Cataract Surgery in Patients with Previous Keratorefractive Surgery (RK, PRK, and LASIK)

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Abstract

Successful cataract surgery is more difficult to achieve in patients who have developed cataracts following RK, PRK, LASIK, or other keratorefractive procedures than in the standard cataract patient. Preoperative considerations are directed at measuring the health, optical quality, and refractive power of the cornea. The health of the cornea can be assessed by specular microscopy, pachymetry, and biomicroscopy. Preoperative assessment of the optical quality of the cornea is very important to ensure that the reduced vision is due to the cataract and not the cornea. Direct ophthalmoscopy and corneal topography are both valuable in separating these factors. Corneal Topography Software that predicts the limiting visual acuity due to the cornea is also valuable for quantifying the corneal distortion.

Determining the correct corneal refractive power is difficult and usually requires multiple methods to arrive at a reliable value. Although topography instruments are usually better than automated keratometers, which are usually better than manual keratometers, none of these instruments measures the posterior radius of the cornea, which is necessary to determine the exact power. The most accurate methods are those calculated from the perioperative keratorefractive data or a trial rigid contact lens.

Visualization during surgery is sometimes more difficult due to the RK incisions in the cornea. The greater the number of incisions, the more difficult the visualization through the peripheral cornea. Postoperatively, patients with previous RK may have a hyperopic shift in their refraction the first few days, similar to the original procedure. Also, long-term hyperopic drifts with progressive against-the-rule astigmatism will be present in a minority of patients.

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Background

The number of patients who have had keratorefractive surgery — radial keratotomy (RK), photorefractive keratectomy (PRK), or laser-assisted in situ keratomileusis (LASIK) — has been steadily increasing over the past 20 years. With the clinical approval of the excimer laser, these numbers are predicted to increase dramatically. Determining their corneal power accurately is difficult and usually is the determining factor in the accuracy of the predicted refraction following cataract surgery. Providing this group of patients the same accuracy with intraocular lens (IOL) power calculations as we have provided our standard cataract patients presents an especially difficult challenge for the clinician.

Preoperative Evaluation

Corneal Evaluation

At present, far more patients have had RK than PRK and LASIK combined. Also, our long-term follow-up of RK patients is much greater. The long-term studies of RK patients reveal that some have hyperopic shifts in their refraction and develop progressive against-the-rule astigmatism.[1] The long-term refractive changes in PRK and LASIK are unknown, except for the regression effect following attempted PRK corrections exceeding 8.00 diopters (D). No matter which procedure the patient has had, the stability or instability of the refraction must be determined. This determination includes daily fluctuations from morning to night as well as long-term changes over the past few years. Each of these factors must be used in determining the desired postoperative target refraction and to prepare the patient for the visual changes and realistic expectations following the procedure.

In all of these cases, biomicroscopy, retinoscopy, corneal topography, and endothelial cell counts are recommended. The first three tests are directed primarily at evaluating the amount of irregular astigmatism. This determination is extremely important preoperatively, because the irregular astigmatism, as well as the cataract, may be contributing to the reduced vision. The irregular astigmatism may also be the limiting factor in the patient's vision following cataract surgery. The endothelial cell count is necessary to recognize any patients with low cell counts from the previous surgery who may be at higher risk for corneal decompensation or prolonged visual recovery.

The potential acuity meter (PAM), super pinhole, and hard contact lens trial are often helpful as secondary tests in determining the respective contribution to reduced vision by the cataract and the corneal irregular astigmatism. The patient should also be informed that only the glare from the cataract will be eliminated; any glare from the keratorefractive procedure will essentially remain unchanged.

Limitations of IOL Power Calculation Formulas

When calculating IOL power, the third-generation formulas (Holladay 1, Hoffer Q, and the SRK/T) and the new Holladay 2 formula are much more accurate than previous formulas. In the more unusual eye (short or long axial lengths, or flat or steep corneas), older formulas such as the SRK1, SRK2, and Binkhorst 1 should not be used, as none of these formulas will give the desired result if the central corneal power is measured incorrectly. The resulting errors are almost always in the hyperopic direction following keratorefractive surgery, because the measured corneal powers are usually greater than the true refractive power of the cornea. The following discussion explains the calculation method and the contact lens method for determining the corneal power, as well as the limitations of the keratometers and topography units.

