Pentacam Equivalent K-reading

To the Editor:

The equivalent K-reading (EKR) of the Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) as reported in the article by Holladay et al., which appeared in the October 2009 issue of the Journal of Refractive Surgery, has been the object of controversy for two reasons. First, recent studies have failed to confirm its accuracy in estimating corneal power for intraocular lens (IOL) power calculation in eyes that have undergone excimer laser surgery. Second, although the EKR has been available on the Pentacam since 2006, Holladay et al. formally described its mathematical formula only recently. A careful analysis of the article led us to some observations and raised some questions.

1. It is unclear why the authors used postoperative LASIK eyes in the pilot study and subsequently tested the EKR in postoperative radial keratotomy (RK) eyes undergoing cataract surgery (rather than in postoperative LASIK eyes). It is generally recognized that the reasons for corneal power calculation errors with traditional keratometry and videokeratography are different for postoperative excimer laser surgery and postoperative RK eyes: in the former case, a major role is played by the keratometric refractive index, which is no longer valid, whereas in the latter case, a major role is played by the curvature measurement, as the keratometry readings are likely to be taken outside the small optical zone and are no longer a representative sampling of the central curvature.

2. In the Patients and Methods section, the authors did not carefully differentiate between the “equivalent power” of the cornea and the power calculated according to the Gaussian optics formula. On the basis of the mean ratio (0.822), the authors derived the back surface radius (6.165 mm) and power (−6.488 diopters [D]) of a cornea with a 7.5-mm anterior radius and subsequently calculated the “equivalent power” of this cornea as 43.78 D. They might have acknowledged that this value corresponds to the Gaussian optics formula using a central corneal thickness of 550 µm. As a consequence, the term “equivalent power of the cornea” seems to correspond to the “true net power” automatically calculated by the Pentacam using the Gaussian optics formula. Accordingly, the difference between the corneal power calculated with the keratometric index of 1.3375 (45.00 D) and the equivalent power (43.78 D) is 1.22 D, a value similar to that already reported by previous studies investigating this topic.

3. In the same section, the authors report an average ratio of the back-to-front surface central radius of 0.822±0.021. In addition to the standard deviation, the authors might have reported the range, which was quite large in a previous study (0.765 to 0.874). This variability may have relevant consequences on corneal power measurements.

4. Some doubts arise when the authors describe how the EKR changes if the posterior radius is flatter by 2 standard deviations. First, because they aimed to study an eye whose posterior corneal radius is flatter by 2 standard deviations, it is not clear why they added +0.021 to the original ratio of 0.822 and did not directly add 2 standard deviations to the radius. Given that the standard deviation of the mean posterior radius is ±0.24 mm, the radius should change from 6.165 to 6.465 mm (6.165 + [0.24×2]). This number would be considerably higher than the one reported in the same example (6.323 mm). If, conversely, they refer to the posterior/anterior ratio, the value should be increased from 0.822 to 0.864 (0.822+[0.021×2]) rather than 0.843; in such a case, the posterior corneal radius would change from 6.165 to 6.48 mm. Second, in the same example, they use the 0.843 ratio to derive an anterior radius of 7.692 mm and a K-reading of 43.88 D (using the 1.3375 keratometric index). We fear that the 7.692 mm radius is incorrectly extrapolated, as it is back-calculated from a posterior corneal radius (6.323 mm), which in turn was derived from an anterior corneal radius (7.5 mm). The authors thus create something similar to a circular reference, ie, a value that refers back to itself. It would have been different if the posterior corneal radius had not been calculated but rather directly measured. As a consequence, the corneal power of 43.88 D is also likely to be incorrect.

5. It is also unclear why, in the same example, the EKR would be obtained by adding 0.13 D to the original 45.00 D. In the example of the postoperative LASIK eye, it is similarly unclear why the EKR is obtained by subtracting 1.02 to obtain 36.02 D.

6. The steps leading to the EKR formula are unclear and require further description. Interestingly, applying this formula to the unoperated eyes of our sample resulted in a mean EKR of 43.23±1.55 D, which was not statistically different from the Sim-K value provided by the Pentacam (43.25±1.55 D, P=.068). Applying the same formula to the sample of eyes that had undergone myopic excimer laser surgery gave a mean value of 38.37±1.18 D, which was statistically higher than the one provided by the clinical history method (37.69±1.09 D, P<.001) and almost identical to the Sim-K (38.38±1.18 D). This is one more theoretical demonstration that the Pentacam...
EKR 4.5-mm zone (available since software version 1.16) is not reliable in eyes with previous excimer laser surgery.

7. In the Results section, the authors claim that the 4.5-mm EKR yielded the highest correlation when compared with the historical method K-reading, but they do not provide r and r² values and they do not provide the P value. Moreover, when reporting the data of Bland-Altman plots, they do not report the usual 95% limits of agreement; rather they report a mean prediction error, whose definition is lacking.

8. Finally, the authors should include adequate references to support their statement in the introduction that states “For eyes with prior refractive surgery, a 1.00-diopter (D) error in the corneal power results in a 1.00-D error in the postoperative refraction.” It is our experience that this correlation can vary according to the corneal power and axial length of each individual eye.

