

Determining Ocular Fixation for Centering IOLs With Purkinje Images

A proper understanding and identification of the ocular axes are important in achieving good centration of IOLs. This article is the second in a three-part series.

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With the advent of aspheric and diffractive multifocal IOLs, interest in how to improve the centration of these lenses is growing. A poorly centered IOL can significantly reduce patients' quality of vision, increase night vision symptoms, and lower their satisfaction. Surgeons have not previously had a reliable way to determine the accuracy of IOLs' centration intraoperatively, however.

In the June issue of *Cataract & Refractive Surgery Today*, I described a simple method for using Purkinje images as real-time markers of the IOL's position. Briefly, the surgeon or technician takes a preoperative photograph of the eye and notes the location of the first Purkinje image (PI) relative to the center of the undilated pupil. Intraoperatively, the surgeon uses the PI as a marker to find the location of that undilated pupillary center while he or she is operating on the dilated eye. This technique works well but requires the patient to maintain good fixation intraoperatively. If a patient is unable to fixate properly, the surgeon can manually rotate the eye to find the line of sight, using Purkinje images as positional markers.

OCULAR AXES AND ANGLES

The eye has four axes relevant to the alignment of IOLs: the optical axis, the pupillary axis, the line of sight, and the visual axis (Figure 1). The optical and pupillary axes have anatomic definitions based on the anterior segment's structures: the optical axis is the line connecting all three Purkinje images (Figure 1A), and the pupillary axis is the line orthogonal to the cornea that passes through the center of the pupil (Figure 1B). Unless the IOL is tilted or the pupil is

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corectopic, the optical and pupillary axes are functionally the same. The line of sight and the visual axis have functional definitions based on fixation: the line of sight is the line connecting the fixation point with the center of the pupil (Figure 1C), and the visual axis is the line connecting the fixation point with the nodal point of the eye (Figure 1D). Unless the fixation point is very close to the eye, the line of sight and visual axis are functionally the same.

Note that, although the pupillary axis and the line of sight are anatomically defined, the optical axis and visual axis are theoretically defined. The optical axis, depending upon the proper alignment of all three Purkinje images, may not be definable in the situation of a tilted (or absent) lens. Similarly, the visual axis is defined with respect to the nodal point of the eye, which is a theoretical construct in ocular models with perfect radial symmetry. Therefore, for the purpose of centering an IOL, the pupillary axis and the line of sight are the relevant axes of concern.

Although the pupillary axis and the line of sight are anatomically defined, all four ocular axes are essentially theoretical constructs that help define certain relationships within the eye. Their definitions fall apart when applied to eyes that have significant variations from the assumptions made by the ocular model. For example,