Methods of Determining Corneal Power

Accurately determining the central corneal refractive power is the most important and difficult part of the entire IOL calculation process. The explanation for this is quite simple. Our current instruments for measuring corneal power make too many incorrect assumptions with corneas that have irregular astigmatism. The cornea can no longer be compared to a sphere centrally, the posterior radius of the cornea is no longer 1.2 mm steeper than the anterior corneal radius, etc. Because of these limitations, the calculated method and the hard contact lens trial method are most accurate, followed by corneal topography, automated keratometry, and finally manual keratometry.

Calculation Method

For the calculation method, three parameters must be known: the K-readings and refraction before the keratorefractive procedure and the stabilized refraction after the keratorefractive procedure. It is important that the stabilized postoperative refraction be measured before any myopic shifts from nuclear sclerotic cataracts occur. It is also possible for posterior subcapsular cataracts to cause an apparent myopic shift, similar to capsular opacification, where the patient wants more minus in the refraction to make the letters appear smaller and darker. The concept that we described in 1989[2] subtracts the change in refraction due to the keratorefractive procedure at the corneal plane from the original K-readings before the procedure, to arrive at a calculated postoperative K-reading.[2] This method is usually the most accurate because the preoperative Ks and refraction are usually accurate to ± 0.25 D. An example illustrating the calculation method follows:

Example:

Mean Preoperative K = 42.50 @ 90° and 41.50 @ 180° = 42.00 D
Preoperative Refraction = −10.00 + 1.00 x 90°, Vertex = 14 mm
Postoperative Refraction = −0.25 + 1.00 x 90°, Vertex = 14 mm

Step 1. Calculate the sphero-equivalent refraction for refractions at the corneal plane (SEQ_C) from the sphero-equivalent refractions at the spectacle plane (SEQ_S) at a given vertex, where

a) SEQ = Sphere + 0.5 (Cylinder)

b) $$SEQ_C = \frac{1000}{\frac{1000}{SEQ_S} - \text{Vertex (mm)}}$$

Calculation for *preoperative* sphero-equivalent refraction at corneal plane:

a) $SEQ_R = -10.00 + 0.5 * (1.00) = -9.50$ D

b) $$SEQ_C = \frac{1000}{\frac{1000}{-9.50} - 14} = -8.38 \text{ D}$$

Calculation for *postoperative* sphero-equivalent refraction at corneal plane:

a) $SEQ_R = -0.25 + 0.5 * (1.00) = +0.25$ D

b) $$SEQ_C = \frac{1000}{\frac{1000}{+0.25} - 14} = +0.25 \text{ D}$$

Step 2. Calculate the change in refraction at the corneal plane.

Change in refraction = Preoperative SEQ_C − Postoperative SEQ_C

Change in refraction = −8.38 − (+.025) = −8.68 D

Step 3. Determine calculated postoperative corneal refractive power.

Mean Postoperative K = Mean Preoperative K – Change in refraction at corneal plane
Mean Postoperative K = 42.00 – 8.68 = 33.32 D

This value is the calculated central power of the cornea following the keratorefractive procedure. For IOL programs requiring two K-readings, this value would be entered twice.

Hard Contact Lens Trial Method

The hard contact lens trial method requires a plano hard contact lens with a known base curve and a patient whose cataract does not prevent refraction to approximately ± 0.50 D. This tolerance usually requires a visual acuity of better than 20/80. The patient's sphero-equivalent refraction is determined by normal refraction. The refraction is then repeated with the hard contact lens in place. If the sphero-equivalent refraction does not change with the contact lens, then the patient's cornea must have the same power as the base curve of the plano contact lens. If the patient has a myopic shift in the refraction with the contact lens, then the base curve of the contact lens is stronger than the cornea by the amount of the shift. If there is a hyperopic shift in the refraction with the contact lens, then the base curve of the contact lens is weaker than the cornea by the amount of the shift.

Example: The patient has a current sphero-equivalent refraction of +0.25 D. With a plano hard contact lens with a base curve of 35.00 D placed on the cornea, the spherical refraction changes to –2.00 D. Since the patient had a myopic shift with the contact lens, the cornea must be weaker than the base curve of the contact by the 2.25 D. Therefore, the cornea must be 32.75 D (35.00 – 2.25), which is slightly different than the value obtained by the calculation method. In equation form, we have:

SEQ refraction without hard contact lens = +0.25 D
Base curve of plano hard contact lens = 35.00 D
SEQ refraction with hard contact lens = –2.00 D

Change in refraction
= –2.00 – (+0.25) = –2.25 D (myopic shift)
Mean corneal power
= base curve of plano HCL + change in refraction
Mean corneal power = 35.00 + –2.25
Mean corneal power = 32.75 D

N.B.: This method is limited by the accuracy of the refractions which may be limited by the cataract.

