Centering Cataract Surgery on the Visual Axis

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Financial Disclosures

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Centricity: Consultant/Advisor/Research
EyeGate Pharmaceuticals: Consultant/Research
RxSight: Consultant/Research
TearClear: Consultant/Advisor, Equity Owner
Implant

Anatomic and Optical Goal

1. IOL centered

Implant

Anatomic and Optical Goal

1. IOL centered
2. 360° overlap of anterior capsule over the optic

Automated Capsulotomy
Femtosecond Laser

From: Assessment of Lens Center Using Optical Coherence Tomography, Magnetic Resonance Imaging, and Photographs of the Anterior Segment of the Eye
Manual Capsulotomy
Automated Capsulotomy
Zepto
Implant

Anatomic and Optical Goal

1. IOL centered
2. 360° overlap of anterior capsule over the optic

Need to center both the IOL and the Capsulotomy

Implant

Anatomic and Optical Goal

1. IOL centered
2. 360° overlap of anterior capsule over the optic

Prevent/Minimize
PCO Induced
IOL tilt
and/or
Decentration

Cornea

Iris

Lens
Cornea

Iris

Lens
MAJOR REVIEW

Posterior Capsule Opacification

DAVID J. APPLE, M.D., KERRY D. SOLOMON, M.D., MANFRED R. TETZ, M.D.,
EHUD I. ASSIA, M.D., ELIZABETH Y. HOLLAND, B.S., ULRICH F.C. LEGLER, M.D.,
JULIE C. TSAL, M.D., VICTORIA E. CASTANEDA, M.D., JUDY P. HOGGATT, M.D.,
ALEXANDRA M.P. KOSTICK, M.D.

Departments of Ophthalmology and Pathology, Center for Intraocular Lens Research, Storm Eye
Institute, Medical University of South Carolina, Charleston, South Carolina

• Pearl-type PCO  Less aggressive
• Fibrosis-type PCO  More aggressive
...apposition of the anterior capsule edge onto the posterior capsule near the posterior surface of the IOL optic may be dangerous.


...an increased incidence of cases of fibrosis-type PCO in cases of ciliary sulcus fixation, where the cut edge of the anterior capsule was placed in direct apposition to the posterior capsule near the optic.

Nagamoto T, et. al: Lens epithelial expansion rate onto the posterior capsule (Video). Presented at the annual meeting of the Americal Society of Cataract and Refractive Surgery, San Diego, Calitornia, April, 1992

...an apposition of the anterior and posterior capsules places the eye at higher risk for the fibrosis-type PCO.
Early central posterior capsular fibrosis in sulcus-fixated biconvex intraocular lenses


J Cataract Refract Surg 19, JULY 1993

PCO
• Elschnig Pearls
• Fibrotic PCO

Risk factors for developing this aggressive form of opacification were close apposition of peripheral anterior and posterior capsules .....occurred most often in cases of haptic fixation in the ciliary sulcus.
DIAGNOSTIC AND SURGICAL TECHNIQUES

Intraocular Lens Complications Requiring Removal or Exchange

ALAN N. CARLSON, MD,1 WILLIAM C. STEWART, MD,2,3 AND PATRICK C. TSO, MD1

1Department of Ophthalmology, Duke University Eye Center, Durham, North Carolina, 2Pharmaceutical Research Corporation, Charleston, South Carolina, and 3University of South Carolina Medical School, Columbia, South Carolina, USA
TABLE 1

Mechanisms for IOL-Related Complications

<table>
<thead>
<tr>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
</tr>
<tr>
<td>Intraoperative</td>
</tr>
<tr>
<td>Postoperative</td>
</tr>
<tr>
<td>Inflammatory</td>
</tr>
<tr>
<td>Noninfectious</td>
</tr>
<tr>
<td>Infectious</td>
</tr>
<tr>
<td>Optical</td>
</tr>
<tr>
<td>IOL Power</td>
</tr>
<tr>
<td>IOL Malposition</td>
</tr>
</tbody>
</table>

