TECHNIQUE

Streamlined method for anchoring cataract surgery and intraocular lens centration on the patient’s visual axis

Vance Thompson, MD

I describe an intraoperative method for the consistent anchoring of the intraocular lens (IOL) and cataract surgery and on the patient’s visual axis using coaxial microscope optics, surgeon-guided patient fixation, the precision pulse capsulotomy (PPC) device (Zepto) and utilizing the first (and fourth) Purkinje images. During surgery using a microscope with coaxial lights and optics, the patient is instructed to fixate on a given microscope light while the surgeon looks through the corresponding coaxial eyepiece. Then, the PPC device is centered on the Purkinje I image and a capsulotomy is performed. The resulting capsulotomy serves as a reference marker for the visual axis and IOL placement, with even capsule overlap, which results in IOL centration on this axis landmark. This method might help address the high variability in angle \( \kappa \) from patient to patient and provide visual benefits in cases of implantation of multifocal IOLs and other IOLs.

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Surgeons vary in their approach to capsulotomy and intraocular lens (IOL) centration during cataract surgery. Some do not consider the anatomic or functional axes of the eye and do not routinely practice centration. Others commonly use the center of the dilated pupil because of its convenience as an easily visible landmark. In these cases, a manual continuous curvilinear capsulorhexis (CCC) is created to approximate a circular capsule opening centered on the pupillary center and the IOL is positioned to achieve capsule overlap as evenly as possible. Imprecision comes about as a result of the inherent deviation from roundness and centration of a capsulotomy created by hand and the potential asymmetry of the dilated pupil. In addition, the pupillary axis is displaced with respect to the visual axis by angle \( \kappa \), which is highly variable in pseudophakic patients. This high degree of variability in angle \( \kappa \) between patients translates into a high degree of variability in chord \( \mu \), which closely approximates the distance between the location of the visual axis and the pupillary center on the capsule plane. Chord \( \mu \) variability might contribute to inconsistent or suboptimum outcomes when the pupillary center is used for alignment, in particular in cases using aspheric, toric, and multifocal IOLs.

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 (Zepto, Mynosys Cellular Devices, Inc.) to center on the first Purkinje image as it becomes aligned with the fourth Purkinje image. This technique is based on the subject-fixated 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 sighting 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 later in surgery. During surgery, with the transparent PPC suction cup inserted into the anterior chamber, the patient is instructed to fixate on a microscope light selected by the surgeon while the surgeon looks through the corresponding coaxial eyepiece. The PPC device is then centered on the Purkinje I (PI) image, which marks the patient’s visual axis, and a capsulotomy is performed. The fourth Purkinje image should be aligned and mostly hidden behind...
PI when the patient is fixating on the co-axial light and can also be a very helpful guide. The resulting capsulotomy preserves the visual axis information and acts as a surrogate reference marker to guide IOL centration on this axis.

SURGICAL TECHNIQUE

Figure 1, A, shows the commonly used methods of creating the CCC at a convenient location on the capsule or approximately around the center of the dilated pupil without prespecified patient fixation. Figure 1, B, shows the technique of using patient fixation to determine the true visual axis followed by the creation of a PPC capsulotomy precisely on this axis. The technique requires the use of a surgical microscope with lights that are coaxial to the eyepieces. First, the surgeon selects 1 eyepiece through which the visual axis alignment procedure will be viewed (panel 1). Next, the PPC device is inserted into the eye and opened to its circular shape. The patient is then instructed to fixate on the microscope light through the transparent PPC device; the light is coaxial to the selected eyepiece (panel 2). After fixation is accomplished, the surgeon identifies the PI image and the center of the PPC device is maneuvered to coincide with the position of the PI image (Figure 1, B, panel 3, and Figure 2). The PI image under these coaxial lighting, patient fixation, and surgeon viewing conditions is the subject-fixated coaxially sighted corneal light reflex described by Chang and Waring2 and is very near the patient’s visual axis in the virgin eye. The surgeon viewing through the selected eyepiece at PI is looking along this axis. After PPC device centering on PI has been completed, a PPC capsulotomy is performed. The center of the PPC capsulotomy corresponds exactly to that specific patient’s visual axis, and the capsulotomy edge serves as a reference marker that can be used later in surgery for IOL centration.