Corneal Topography

Current corneal topography units measure more than 5000 points over the entire cornea and more than 1000 points within the central 3 mm. This additional information provides greater accuracy in determining the power of corneas with irregular astigmatism compared to keratometers. The computer in topography units allows the measurement to account for the Stiles-Crawford effect, actual pupil size, etc. These algorithms allow a very accurate determination of the anterior surface of the cornea.[3] They provide no information, however, about the posterior surface of the cornea. In order to accurately determine the total power of the cornea, the power of both surfaces must be known.

In normal corneas that have not undergone keratorefractive surgery, the posterior radius of curvature of the cornea averages 1.2 mm less than the anterior surface.[3] In a person with an anterior corneal radius of 7.5 mm using the Standardized Keratometric Index of Refraction of 1.3375, the corneal power would be 45.00 D. Several studies have shown that this power overestimates the total power of the cornea by approximately 0.56 D. Hence, most IOL calculations today use a net index of refraction of 1.3333 (4/3) and the anterior radius of the cornea to calculate the net power of the cornea. Using this lower value, the total power of a cornea with an anterior radius of 7.5 mm would be 44.44 D. This index of refraction has provided excellent results in normal corneas for IOL calculations.

Following keratorefractive surgery, the assumptions that the central cornea can be approximated by a sphere (no significant irregular astigmatism or asphericity) and that the posterior corneal radius of curvature is 1.2 mm less than the anterior radius are no longer true. Corneal topography instruments can account for the changes in the anterior surface, but are unable to account for any differences in the relationship to the posterior radius of curvature. In RK, the mechanism of having a peripheral bulge and central flattening apparently causes similar changes in both the anterior and posterior radius of curvature. Therefore, using the net index of refraction for the cornea (4/3) usually gives fairly accurate results, particularly for optical zones larger than 4 to 5 mm. In RKs with optical zones of 3 mm or less, the accuracy of the predicted corneal power diminishes. Whether this inaccuracy is due to the additional central irregularity with small optical zones or to the difference in the relationship between the front and back radii of the cornea is unknown at this time. Studies measuring the posterior radius of the cornea in these patients will be necessary to answer this question.

In PRK and LASIK, the inaccuracies of these instruments to measure the net corneal power is almost entirely due to the change in the relationship of the radii of the front and back of the cornea, since the irregular astigmatism in the central 3-mm zone is usually minimal. In these two procedures, the anterior surface of the cornea is flattened with little or no effect on the posterior radius. Using a net index of refraction (4/3) will overestimate the power of cornea by 14% of the change induced by the PRK or LASIK. For example, if patient had a 7.00-D change in the refraction at the corneal plane from a PRK or LASIK with spherical preoperative Ks of 44.00 D, the actual power of the cornea is 37.00 D and the topography units will give 38.00 D. If a 14.00-D change in the refraction has occurred at the corneal plane, the topography units will overestimate the power of the cornea by 2.00 D.

In summary, the corneal topography units do not provide accurate central corneal power following PRK, LASIK, or in RKs with optical zones of 3 mm or less. In RKs with larger optical zones, the topography units become more reliable. The calculation method and hard contact lens trial are always more reliable than direct measurements.

Automated Keratometry

Automated keratometers are usually more accurate than manual keratometers in corneas with small optical zone ($\leq$ 3 mm) RKs, because they sample a smaller central area of the cornea (nominally 2.6 mm). In addition, the automated instruments often have additional eccentric fixation targets that provide more information about the paracentral cornea. When a measurement error on an RK cornea is made, the instrument almost always gives a central corneal power that is greater than the true refractive power of the cornea. This error occurs because the samples at 2.6 mm are very close to the paracentral knee of the RK. The smaller the optical zone and the greater the number of RK incisions, the greater the probability and magnitude of the error. Most of the automated instruments have reliability factors that are given for each measurement helping the clinician decide on the reliability in the measurement.

Automated keratometry measurements following LASIK or PRK yield accurate measurements of the front radius of the cornea, because the transition areas are far outside the 2.6-mm zone that is measured. The measurements are still not accurate, however, because the assumed net index of refraction (4/3) is no longer appropriate for the new relationship of the front and back radii of the cornea after PRK or LASIK, just as with the topographic instruments. The change in central corneal power as measured by the keratometer from PRK or LASIK must be increased by 14% to determine the actual refractive change at the plane of the cornea. Hence, the automated keratometer will overestimate the power of the cornea proportional to the amount of PRK or LASIK performed.

