Achieving Proper Centration and Alignment in Intraocular and Keratorefractive Surgery

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Course Outline

Introduction (Chang)
- Importance of centration and alignment
- Ocular axes and angles
- Purkinje images

Centering and aligning keratorefractive procedures
- Laser Vision Correction (Waring)
- Corneal inlays (Waring)

Centering and aligning intraocular procedures
- Toric IOL Alignment (Berdahl)
- Diffractive Multifocal IOLs (Chang)

Discussion / Conclusion

Introduction

Importance of centration and alignment

IOL Centration

Good centration important
- Maximize visual quality
- Minimize visual side-effects

Aspheric IOLs
- Advantage lost when >0.8 mm decentration

Diffractive multifocal IOLs
- Effects not yet quantified
- "Scapegoat" to explain why some patients with good Snellen VA are unhappy

IOL Centration

Definition

Laboratory studies
- Optical center or pupil (dilated) center
- Scheimpflug or Purkinje devices to find IOL center

Clinical observation
- Monofocal IOLs
- Edge not seen in pupil
- Multifocal IOLs
- Pupil center
  - Rings concentric with pupil
  - What about visual axis?
Introduction

Ocular Axes and Angles

Ocular Axes

- Optical Axis
  - Alignment of all 3 Purkinje images
- Pupillary Axis
  - Pupil center / orthogonal to cornea
- Line of Sight
  - Pupil center to fixation point
- Visual Axis
  - Nodal point to fixation point

Ocular Angles

- Angle $\alpha$ (alpha)
  - Optical Axis to Visual Axis
- Angle $\kappa$ (kappa)
  - Pupillary Axis to Line of Sight
- Angle $\lambda$ (lambda)
  - Originally: Pupillary Axis to Visual Axis
  - Pupillary Axis to Line of Sight
  - Less commonly used than angle $\kappa$

Pupillary Axis (and Line of Sight) can change with pupil dilation

Ocular Axes

Ocular Axes

- Optical Axis
- Pupillary Axis

Alignement of all 3 Purkinje images

Pupil center / orthogonal to cornea
Ocular Axes

Line of Sight

Pupil center to fixation point

Visual Axis

Nodal point to fixation point

Optical Axis to Visual Axis

Ocular Axes

Angle $\alpha$

Optical Axis

Pupil center to fixation point

Angle $\kappa$ (original definition)

Pupillary Axis

Pupillary Axis to Visual Axis
Ocular Axes
Angle $\lambda$ / Angle $\kappa$ (new definition)

Pupillary Axis to Line of Sight

Ocular Axes and Angles
Problems with Definition

Ocular Axes
- Optical Axis
  - Alignment of all 3 Purkinje images
- Pupillary Axis
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Eye model / research definitions were not intended for intraocular surgery use.

Optical Axis
- Alignment of all 3 Purkinje images
Ocular Axes and Angles
Problems with Definition

Optical Axis
- Alignment of all 3 Purkinje images

Undefined in aphakia

Ocular Axes and Angles
Problems with Definition

Optical Axis
- Alignment of all 3 Purkinje images

Undefined with lens / IOL tilt or decentration
(Purkinje images do not align)

Ocular Axes and Angles
Problems with Definition

Pupillary Axis
- Pupil center / orthogonal to cornea

Possible to have multiple rays “orthogonal to cornea” that intersect the pupil center
Ocular Axes and Angles
Problems with Definition

Pupillary Axis
- Pupil center / orthogonal to cornea

Changes with pupil centroid shift
(Can occur with dilation)

Line of sight
- Pupil center to fixation point

What about irregular cornea or ectasia?
Ocular Axes and Angles
Problems with Definition

Visual axis
- Nodal point to fixation point

Where is the nodal point?
Theoretical concept in paraxial eye model

Cannot be defined in some (all?) eyes
Useful to communicate concepts
How to translate into clinical and surgical practice
How do we find the pupillary axis or visual axis on a real eye?