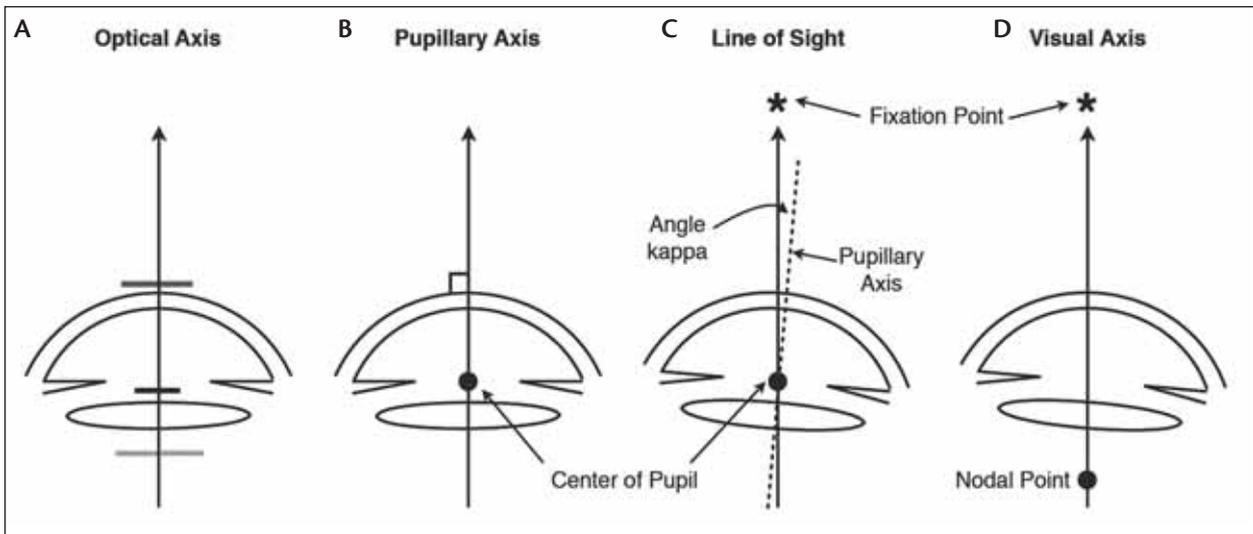


Figure 1. The four axes of the eye. The optical axis is the line connecting all three Purkinje images (A). The pupillary axis is the line orthogonal to the cornea that passes through the center of the pupil (B). The line of sight is the line connecting the fixation point with the center of the pupil (C). The visual axis is the line connecting the fixation point with the nodal point of the eye (D). Angle kappa is the angle between the pupillary axis and the line of sight (C).

eyes with corneal ectatic disease, abnormalities of the iris' shape, tilted lenses, or aphakia may have axes that are not definable. Nevertheless, the ocular axes in general, and the pupillary axis and line of sight in particular, serve as good references for the orientation and position of the eye.

By definition, the pupillary axis and the line of sight intersect at the pupillary plane. In other words, at the pupillary plane, the pupillary axis and the line of sight cross the exact same X, Y, and Z positions. Angle kappa denotes the angular difference between the pupillary axis and the line of sight as they diverge from the pupillary plane (Figure 1C). For most eyes, angle kappa is approximately 5° ; because the IOL plane is less than 1.5 mm posterior to the anterior iris plane,² the X and Y positions of the pupillary axis and the line of sight will only differ by about 0.1 mm in the IOL plane. Therefore, the pupillary axis and the line of sight are functionally the same when used to center an IOL.

Because their definitions are based on the location of the pupillary center, the exact positions of the pupillary axis and the line of sight can change by nearly 1 mm with pupillary constriction and dilation.^{3,4} Therefore, it is important to align the center of the IOL with the center of the undilated pupil to achieve good alignment with the pupillary axis and the eye's line of sight in its normal physiologic state.

CONFIRMING FIXATION INTRAOPERATIVELY

To use Purkinje images to align a diffractive multifocal IOL to the center of the undilated pupil, the light

source and the observer must be aligned coaxially with the patient's fixation during each step of the process. Preoperatively, the surgeon locates an eye's PI when the eye is fixated at a light source that is coaxial to the imaging camera. To re-create the same X and Y locations of the PI intraoperatively, the eye must fixate on a microscope's light coaxial to the surgeon's view (ie, the patient's line of sight must be aligned with the microscope's light). If the patient is able to fixate, the location of PI will be consistent with the preoperative photograph and can therefore be used as a marker for locating the undilated pupillary center.

If the patient does not voluntarily fixate, the third and the fourth Purkinje images (PIII and PIV) can be used to determine fixation. In three-dimensional space, PIII and PIV float below and above the PI, and their X and Y positions are sensitive to small degrees of ocular rotation. Because PIII and PIV come from the anterior and posterior surfaces of the IOL, it is important that the IOL be planar (no tilt), which is achieved with complete unfolding and implantation of the IOL within the capsular bag. In this configuration, the optical axis is visualized when all three Purkinje images (PI, PIII, and PIV) are aligned (Figure 2A). As mentioned previously, when the IOL is planar, the optical axis and pupillary axis are functionally the same.

FINDING THE LINE OF SIGHT

To find the line of sight, one must consider angle kappa, the angle between the pupillary axis and the