Manual Keratometry

Manual keratometers are the least accurate in measuring central corneal power following keratorefractive procedures, because the area that they measure is usually larger than automated at 3.2 mm in diameter. Therefore, measurements in this area are extremely unreliable for RK corneas with optical zones $\leq$ 4 mm. The one advantage with the manual keratometer is that the examiner is actually able to see the reflected mires and the amount of irregularity present. Seeing the mires does not help get a better measurement, but does allow the observer to discount the measurement as unreliable.

The manual keratometer has the same problem with PRK and LASIK as topographers and automated keratometers, and is therefore no less accurate. The manual keratometer will overestimate the change in the central refractive power of the cornea by 14% following PRK and LASIK.

Choosing the Desired Postoperative Refraction Target

Determining the desired postoperative refractive target is no different than in other patients with cataracts in which the refractive status and the presence of a cataract in the other eye are the major determining factors. A complete discussion of avoiding refractive problems with cataract surgery is beyond the scope of this paper, and is thoroughly discussed in the reference given.[4] A short discussion of the major factors will follow.

If the patient has binocular cataracts, the decision is much easier, because the refractive status of both eyes can be changed. The most important decision is whether the patient prefers to be myopic and read without glasses, or near emmetropic and drive without glasses. In some cases, the surgeon and patient may choose the intermediate distance (−1.00 D) for the best compromise. Targeting for monovision is certainly acceptable, provided the patient has successfully utilized monovision in the past. Trying to produce monovision in a patient who has never experienced this condition may cause intolerable anisometropia and require further surgery.

Monocular cataracts allow fewer choices for the desired postoperative refraction because the refractive status of the other eye is fixed. The general rule is that the operative eye must be within 2.00 D of the nonoperative eye in order to avoid intolerable anisometropia. In most cases this means matching the other eye or targeting for up to 2.00 D nearer emmetropia, i.e., if the unoperative eye is –5.00 D, then the target would be –3.00 D for the operative eye. If the patient is successfully wearing a contact in the unoperative eye or has already demonstrated his ability to accept monovision, then an exception can be made to the general rule. It should always be stressed, however, that should the patient be unable to continue wearing a contact, the necessary glasses for binocular correction may be intolerable and additional refractive surgery may be required.

Intraoperative Evaluation

Intraoperative Visualization and Corneal Protection

Intraoperative visualization is usually more difficult in patients with previous RK than in the normal cataract patient, and is somewhat similar to severe arcus senilis or other conditions that cause peripheral corneal haze. The surgeon should be prepared for this additional difficulty by making sure that the patient is lined up to visualize the cataract through the optical zone. This usually means lining the microscope perpendicular to the center of the cornea so that the surgeon is looking directly through the optical zone at the center of the cataract. When removing the peripheral cortex, the eye can be rotated, so that visualization of the periphery is through the central optical zone. It is also prudent to coat the endothelium with viscoelastic to minimize any endothelial cell loss, since the keratorefractive procedure may have caused some prior loss.

Intraoperative Autorefractor/Retinoscopy

Large refractive surprises can be avoided by using intraoperative retinoscopy or hand-held autorefractors. These refractions should not be relied upon, however, for fine-tuning the IOL power, since there are many factors at surgery that may change in the postoperative period. Factors such as the pressure from the lid speculum, axial position of the IOL, intraocular pressure, etc., may cause the intraoperative refraction to be different than the final stabilized postoperative refraction. If the intraoperative refraction is within 2.00 D of the target refraction, no lens exchanges should be considered unless intraoperative keratometry can also be performed.

Postoperative Evaluation

Refraction on the First Postoperative Day

On the first postoperative day following cataract surgery, patients who previously have had RK usually have a hyperopic shift, similar to the first postoperative day following their RK. This phenomenon is primarily due to the transient corneal edema that usually exaggerates the RK effect. These patients also exhibit the same daily fluctuations during the early postoperative period after their cataract surgery as they did after the RK. Usually this daily shift is in a myopic direction during the day, due to the regression of corneal edema after awakening in the morning.[5] Because the refractive changes are expected and vary significantly among patients, no lens exchange should be contemplated until after the first postoperative week or until after the refraction has stabilized, whichever is longer.