Results

Intraoperative PPC visual axis anchoring was performed in 86 patients having routine cataract surgery with monofocal or multifocal IOL implantation. All patients were able to fixate as instructed and received individualized PPC capsulotomies anchored on their specific visual axis. Monofocal and multifocal IOLs were then centered on the visual axis by alignment with the round PPC capsulotomy to achieve even 360-degree capsule overlap.

A series of photographs from a typical case in which anchoring to the visual axis using PPC was performed is shown in Figure 3 and Video 1 (available at http://jcrsjournal.org). At the beginning of surgery, with the patient lightly sedated, the surgeon practices fixation with the patient (Figure 3, A and B). The PPC device was removed from its packaging and inspected (Figure 3, C). The device push rod was extended forward to elongate the PPC capsulotomy ring and suction cup to facilitate insertion into the eye (Figure 3, D and E). Once in the anterior chamber, the push rod was retracted and the PPC tip regained its original circular shape (Figure 3, F). At this point, the patient was instructed to fixate on the selected microscope light coaxial with the left eyepiece, which is visible through the transparent PPC suction cup. As the patient maintained fixation, the center of the PPC device was maneuvered by the surgeon to coincide with the PI (Figure 3, G). The capsulotomy ring itself can also be used as a circular guide for centering the device on PI. During positioning, it was helpful to ensure that the push rod was left in the silicone neck with the tip of the push rod left just proximal to the capsulotomy ring (Figure 3, G, arrow) to provide stiffness in the neck region and facilitate device maneuverability.

Once PPC suction cup centration on PI was achieved, suction was activated and the push rod then fully retracted.
to its limit (Figure 3, H, arrow) to ensure adequate suction. The PPC capsulotomy was then performed (Figure 3, I). The ophthalmic viscosurgical device (OVD) originally removed during suction was reintroduced back into the PPC suction cup along with a small amount of a balanced salt solution to float the PPC suction cup and capsulotomy ring off the capsule (Figure 3, J). The PPC device was then removed from the eye (Figure 3, K), and hydrodissection and phacoemulsification performed per routine. The IOL was positioned using the PPC capsulotomy as a surrogate marker for the patient’s true visual axis (Figure 3, L). Even, 360-degree capsule overlap was used to guide IOL positioning directly on the patient’s visual axis.

Figure 4, A, shows the IOL position at the end of the surgery (the 2 dimmer reflections below (arrows) are from the IOL surface. Figure 4, B shows the dilated pupil (blue circle) and the PPC capsulotomy (green circle) are displaced with respect to one another. The linear distance between the center of the pupil and the center of the PPC capsulotomy centered on PI (chord mu) is directly proportional to the patient’s angle $\kappa$. Angle $\kappa$ has been documented to vary significantly between patients.

**DISCUSSION**

The method described here uses surgeon-guided patient fixation to identify the patient’s visual axis intraoperatively. The optically clear PPC device is then used to convert this axis location into an individualized capsulotomy centered on the patient’s visual axis, preserving this visual axis information that is lost once cataract surgery commences. The PPC capsulotomy in turn acts as a visual axis reference marker that is then used later in the surgery for IOL centration on that particular patient’s visual axis. The PPC device provides an optically clear window during patient fixation and capsulotomy. Any obstruction limiting the patient’s ability to fixate on the coaxial light eliminates the opportunity to perform visual axis anchoring as described.

Commercially available femtosecond laser platforms place the capsulotomy on the center of the pupil or use imaging to approximate and center on the capsular bag. Capsulotomy centration on the capsular bag centers on the eye’s optical axis, which is offset from the eye’s visual axis (reviewed by Chang and Waring). The present method of visual axis anchoring using patient fixation and PPC capsulotomy cannot be performed with a femtosecond laser because interface docking inhibits patient fixation and likely moves the eye as docking is performed. Furthermore, the use of an air or liquid interface for the docking process might also complicate attempts at fixation.