IOL = intraocular lens.
Incomplete capsule overlap of the optic: allow capsular fusion peripheral to the optic with progressive adherence. This fusion can produce IOL decentration from the edge of the capsulorhexis.
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Incomplete capsule overlap of the optic: allow capsular fusion peripheral to the optic with progressive adherence. This fusion can produce IOL decentration from the edge of the capsulorhexis.
Capsular Fusion Syndrome
The Effect of Capsulorhexis Size on Posterior Capsular Opacification: One-Year Results of a Randomized Prospective Trial

EMMA J. HOLLICK, BA, FRCOPHTH, DAVID J. SPALTON, FRCP, FRCS, FRCOPHTH, AND WILL R. MEACOCK, BSC, FRCOPHTH
The Effect of Capsulorhexis Size on Posterior Capsular Opacification: One-Year Results of a Randomized Prospective Trial

EMMA J. HOLLICK, BA, FRCOPHTH, DAVID J. SPALTON, FRCP, FRCS, FRCOPHTH, AND WILL R. MEACOCK, BSC, FRCOPHTH

METHODS: In this prospective study 75 patients underwent standardized phacoemulsification with capsulorhexis and in-the-bag placement of a 5.5-mm polymethylmethacrylate intraocular lens implant. The patients were randomly assigned to receive either a small capsulorhexis of 4.5 to 5 mm to lie completely on the intraocular lens optic or a large capsulorhexis of 6 to 7 mm to lie completely off the lens optic. Patients were examined at days 1, 14, 30, 90, and 180 and at year 1 with logMAR visual acuity assessment, Pelli-Robson contrast sensitivity testing, anterior chamber flare and cell measurement, and high-resolution digital retroillumination imaging of the posterior capsule. The pattern of posterior capsular opacification was determined, and the percentage area of posterior capsular opacification was calculated for each image with dedicated image analysis software.

RESULTS: Large capsulorhexes were associated with significantly more wrinkling of the posterior capsule and worse posterior capsular opacification than small capsulorhexes. At 1 year the average percentage area of posterior capsular opacification was 32.7% for small capsulorhexes (95% confidence interval, 19.8 to 45.6) and 66.2% for large capsulorhexes (95% confidence interval, 57.7 to 74.6) (P < .0001). The patients with large capsulorhexes had significantly poorer visual acuities and a trend toward worse contrast sensitivities.
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FIGURE 1. A large capsulorhexis in a 75-year-old man. (Top left) One day postoperatively, its edge is almost completely off the lens optic except for a small lip touching the optic rim superiorly (arrow). (Top right) At 2 weeks postoperatively there is extensive fine wrinkling of the posterior capsule. (Bottom left) By 6 months after surgery the wrinkling has increased with early lens epithelial cell infiltration. (Bottom right) By 1 year postoperatively the wrinkling and lens epithelial cells remain with Elschnig pearl formation superiorly (arrows).
The Effect of Capsulorhexis Size on Posterior Capsular Opacification: One-Year Results of a Randomized Prospective Trial

EMMA J. HOLLICK, BA, FRCOPHTH, DAVID J. SPALTON, FRCP, FRCS, FRCOPHTH, AND WILL R. MEACOCK, BSC, FRCOPHTH

FIGURE 2. Example of a small capsulorhexis lying completely on the implant surface in a 69-year-old man. (Top left) One day after surgery there are two tension lines in the posterior capsule caused by the contact of the lens haptic with the equatorial capsular bag. (Top right) Two weeks after surgery the capsular folds have disappeared. (Bottom left) By 6 months postoperatively fibrosis and remodeling of the anterior capsule rim can be seen with a fine reticular pattern of lens epithelial cells on the posterior capsule. (Bottom right) A fine lens epithelial cell membrane can be seen on the posterior capsule (arrows).
FIGURE 4. The percentage of patients with each grade of wrinkling at 3 months postoperatively for small and large capsulorhexis groups (P < .0001).
The Effect of Capsulorhexis Size on Posterior Capsular Opacification: One-Year Results of a Randomized Prospective Trial

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FIGURE 5. Graph demonstrating the mean percentage area of posterior capsular opacification (PCO) for small and large capsulorhexis groups (error bars represent 95% confidence intervals) (P < 0.0001).
The Effect of Capsulorhexis Size on Posterior Capsular Opacification: One-Year Results of a Randomized Prospective Trial

