may be a reason for patient dissatisfaction after implantation of a rotationally symmetrical aspheric IOL. In fact, the degradation of image quality is mainly caused by dislocation (tilt or decentration) of the IOL relative to the optical elements of the eye. This is because aspheric IOLs are much more sensitive to decentration or tilt than spherical IOLs. In the case of dislocation, aspheric IOLs induce asymmetrical errors, which disturb visual comfort more than symmetrical errors do.

Theoretically, it is possible to correct all aberrations up to a defined order. That means we are able to measure the corneal surface and the resulting aberrations in detail and an appropriate IOL that corrects all aberrations can be manufactured. However, it is not possible for even the most skilled surgeon to implant the IOL with the necessary precision because the correction of an increased number of higher-order aberrations (HOAs) will increase the sensitivity to IOL decentration or tilt. This subject is discussed in a recent study by Eppig et al.[1]

The reason for few complaints by patients with spherical IOLs may be that the blurred spot and the increased depth of focus disguise the effect of HOAs. This may compensate for small refractive errors and be helpful in intermediate vision but may decrease the contrast sensitivity of the patient's eye. A comprehensive overview of the advantages/disadvantages of spherical and aspheric IOLs is provided by Montés-Micó et al.[2]—*Katja Scholz, Timo Eppig, PhD, Holger Bruenner, PhD, Achim Langenbucher, PhD*

REFERENCES

1. Eppig T, Scholz K, Löffler A, Meßner A, Langenbucher A. Effect of decentration and tilt on the image quality of aspheric intraocular lens designs in a model eye. J Cataract Refract Surg 2009; 35:1091–1100
2. Montés-Micó R, Ferrer-Blasco T, Cerviño A. Analysis of the possible benefits of aspheric intraocular lenses: review of the literature. J Cataract Refract Surg 2009; 35:172–181

Accuracy of Scheimpflug Holladay equivalent keratometry readings after corneal refractive surgery

In their article, Tang et al.[1] conclude that the "Holladay equivalent keratometry readings (EKR) calculated using version 1.16r04 of the Scheimpflug system software was inaccurate in virgin corneas and in those with a history of laser in situ keratomileusis (LASIK), photorefractive keratectomy (PRK), or radial keratotomy using current intraocular lens (IOL) power calculation formulas." Unfortunately, their erroneous conclusions are due to 3 methodological errors.

The first error was in the determination of the thin lens principal plane of the IOL, recently named the effective lens position (ELP). The authors measured the external anterior chamber depth (ACD) (corneal vertex to anterior IOL vertex) and added "50% of the manufacturer-reported central thickness of the implanted IOL." This is incorrect. The correct method for determining the ELP from the measured external ACD was described by Holladay and Maverick[2] in 1998. The actual ELP is posterior to the secondary principal plane of the thick IOL, which is approximately 0.3 mm posterior to the midpoint of the central IOL thickness for equiconvex IOLs (current Abbott Medical Optics, Inc. IOLs) and approximately 0.4 to 0.5 mm for asymmetric biconvex IOLs (current Alcon, Inc. IOLs). This error results in an underestimation of the back-calculated corneal power of approximately 0.6 diopter (D) to 1.0 D, depending on the exact IOL power. Second, when using the measured ELP, one must convert from labeled IOL power (paraxial power) to actual equivalent power, which results in an underestimation of the back-calculated corneal power of approximately 0.5 D.

The third error relates to incorrect assumptions in the formula when using the actual ACD measurement. The authors referenced the formula from the Hoffer-Q article and errata[3] in 1993 and 1994 ("without the Q-formula which manipulates the ACD"), although stating they used the "original Hoffer 1974 formula." The actual reference is Colenbrander in 1973.[4] Using this formula, the authors back-calculated the corneal power using the axial length, calculated ELP, power of the implanted IOL, and postoperative refraction. The Colenbrander and Hoffer formulas use 1.336 (rather than 1.3375) for the standardized keratometric index, subtract 0.05 mm from the ELP in their calculation, and use the approximation formula rather than the exact formula to vertex the refraction. The resulting error is approximately 0.3 D.

The combined errors would result in an underestimation of the equivalent keratometry (K) reading of approximately 1.4 to 1.8, which is very close to 1.38 D in control eyes and 1.84 D in LASIK or PRK eyes found in their study. In the seminal article on Holladay EKR, our highest priority was to confirm agreement with standard keratometry/topography from normal eyes as well as post-refractive eyes.[5] We would respectfully request that the authors make the corrections above and additionally run the back calculations for standardized K readings using the Hoffer Q, Holladay 1 and 2, and SRK/T and compare these results with the values for the Holladay EKR.