The described method of visual axis anchoring requires only a surgical microscope with coaxial lights and optics and a small disposable PPC device. It uses the built-in transparency of the PPC suction cup, and no preoperative imaging or heads up display of images are needed. Given that patient fixation is used to inform the surgeon on PPC placement, patient sedation must be adjusted to allow for patient cooperation during the process. Additional sedation can be given once the capsulotomy has been completed. Patients who cannot follow surgeon instructions for fixation, have higher grade cataracts or ocular pathologies limiting vision, or those requiring full anesthesia are not candidates for the procedure.

The present study describes a cataract surgery centration method using a PPC device that was recently approved by the U.S. Food and Drug Administration PPC. It has been reported that the PPC device is easy to use for creating round, consistent capsulotomies in simple and challenging cases of cataract surgery. Well-constructed capsulotomies with even capsular overlap are thought to minimize posterior capsule opacification, asymmetric anterior capsule contraction, IOL tilt, late decentration of the optic, and encourage a stable tilt. The visual axis anchoring technique described here extends the PPC’s role beyond
Figure 3. A typical case in which a personalized cataract surgery anchored on the patient’s visual axis is performed using the PPC device. A and B: At the start of surgery, the patient practices fixating on the surgical light selected by the surgeon. C: The protective covering is removed from the PPC device and the device is inspected according to manufacturer’s instructions. D: The PPC suction cup and capsulotomy ring are elongated using the finger slider to extend the push rod forward. E: The PPC tip is inserted through the primary incision into the anterior chamber. F: The push rod is retracted and the suction cup and capsulotomy ring spontaneously open to their original circular shapes. G: The tip of the push rod (yellow arrow) is left just proximal to the capsulotomy ring. The presence of a rigid push rod in the PPC silicone neck aids in maneuvering the PPC suction cup in the anterior chamber and lining up its center with the Purkinje I image. In this case, the patient was instructed to fixate on the light (white arrow) coaxial with the left eyepiece. H: After PPC positioning is achieved, suction is activated and simultaneously the push rod is retracted all the way out of the device neck so as to not interfere with the development of suction required for consistent capsulotomy. I: The PPC capsulotomy is performed centered on the patient’s visual axis. J: The OVD that was removed from the suction cup during the suction step is reintroduced back into the suction cup along with a small amount of a balanced salt solution. K: The PPC device is removed from the eye and the surgeon continues with hydrodissection, phacoemulsification, and irrigation/aspiration. L: An IOL (Symphony, Johnson & Johnson Vision) positioned to achieve 360-degree even overlap with the visually centered PPC capsulotomy (IOL = intraocular lens; OVD = ophthalmic viscosurgical device; PPC = precision pulse capsulotomy).

Figure 4. A: The IOL was aligned using the PPC as a reference marker. The 360-degree even overlap with the visually centered PPC capsulotomy places the IOL on the patient’s visual axis. The 2 dimmer light reflections below (white arrows) are from the IOL surface. B: The blue circle demarcates the pupil. The green circle demarcates the PPC capsulotomy. Note that the blue and green circles are not concentric. The displacement of their respective centers from one another corresponds to chord $\mu$ and is proportional to angle $\kappa$ in this patient (IOL = intraocular lens; PPC = precision pulse capsulotomy).
being an automated capsulotomy device into a surgical tool that might bring additional visual benefits related to IOL centration on the visual axis.

Purkinje images are very helpful in centering cataract surgery on the patient’s visual axis. (See Chang and Waring 2014 for a complete discussion of the Purkinje images and their relative positions as seen by the surgeon during patient fixation on the co-axial light.) In addition to locating the PI image during patient co-axial fixation, the fourth Purkinje image may be very helpful as it should be mostly hidden behind PI if proper patient fixation on the co-axial light is achieved. For certain patients with difficulty fixating on the co-axial light as instructed, the surgeon can use a second instrument to move the eye and align the first and forth Purkinje images and then center the PPC capsulotomy on PI.