Very few results of cataract surgery following PRK and LASIK are available. In the few cases that have been performed, the hyperopic shift on the first day and daily fluctuations appear to be much less, similar to the early postoperative period following these procedures. In most cases, the stability of the cornea makes these cases no different than patients who have not had keratorefractive surgery.

Long-Term Results

Long-term results of cataract surgery following RK are very good. The long-term hyperopic shifts and development of against-the-rule astigmatism over time following cataract surgery should be the same as in the long-term studies following RK. The problems with glare and starburst patterns are usually minimal because the patients have had to adjust to these unwanted optical images following the initial RK. If the patient's primary complaint before cataract surgery is glare and starbursts, it should be made clear to the patient that only the glare due to the cataract will be removed by surgery, and the symptoms that are due to the RK will remain unchanged.

Long-term results following PRK and LASIK are nonexistent. Since there are no signs of hyperopic drifts or development of against-the-rule astigmatism in the five-year studies following PRK, one would not expect to see these changes. However, the early studies following RK did not suggest any of these long-term changes either. Only time will tell whether central haze, irregular astigmatism, etc., will be problems that develop in the future.

IOL Calculations Using Ks and Preoperative Refraction for Refractive Surprises in Pseudophakia

Formula and Rationale for Using Preoperative Refraction versus Axial Length

In a standard cataract removal with IOL implantation, the preoperative refraction is not very helpful in calculating the power of the implant, because the crystalline lens will be removed, so dioptric power is being removed and then replaced. In cases where no power is being removed from the eye, the necessary IOL power for a desired postoperative refraction can be calculated from the corneal power and preoperative refraction — the axial length is not helpful. Such cases would include a secondary implant in aphakia, piggy-back IOL in pseudophakia, or a minus IOL in the anterior chamber of a phakic patient. The formula for calculating the necessary IOL power is given below:[6]

$$IOL = \frac{1336}{\dfrac{1336}{\dfrac{1000}{\dfrac{1000}{PreRx} - V} + K} - ELP} - \frac{1336}{\dfrac{1336}{\dfrac{1000}{\dfrac{1000}{DPostRx} - V} + K} - ELP}$$

where

ELP = expected lens position in mm (distance from corneal vertex to principal plane of intraocular lens),

IOL = intraocular lens power in diopters,

K = net corneal power in diopters,

PreRx = preoperative refraction in diopters,

DPostRx = desired postoperative refraction in diopters,

and V = vertex distance in mm of refractions.

Example: Secondary Piggy-Back IOL for Pseudophakia. In patients with a significant residual refractive error following the primary intraocular lens implant, it is often easier surgically and more predictable optically to leave the primary implant in place and calculate the secondary piggy-back IOL power to achieve the desired refraction. This method does not require knowledge of the power of the primary implant nor the axial length. This method is particularly important in cases where the primary implant is thought to be mislabeled. The formula works for plus or minus lenses.

The patient is 55 years old and had a refractive surprise after the primary cataract surgery and was left with a +5.0 D spherical refraction in the right eye. There is no cataract in the left eye and he is plano. The surgeon and the patient both desire him to be –0.50 D, which was the target for the primary implant. The refractive surprise is felt to be from a mislabeled IOL that is centered in-the-bag and would be very difficult to remove. The secondary piggy-back IOL will be placed in the sulcus. This is very important, since trying to place the second lens in-the-bag several weeks after the primary surgery is very difficult. More importantly, it may displace the primary lens posteriorly, reducing its effective power and leaving the patient with a hyperopic error. Placing the lens in the sulcus minimizes this posterior displacement.

Mean Keratometric K = 45.00 D
Pseudophakic Refraction = +5.00 sphere @ vertex of 14 mm
Manufacturers ACD Lens Constant = 5.25 mm
Desired Postoperative Refraction = –0.50 D

Using the same style lens and constant as the previous example and modifying the K-reading to net power, the formula yields a +8.64 D IOL for a –0.50 D target. The nearest available lens is +9.0 D that would result in –0.76 D. In these cases, extreme care should be taken to assure that the two lenses are well centered with respect to one another. Decentration of either lens can result in poor image quality and can be the limiting factor in the patient's vision.

Conclusion

Using the methods described above, excellent results can be achieved with cataract surgery in patients with previous refractive surgery. Preoperative, intraoperative, and postoperative evaluations are more demanding than that required for standard cataract surgery.❑

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