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FIGURE 3. The logMAR visual acuities for small and large capsulorhexis (CCC) groups over the year (error bars represent 95% confidence intervals) (P 5 .025).
The Subject-Fixated Coaxially Sighted Corneal Light Reflex: A Clinical Marker for Centration of Refractive Treatments and Devices

DANIEL H. CHANG AND GEORGE O. WARING IV

PURPOSE: To describe the inconsistencies in definitions, application, and usage of the ocular reference axes (optical axis, visual axis, line of sight, pupillary axis, and topographic axis) and angles (angle kappa, lambda, and alpha) and to propose a precise, reproducible, clinically defined reference marker and axis for centration of refractive treatments and devices.

METHOD: Literature review of papers dealing with ocular reference axes, angles, and centration.

RESULTS: The inconsistent definitions and usage of the current ocular axes and derived angles from models limit their clinical utility. With a clear understanding of Pupils images and a defined alignment of the observer, light source/fixed target, and subject eye, the subject-fixated coaxially sighted corneal light reflex can be a clinically useful reference marker. The axis formed by connecting the subject-fixated coaxially sighted corneal light reflex and the fixation point, the subject-fixated coaxially sighted corneal light reflex axis, is independent of pupillary dilation and phasic status of the eye. The relationship of the subject-fixated coaxially sighted corneal light reflex axis to a defined visual axis without reference to nodal points, the form-determination axis, is discussed. The displacement between the subject-fixated coaxially sighted corneal light reflex and pupil center is described not by an angle, but by a chord, here termed chord mc.

The application of the subject-fixated coaxially sighted corneal light reflex to the vertical centration of refractive treatments and devices is discussed.

CONCLUSION: As a clinically defined reference marker, the subject-fixated coaxially sighted corneal light reflex avoids the shortcomings of current ocular axes for clinical application and may contribute to better consensus in the literature and improved patient outcomes. (Am J Ophthalmol 2014;158:865-874. © 2014 by Elsevier Inc. All rights reserved.)

CENTRATION OF INTRACLASSIC LENSES (OKS) AND refractive corneal treatments has always been important, but with the development of wavefront and topography-guided treatments, phototherapeutic keratectomy, and corneal inlays, there has been increased interest in the matter. Any attempt at centration implies the identity of a reference center point. Without the proper frame of reference, descriptions of centration have limited reproducibility, utility, and reference. This article examines the ocular axes and angles as described in the literature and suggests an alternative to applying the theoretical reference axes in the clinical setting. Reference markers that can be identified clinically are described, and a new clinically defined reference axis for preoperative measurement, intraoperative alignment, and postoperative assessment of refractive treatments and devices is presented.

THE REFERENCE AXES AND THEIR LIMITATIONS

The human eye is not a centric optical system, as the lens does not lie along the optical axis of the eye.2 The lens and cornea are slightly tilted and deviated relative to one another.2 These multiple unaligned refractive surfaces create challenges in both the optical description of the eye and the clinical determination of centration. In an attempt to study the optical properties of the eye, vision researchers have created simplified models and described ocular reference axes to characterize these models.2,3,4 These axes have proven useful in modeling the eye and describing angular alignment and motility issues.3 However, they lack the specificity and precision to be clinically useful in refractive corneal and intracocular surgery.

A review of the literature reveals that a number of ocular axes have been used to relate the optical structures of the eye, namely the optical axis, visual axis, line of sight, and...
The Subject-Fixated Coaxially Sighted Corneal Light Reflex: A Clinical Marker for Centration of Refractive Treatments and Devices

DANIEL H. CHANG AND GEORGE O. WARING IV
Specular reflection

Specular reflection, also known as regular reflection, is the mirror-like reflection of waves, such as light, from a surface.
Johann Evangelist Purkinje
18 December 1787 – 28 July 1869

Czech anatomist and physiologist

Purkinje Images
Or
Purkinje-Sanson Images

Louis Joseph Sanson
French surgeon and ophthalmologist
Patient Fixating Their Unique P1/P4 relationship Equals Visual Axis
Optical Axes and Angles
The Purkinje Light Reflexes

Image Orientation

P1-upright

P2-upright

P3- upright

P4- inverted
The Purkinje Light Reflexes

Image Orientation

P1-upright
P2-upright
P3- upright
P4- inverted
The Purkinje Light Reflexes

**Image Orientation**
- P1-upright
- P2-upright
- P3-upright
- P4-inverted
The Purkinje Light Reflexes

Useful for Centering Cataract Surgery
- The capsulotomy
- The implant
OC = the optical center of the cornea; PC = the pupillary center; VA = Purkinje-Sanson I image and visual axis. Houston ophthalmologist Jack Holladay says the ideal place to center a multifocal IOL is between PC and VA.