Visual axis anchoring of cataract surgery using PPC requires minimal equipment, provides seamless integration into routine cataract surgery, and is easy to learn. A recent study of a large number of pseudophakic patients found a high degree of variability in angle $\kappa$ from individual to individual. In addition, multiple researchers have examined the relationship between angle $\kappa$ and the occurrence of undesired photic phenomena and concluded that consideration of angle $\kappa$ is important for optimizing the quality of vision and patient satisfaction. An easy-to-perform methodology for true visual axis alignment intraoperatively that is based on fundamental principles might therefore provide more consistent and better outcomes for patients. This is likely the case for those receiving aspheric, toric, and multifocal IOLs but might also be true for the general population of cataract surgery patients. Given the limitations in the size of the light in current surgical microscopes and the current lack of a visual aid for centration on the PPC device limiting the surgeon’s ability to manually place the center of the PPC device onto the PI image, a certain lack of precision is inherent in this method. However, it is likely to be an improvement over guessing the location of a patient’s visual axis, especially given its high variability among patients. Furthermore, for surgeons who place diffractive optics somewhere between the center of the pupil and the visual axis, the specific localization of the patient’s visual might be helpful and the location of the capsulotomy can be adjusted accordingly.

At present, many surgeons place the capsulorhexis slightly nasally to account for angle $\kappa$ and correspondingly manually move the optic nasally in the horizontal plane to achieve optimum capsulotomy overlap. This is often performed using 1-piece acrylic IOLs with the haptics directed at 6 o’clock and 12 o’clock. The surgeon nudges the optic nasally to move the haptic–capsular bag contact points, taking advantage of the ability of the haptic’s geometric design to be accommodated at a range of locations within the capsular bag off the vertical axis. This IOL positioning procedure can be used with the visual axis–centered PPC capsulotomy described here. However, this ability to position the IOL in the horizontal plane is not universally accepted because others believe the optic will always center in the center of the capsular bag as a result of the properties of the haptics. An automated capsulotomy that can serve as a reference marker for centering IOLs on the visual axis could encourage the development of IOLs with adjustable haptics or other technologies for positioning in the horizontal plane. Edge-captured IOLs, such as the Femtis IOL (Oculentis GmbH) available in Europe, have been used in conjunction with PPC capsulotomies. Because the horizontal position of these IOLs in the eye is dictated solely by the location of the capsulotomy, the present method of intra-operative capsulotomy centration on the visual axis might be useful.

The nature of any visual benefit must await formal controlled studies of an appropriate number of patients. The intent of this paper is to introduce a method whereby surgeons can routinely anchor cataract surgery and center the IOL on the visual axis. This form of individualized cataract surgery in which the patient’s personal visual axis is used might help optimize outcomes and benefit patients.

WHAT WAS KNOWN

- Cataract surgery commonly involves the creation of a manual CCC approximately centered on the dilated pupil. Because pupil dilation is often asymmetric and the maintenance of a precise central point during CCC is exceedingly difficult, surgeons have little reference to important functional axes in the eye, including the visual axis, once surgery has started.
- There is substantial variability in angle $\kappa$ among pseudophakic patients.

WHAT THIS PAPER ADDS

- The combination of patient fixation on a light from a microscope with coaxial lights and optics and surgeon viewing through the corresponding coaxial eyepiece allows the creation of a PPC capsulotomy that is centered precisely on the patient’s visual axis.
- This individualized PPC capsulotomy can act as a reference marker for IOL implantation on the visual axis, and may provide benefits in implantation of toric, multifocal, or other IOLs.

REFERENCES


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First author:
Vance Thompson, MD
Vance Thompson Vision, Sioux Falls, South Dakota, USA