Partially Successful?

- Biomechanical factors
- Aberration interactions
- Measurement limitations
PreOp: 5 Yr. Post Decent. PRK
HOA: 2.20 RMS (6.0mm)

H. Coma
1 Wk. Post Custom LASIK Retreat for Decent. PRK (↓ HOA 2.20 to 1.04µ)
Preop Decentered PRK

Horizontal Coma 1.9 microns
1 Wk. Post Z LASIK for PRK Decentration

H. Coma 0.7 microns 63% Reduced

+0.25 -0.75 X 157
Unanswered Technical Questions

• Aberration Interaction:
  Relationship between HOA and LOA aberration correction:
  – LOA affecting HOA
  – HOA affecting LOA

• It Goes Both Ways
Aberration Interaction

• Important in:
  – High myopes
  – High HOA eyes:
    • PKP,
    • Post LASIK irregular eyes
    • Scarred Corneas, Herpes, Trauma
    • “Orphan eyes”
Aberration Interaction: Lower Order Aberrations Effects Higher Order Aberrations

- **Sphere Correction** induces spherical aberrations:
  - **Sphere**
    - Myopia Rx. Causes + SA
    - Hyperopia Rx. Causes – SA
  - **Cylinder**
    - Large cylinder Rx may induce 2\textsuperscript{nd} Astigmatism with baby bowtie pattern
Aberration Interaction: Preop Sphere Influence on Postop HOA

- Radial order
  - 2nd
    - astigmatism
    - defocus
    - astigmatism
  - 3rd
    - trefoil
    - coma
    - coma
    - trefoil
  - 4th
    - quadrafoil
    - secondary astigmatism
    - spherical ab.
    - secondary astigmatism
    - quadrafoil

Lower Order Aberrations
Higher Order Aberrations
Myopic Positive Sph. Aberration Post Conventional LASIK

Increase in spherical aberration ($\mu$m)

Porter, Yoon MacRae et. al.
AJO.
U. Of Rochester

R = 0.739
Corneal biomechanics increases (decreases) positive spherical aberration for myopic (hyperopic) correction.

Yoon, MacRae Williams, Cox JCRS, 2005
Tangential curvature difference map (postOP – preOP) 3 month after LASIK

Myopic treatment in Peripheral OZ
Steepening
Positive SA

Hyperopic treatment in Peripheral OZ
Flattening
Negative SA

-2.75D myopic correction
+3.62D hyperopic correction

Yoon, MacRae Williams, Cox JCRS, 2005
Aberration Interaction: Preop Sphere Influence on Postop HOA

Radial order
2nd

2nd order aberrations:
- Astigmatism
- Defocus
- Astigmatism

3rd

3rd order aberrations:
- Trefoil
- Coma
- Coma
- Trefoil

4th

4th order aberrations:
- Quadrafoil
- Secondary astigmatism
- Spherical aberration
- Secondary astigmatism
- Quadrafoil
Aberration Interactions

- Higher order aberrations (HOA) affecting lower order aberrations (LOA)
Cascade Effect: Preop HOA Influence on Postop Sphere and Cylinder

- **Radial order**
  - 2nd
  - 3rd
  - 4th

- **Lower Order Aberrations**
  - astigmatism
  - defocus
  - astigmatism

- **Higher Order Aberrations**
  - trefoil
  - coma
  - trefoil

- **Images**
  - 2nd order: astigmatism, defocus, astigmatism
  - 3rd order: trefoil, coma, coma, trefoil
  - 4th order: quadrafoil, secondary astigmatism, spherical ab., secondary astigmatism, quadrafoil
The Rochester Nomogram

- Effect of preop HOA on postop refractive error
  - 3rd order aberrations
  - Effect of Spherical Aberration
## Zyoptix Customized Rx. with Rochester Nomogram

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zyoptix FDA trial (112 eyes)</th>
<th>Rochester Nomogram</th>
<th>Pharmacological dilation (n=175)</th>
<th>Natural mesopic pupil (n = 90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop SE (D)</td>
<td>-3.41 ± 1.44</td>
<td>-4.89 ± 2.06</td>
<td>-4.39 ± 2.08</td>
<td></td>
</tr>
<tr>
<td>Preop HOA (um)</td>
<td>0.45 ± 0.16</td>
<td>0.53 ± 0.16</td>
<td>0.53 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>Postop UCVA &gt; 20/20</td>
<td>89.3%</td>
<td>93.1%</td>
<td>94.6%</td>
<td></td>
</tr>
<tr>
<td>Postop SE (D)</td>
<td>+0.26 ± 0.50</td>
<td>-0.11 ± 0.34</td>
<td>-0.08 ± 0.23</td>
<td></td>
</tr>
<tr>
<td>(-1.04 to +1.81)</td>
<td></td>
<td>(-1 to +1)</td>
<td>(-0.63 to +0.50)</td>
<td></td>
</tr>
<tr>
<td>Postop SE ≤ +0.50D</td>
<td>71.4%</td>
<td>91.4%</td>
<td>97.8%</td>
<td></td>
</tr>
</tbody>
</table>
Postop Astigmatism Risk Factor #2

- **Treatment of preoperative Coma**
  - Decentration of Laser ablation induces astigmatism

\[
\begin{align*}
Z_2^0 & \quad z_2^0 & \quad Z_2^0 \\
Z_3^1 & \quad Z_3^1 & \quad Z_3^3 \\
Z_3^1 & \quad Z_3^1 & \quad Z_3^3
\end{align*}
\]

2\textsuperscript{nd} order
3\textsuperscript{rd} order
### Aberration Interaction: Preop Coma and Postop Astigmatism (n=175)

<table>
<thead>
<tr>
<th>Postop Cyl</th>
<th>&lt; 0.50 D</th>
<th>≥ 0.50 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence</td>
<td>104/175 (60%)</td>
<td>71/175 (40%)</td>
</tr>
<tr>
<td>Preop coma</td>
<td>0.26 ± 0.43 (\mu) m</td>
<td>0.40 ± 0.17 (\mu) m</td>
</tr>
</tbody>
</table>

\[ p < 0.0001 \]
We Need To Look Systematically Beyond the Optic Zone To The Interaction between Optical Zone and Transition Zone

- Look beyond the pupil diameter i.e. – Corneal Topography
- Requires both wavefront sensor and corneal topography wavefront to optimize wavefront design
Summary: Unanswered Technical Questions?

- Biomechanical factors?
- Aberration interactions?
- Measurement limitations?