Introduction
Purkinje Images
Purkinje Images

Reflections from the light-transmitting interfaces

Four Purkinje reflections
PI: anterior cornea
PII: posterior cornea
PIII: anterior lens/IOL
PIV: posterior lens/IOL

PII
PI / PII
PIV

PI: Reflection from anterior corneal surface
Corneal light reflex
- Air / anterior cornea (tear film)
- Bright, upright image
Applications
- Keratometry
- Corneal topography / Video keratoscopy
- Commercial eye tracking applications

PIII
PI / PII
PIV

PII: Reflection from posterior corneal surface
Specular reflection
- Posterior cornea : aqueous
- Dim, upright image
- Can be seen intraoperatively with air in the AC
Application
- Specular microscopy

Specular Microscopy
**Purkinje Images: PIII**

PIII: Reflection from anterior lens / IOL surface
- Not seen in phakic eyes
- Aqueous: anterior lens / IOL
  - Variable brightness, typically upright
  - Depends on IOL power
  - Fringing with diffractive rings
  - "Cat’s eye reflex"
- High index materials
- Flat anterior IOL curvature

**Purkinje Images: PIV**

PIV: Reflection from posterior lens / IOL surface
- Faintly visible in some phakic eyes
- Posterior IOL: aqueous / capsule / vitreous
  - Variable brightness, typically inverted
  - Depends on IOL power
  - Fringing with diffractive rings
  - Stretched by toric surface
  - Affected by IOL chromophore
### Purkinje Images

**Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>PI</th>
<th>PII</th>
<th>PIII</th>
<th>PIV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td>Cornea, anterior surface</td>
<td>Cornea, posterior surface</td>
<td>Lens/IOL, anterior surface</td>
<td>Lens/IOL, posterior surface</td>
</tr>
<tr>
<td><strong>Seen Clinically</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Image Location</strong></td>
<td>Anterior lens/IOL</td>
<td>—</td>
<td>Anterior vitreous</td>
<td>Corneal surface</td>
</tr>
<tr>
<td><strong>Size</strong>*</td>
<td>Smallest</td>
<td>—</td>
<td>Largest</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Brightness</strong>*</td>
<td>Bright</td>
<td>—</td>
<td>Dim to very bright</td>
<td>Medium to bright</td>
</tr>
<tr>
<td><strong>Orientation</strong>*</td>
<td>Upright</td>
<td>—</td>
<td>Upright (usually)</td>
<td>Inverted (usually)</td>
</tr>
<tr>
<td><strong>Movement</strong></td>
<td>Slow</td>
<td>—</td>
<td>Rapid</td>
<td>Medium</td>
</tr>
</tbody>
</table>

*Dependent on IOL power

### Residual Astigmatism

**Residual Astigmatism after Toric IOL – Now what?**

John Berdahl M.D.

**POM #1 SN6AT9 Toric IOL @ 110°**

**Vas** 20/60

**MRX – -1.00 + 1.75 x 150 20/25**
Causes of Residual Astigmatism:

Wrong Location:
- Poor Measurements
- Poor Calculations
- Surprising SIA
- Posterior Ks
- IOL Rotated
- Poor IOL Placement

Wrong Lens:
- Poor Measurements
- Poor Calculations
- Surprising SIA
- Posterior Ks

Wrong Eye:
- Ocular Surface Disease
- ABMD
- Irregular Astigmatism

Surgically induced Astigmatism
Treat Disease
Causes of Residual Astigmatism

Wrong Location
- Poor Measurements
- Poor Calculations
- Surprising SIA
- Posterior Ks
- IOL Rotated
- Poor IOL Placement

Wrong Lens
- Poor Measurements
- Poor Calculations
- Surprising SIA
- Posterior Ks

Will Rotating IOL Help?

Toric IOL Misalignment

Ideal Axis of Toric IOL

Actual Axis of Toric IOL
Toric Misalignment of T9

IOL Misalignment

<table>
<thead>
<tr>
<th>Misalignment</th>
<th>% Loss</th>
<th>Absolute Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>0deg</td>
<td>0%</td>
<td>T3 (1.03D)</td>
</tr>
<tr>
<td>5deg</td>
<td>17.5%</td>
<td>T9 (4.11D)</td>
</tr>
<tr>
<td>10deg</td>
<td>35%</td>
<td>0.18D</td>
</tr>
<tr>
<td>15deg</td>
<td>50%</td>
<td>0.36D</td>
</tr>
<tr>
<td>20deg</td>
<td>62.5%</td>
<td>0.51D</td>
</tr>
<tr>
<td>25deg</td>
<td>75%</td>
<td>0.65D</td>
</tr>
<tr>
<td>30deg</td>
<td>100%</td>
<td>1.03D</td>
</tr>
</tbody>
</table>