Jack T. Holladay, MD, MSEE
Houston, Texas, USA

REFERENCES

1. Tang Q, Hoffer KJ, Olson MD, Miller KM. Accuracy of Scheimpflug Holladay equivalent keratometry readings after

corneal refractive surgery. J Cataract Refract Surg 2009; 35:1198–1203
2. Holladay JT, Maverick KJ. Relationship of the actual thick intraocular lens optic to the thin lens equivalent. Am J Ophthalmol 1998; 126:339–347
3. Hoffer KJ. The Hoffer Q formula: a comparison of theoretic and regression formulas. J Cataract Refract Surg 1993; 19:700–712; errata 1994; 20:677
4. Colenbrander MC. Calculation of the power of an iris clip lens for distant vision. Br J Ophthalmol 1973; 57:735–740
5. Holladay JT, Hill WE, Steinmueller A. Corneal power measurements using Scheimpflug imaging in eyes with prior corneal refractive surgery. J Refract Surg 2009; 25:862–868

REPLY: Our study was born out of frustration with using the instrument for the very task for which we purchased it, measuring corneal power in post-keratorefractive surgery eyes. That frustration is not ours alone. Many have come to us privately at meetings after hearing the oral presentation of this paper to express misgivings over their Pentacam purchase. Recently, the American Society of Cataract and Refractive Surgery delisted the Pentacam EKR as one of the biometric entries to their post-refractive surgery IOL calculator (http://iol.ascrs.org/. Accessed October 13, 2009). The reason it was delisted is that it is less accurate than a standard corneal topographer. Another study,[1] published in the same month as ours, concluded, "Corneal power measurements with the Pentacam Scheimpflug system should be used in IOL power calculation formulas with caution because the accuracy is good but is not as high as with standard measurement methods."

It might be helpful to explain what we reported in the paper. Our study patients had a history of radial keratotomy (RK), myopic PRK, and myopic or hyperopic LASIK. All subsequently had cataract surgery. The surgeon obtained K values for his IOL power calculations using his best educated "guess," considering the available tools at his disposal at the time of each surgery. The Pentacam Holladay EKR was not considered. Some time after cataract surgery, the study was commenced and these patients were brought back to the office for Pentacam EKR measurements. The Pentacam EKR values were compared with back-calculated "gold-standard" K values based on actual surgical outcomes. The calculation is analogous to determining IOL power in the forward direction if the K value, axial length (AL), and desired postoperative refractive error are known. In the study, we calculated the K value based on the AL measured before surgery, the postoperative spherical equivalent refractive error, the power of the IOL implanted, and the measured position of the IOL inside the eye after surgery. We used an IOL formula that makes no assumptions about ELP based on K or AL. What we found was that the Pentacam overestimated the true corneal power by a mean of +1.84 D for PRK and LASIK study eyes and by a mean of +2.17 D for RK study eyes. Corneal power overestimations have been our clinical experience as well, although the current study was not a forward-looking study.

Before addressing each of Holladay's comments specifically, we wish to make a financial interest statement. We declared in the paper that we have no financial interest in the Pentacam or in any competing instrument such as the Bausch & Lomb Orbscan or the Ziemer Galilei. We wrote our paper to raise awareness of a problem that has the potential to affect patient outcomes, hoping that by doing so a fix to the problem would eventually be found. Post-keratorefractive surgery corneal power measurement remains a difficult problem. If an easy fix were available, the problem would have been solved long ago. The journal does not have a policy regarding declaration of financial interest by those who write letters to the editor. This is unfortunate, and we hope the editorial board will address it one day. Holladay is a consultant to Oculus, but the nature of his financial interest in the company was not disclosed in his letter.

Holladay claims that the ELP for an equiconvex thick IOL is posterior to the secondary principal plane of the IOL or approximately 0.3 mm posterior to the center of the IOL. For a 20 D Alcon SA60AT, which is a symmetrically biconvex IOL with a center thickness of 0.625 mm, this would place the ELP at the posterior IOL surface. There may be a difference in our terminologies, but this does not make sense. The ELP should be where the effective power of the IOL resides, referenced to the corneal apex, not its posterior vertex power.

Holladay also states, "Second, when using the measured ELP, one must convert from labeled IOL power (paraxial power) to actual equivalent power, which results in an underestimation of the back-calculated corneal power of approximately 0.5 D." Neither this statement nor the 0.5 D finding is explained or referenced. Intraocular lens power is a function of how it is measured (front vertex power, equivalent power, back vertex power) and where the IOL sits in the eye with respect to the cornea (vertex position). We assume that labeled IOL power is equivalent power and that ELP places the IOL at the correct vertex position. Perhaps we are incorrect in this assumption, but we have no evidence to the contrary.

Third, when back-calculating corneal power, it does not matter what refractive index is used for the cornea. The net power of the cornea is calculated. This calculated power includes the front and back curvatures, the thickness, the refractive index, and the optical