(Image courtesy Jack Holladay, MD, MSEE, FACS.)
Lens Thickness 4080 um

Ant Capsule 3620 um

Post Capsule 7700 um
Manual Capsulotomy

Automated Capsulotomy
Zepto
Automated Capsulotomy
Zepto
Zepto® Capsulotomy System Design

- Disposable Handpiece
- Capsulotomy Tip
- Control Console
Clinical Feature Capsulotomy Tip

- Soft, clear suction cup 6.1mm diam
- Un-obstructed view for visual axis centration
- Nitinol 4.4mm capsulotomy ring 1.18mm height
Clinical Features

Suction pulls capsule against capsulotomy ring

Electrical energy applied to ring for 4 milliseconds

Phase transition of water molecules (Zepto does not coagulate or cauterize)

Precision Pulse Capsulotomy
Precise, Microscale Cutting Mechanism

Precision Pulse Capsulotomy

- Lens capsule
- Bottom edge of nitinol ring
Precision-Pulse Capsulotomy

Layer of trapped water molecules

Suction applied, capsule pulled against ring edge

Increased tensile stress
Precision-Pulse Capsulotomy

Rapid phase transition of water molecules

Multipulse energy discharges

Capsule membrane cleaved precisely

Cross-section through device and capsule
Cut edge

Schematic
Scanning Electron Microscopy (SEM)

A. Schematic
   - Cut edge
   - Functional edge during surgery

B. ZEPTO

C. ZEPTO
   - 20 microns

D. CCC
Edge Strength – CCC vs Zepto™

CCC

ZEPTO

Tear Strength

16 mN

60 mN
Edge Strength
Zepto™ vs Femto & CCC

Paired cadaver eyes
Wilcoxon matched-pairs signed-ranks test $P = 0.012$

Zepto vs Femto & CCC

Wilcoxon matched-pairs signed-ranks test $P = 0.012$

Thompson, Berdahl, Solano, Chang 2016 Ophthalmology
Edge Strength
Zepto™ vs Femto & CCC

Paired cadaver eyes

Wilcoxon matched-pairs signed-ranks test $P = 0.012$

Thompson, Berdahl, Solano, Chang 2016 Ophthalmology
Streamlined method for anchoring cataract surgery and intraocular lens centration on the patient’s visual axis

Vance Thompson, MD

This paper describes an intraoperative method for the consistent anchoring of cataract surgery and IOL centration on the patient’s visual axis using coaxial microscope lights and optics, brief patient fixation, and a precision pulse capsulotomy (PPC) device (Eclipse, Mynors Cellular Devices, Inc.) to center the first Purkinje image as it becomes aligned with the fourth Purkinje image. This technique is based on the subject-related coaxially sighted corneal light reflex as described by Chang and Waring® paired with the use of the PPC device. In this technique, the PPC device serves a dual function. The first is to assist the surgeon in establishing coaxial alignment along the patient’s visual axis. The second is the conversion of the patient’s individual visual axis into a visual axis-centered capsulotomy that is then used as a reference marker for the visual axis and IOL placement, with even capsular overlap, which results in IOL centration on the axial landmark. This method might help address the high variability in angle α from patient to patient and provide visual benefit in cases of implantation of multifocal IOLs and other IOLs.

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From Vance Thompson Vision, Sioux Falls, South Dakota, USA

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Optic Center
Pupil Center
Visual Axis
Interactive Post-Op Process

• First Ever “Patient Trial” of final outcome
• Patient previews different refractions
Femto vs. Zepto?

No
Femto vs. Zepto vs. Manual?

No
Centering Cataract Surgery on the Visual Axis

Thank You!

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