Math Frowns on Misalignment

Residual Astigmatism

POM #1 SN6AT9 Toric IOL @ 110º

Va_sc 20/60

MRX – -1.00 + 1.75 x 150 20/25
Prior MRX: -1.00 + 1.75 x 150

Predicted MRX: -0.29 + 0.32 x 150

Rotate IOL 10° CCW

Mark Current and Ideal Axis

Before Rotation
-1.00 + 1.75 x 150  Vαsc 20/60

After Rotation
plano +0.50 x 112  Vαsc 20/20
Residual Astigmatism #2

POW#1 SN6AT9 Toric IOL @ 158°

VA_{ac} 20/70

MRX – -1.75 + 3.50 x 092 20/25

ORA Screenshots
Before Rotation | After Rotation
---|---
-1.75 + 3.50 x 92, Va_sc 20/70 | Plano, Va_sc 20/20

Step By Step

1. Measure MRX
2. Measure IOL Axis and know its toricity
3. Plug info to Astigmatismfix.com
4. Does Rotating IOL Neutralize Astigmatism?
5. Is Spherical Equivalent Acceptable?
6. Can IOL be Easily Rotated?
7. Mark Current and Ideal Axis
8. Loosen IOL with Viscoelastic
9. Rotate IOL
10. Remove Viscoelastic

By the way....

An ounce of prevention....

Mark in upright position
Use multiple confirmatory K Sources
Use intraoperative aberrometry Know SIA, including how it affects the axis
Summary

Rotate IOL
S.E. near target
Astigmatism Neutralizable

Laser Vision Correction
S.E. not at target
Astigmatism not neutralizable
IOL cannot be rotated easily

Final Thought

Much more important with higher powered toric IOLs and toric multifocals

Thank you
Centering and aligning intraocular procedures

Diffractive Multifocal IOLs

Identifying Ocular Axes: Clinical
Use Purkinje Images
Ocular Axes

Identifying Ocular Axes: Clinical
Use Purkinje Images

Identifying Ocular Axes: Surgical
Use Purkinje Images

Ocular Axes and Centration
Ocular Axes and Centration

Optically
- Best to center on Visual Axis
- Hyperopic LASIK
- Eye model studies

Cosmetically
- “Looks better” to center on pupillary axis
- Pupil easy to see intraoperatively
- Reference for capsulotomy creation
- Easy to see at slit lamp postoperatively

Visual Axis centration provides best visual outcomes

Intraoperative IOL Positioning

IOL position can be adjusted
- Can primarily be moved in direction perpendicular to area of peripheral bag-haptic contact
- Depends on IOL material and design
  - Tecnis Multifocal 1-Piece IOL
    - Hydrophobic acrylic
    - Modified C loop haptics
- Direction of best movement is ~30° to 45° clockwise from (to the right of) haptic insertion

Intraoperative IOL Positioning

Vector Forces

Slight distention of bag counteracts inward force vectors.
Intraoperative IOL Positioning

Initial IOL Position

Final IOL Position

Intraoperative IOL Positioning

Correlation to Postoperative

- Change in IOL position
  - From Intraoperative to Postoperative (n = 18)
  - $R = 0.91$

Postop IOL Position (mm)

-0.6  -0.4  -0.2  0  0.2  0.4  0.6

Intraop IOL Position (mm)

-0.6  -0.4  -0.2  0  0.2  0.4  0.6

Centration Stability

Excellent centration stability over time

Compared to POD 1

One-piece Tecnis Multifocal IOL

Position Change (Compared to Day 1) of IOL Center Relative to:

<table>
<thead>
<tr>
<th>Relative to Corneal vertex</th>
<th>&lt; 2 months</th>
<th>2-4 months</th>
<th>4-6 months</th>
<th>6-12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean change in IOL position (mm)</td>
<td>0.10 ± 0.05</td>
<td>0.06 ± 0.07</td>
<td>0.08 ± 0.07</td>
<td>0.10 ± 0.07</td>
</tr>
<tr>
<td>Correlation (R)</td>
<td>0.75</td>
<td>0.83</td>
<td>0.87</td>
<td>0.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative to Pupil center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean change in IOL position (mm)</td>
</tr>
<tr>
<td>Correlation (R)</td>
</tr>
</tbody>
</table>

Centering Toric IOLs

Rotational alignment is important

www.astigmatismfix.com
Centering Toric IOLs

Must Center and Align accurately: axis pass through visual axis

Parallel to axis 95°

Aligned on axis 95°

Centering Toric IOLs

Must align 5 points
Two sides of compass
Peripheral corneal marks
Two sets of toric marks
Corneal vertex

Compass too temporal
Compass well-aligned

Discussion / Conclusions

Centration and Alignment