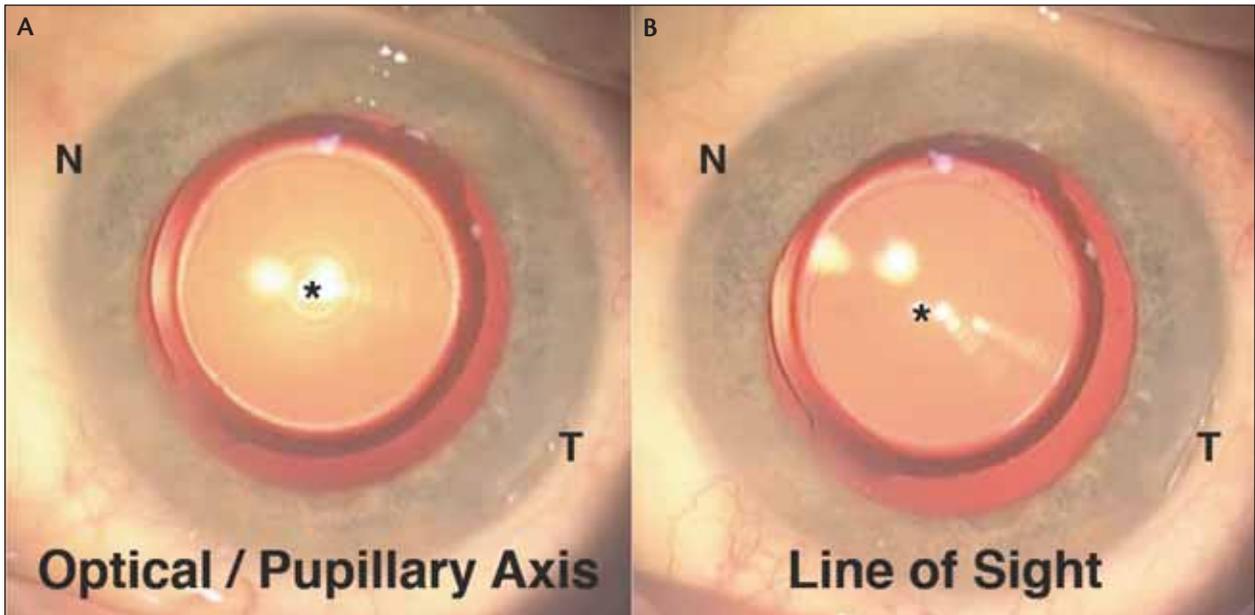


Figure 2. The surgeon’s view of a right eye along the optical/pupillary axis (A) and the line of sight (B), designated with an asterisk. The eye is rotated temporally from the optical/pupillary axis to reach the line of sight. Note the appearance of increased space between the IOL and the temporal iris due to the temporal rotation of the eye from (A) to (B). The IOL is in the same position in both photographs, as evidenced by the unchanged relationship between the IOL and the capsular bag nasally and inferiorly. The third, noncoaxial light of the Lumera microscope (Carl Zeiss Meditec, Inc., Dublin, CA) has been turned off in these photographs.

line of sight. Because the fovea is slightly temporal to the optic nerve, the eye must rotate slightly temporally to place images onto the fovea (Figure 2B). Clinical studies have found the angle kappa typically to be between 5° and 6°.¹ Individuals with hyperopia have a larger angle kappa than those with myopia, but these differences are small.

With this information, I can manually locate the line of sight in patients who do not fixate voluntarily. After centering the eye under the microscope, I rotate the eye until all three Purkinje images align (Figure 2A). The resultant view down the optical/pupillary axis serves as my starting point. I then rotate the eye slightly temporally until PIII is nasal and PIV is temporal to the PI. Although the exact position of PIII and PIV could be precisely calculated in theory, simply placing PIII at the nasal edge of the IOL and PIV at the temporal midperiphery of the IOL serves as a good approximation of the patient’s fixation (Figure 2B). With proper orientation of the eye down the line of sight, I can then use the PI as a marker—in conjunction with the preoperative photograph of the undilated pupil—to center the IOL. Even when a patient appears to fixate on the microscope’s light, I routinely note the position of the PIII and PIV to verify that the patient is indeed fixating appropriately.

CONCLUSION

With an increased awareness and understanding of the ocular axes, surgeons can better address the eye’s orientation and an IOL’s centration. Any study discussing the centration of IOLs should provide a clear explanation or definition of the axis or the location that is considered to be the center. Because most negative visual symptoms tend to occur under scotopic conditions, IOLs are best centered on the undilated scotopic pupil.

Ultimately, more research is needed to verify where best to center an IOL for optimal visual performance. Although the ideal intraoperative location may vary by IOL design, nevertheless, Purkinje images can help surgeons determine the eye’s orientation and the IOL’s position in any cataract surgical case. ■

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