9. In the Patients and Methods section, two typographical errors occurred in the first paragraph of the second column, as the equation to calculate the front surface power should be (1.3375−1.000)/0.0075 and not (1.3375±1.000)/0.0075, whereas the equation to calculate the back surface power should be (1.336−1.376)/0.0061 and not (1.336±1.376)/6.165. Another error occurred in the third paragraph of the same column, as the calculated K-reading should be (1.3375−1.000)/0.0076, not (1.3375−1.000)/7.692.

We appreciate the authors attempt to explain the derivation of the EKR but we believe further explanation is required to better understand the nature of the EKR and more clinical data are needed to support its use in eyes with prior LASIK, RK, or photorefractive keratectomy.

Giacomo Savini, MD
Rome, Italy
Kenneth J. Hoffer, MD, FACS
Santa Monica, California

REFERENCES

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Reply:
We thank Drs Savini and Hoffer for their letter regarding our article.1 Our responses to the specific queries are enumerated below.

The initial general comment that “recent studies have failed to confirm its [Pentacam’s] accuracy in estimating corneal power for IOL power calculations in eyes that have undergone excimer laser surgery” is not true. In Savini et al’s study,2 the simulated keratometry (Sim-K) on the Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) was compared to the Sim-K value on the Tomey TMS-2 (Topcon Corp, Nagoya, Japan) and Keratron Scout (Optikon 2000, Rome, Italy) and the statistical analysis of variance did not disclose any significant difference (values given below [#6]).

The study by Tang et al3 was done incorrectly as described in our letter to the editor.4 The authors measured the distance from the corneal vertex to the vertex of the intraocular lens (IOL), added half of the manufacturer’s IOL thickness for the effective lens position (ELP), and then back-calculated the power of the cornea. As explained in our article in 1998,5 the actual thin lens plane of the IOL (ELP) is much more posterior than the “intuitive” midpoint of the IOL used in the study and results in an underestimate of the K-reading by ~1.60 diopters (D). It is unfortunate that the authors were unaware of this article, which would have made their study valuable, but with the wrong ELP used in the study, the results are erroneous and an invalid basis for confirming the Pentacam’s accuracy.

1. The reason postoperative LASIK and postoperative radial keratotomy (RK) eyes have been treated differently in the past has nothing to do with the standardized keratometric index (1.3375).6 The standardized keratometric index simply converts the anterior corneal radius to a vergence power, so that the 7.5-mm anterior radius equals 45.00 D. This was standardized so that there was no am-
bigness for the anterior radius when a K-reading was given. The major reasons why postoperative LASIK and RK have been treated differently are that with topography/keratometry neither the central area nor the posterior surface is measured. Because tomography (Scheimpflug) measures the central area and the back surface power, it may be used for any corneal refractive procedure including LASIK and RK.

2. In the Patients and Methods section (page 863), we attempted to clearly define and differentiate equivalent corneal power, K-readings, and equivalent K-reading (EKR). We are happy to have another opportunity for clarification of these terms. Equivalent corneal power, as defined in Gaussian optics over 140 years ago, is “the power of a single thin lens that optically replaces and is equivalent to the optical system” (in this case the thick lens is the cornea). The indices of refraction of the cornea and bounding media (air=1.0000, cornea=1.3760, and aqueous=1.3360), front and back radii, and the thickness of the cornea are necessary to calculate this value.

3. We did not use the term true net power, as this is not an optical term used by optical engineers, but a clinical term coined by Oculus, that has no specific optical counterpart. It is the arithmetic sum of the front and back surface power referenced to the anterior corneal vertex (this is not the equivalent power, as misstated by Savini in reference 2 below). The “true net power” on the Pentacam would therefore be the approximation of the equivalent power, if the cornea had no thickness. The error is on the order of 0.12 to 0.25 D, and therefore not clinically significant. The “total corneal refractive power” map on the Pentacam is equivalent to the equivalent corneal power as calculated in the original article and takes into account the corneal thickness and location of the principal planes. In contrast, the EKR is the K-reading that should be used for IOL calculations, which takes into account the front and back surface power and thickness of the cornea. On page 864, the calculations of a normal eye had a 45.00-D K-reading before −10.00-D LASIK and whose K-reading after surgery was 36.02 D. The EKR value is 35.00 D, which is the correct value to use in the IOL calculation.

35. In our data set and that of Ho et al, the front and back radii were measured and the front-to-back ratio calculated and a mean and standard deviation determined for all three variables. For a 7.5-mm anterior radius, the corresponding posterior radius is 6.165 mm and results in an equivalent corneal power of 43.78 D, as stated in the article—it is correct and there is no circularity. Our statement is that in a normal, unoperated cornea the difference in the EKR and a standard K-reading should read <0.13 D in 67% of the population (1 standard deviation) and <0.25 D in 95% of the population (2 standard deviations).

6. The derivation in the EKR is generic and has nothing to do with a specific instrument, such as the Pentacam. The steps are clear in the article and both the full equation and computational equation are given on page 864. In short, with any tomographer or device that measures both the posterior and anterior radius and the thickness of the cornea, a value (EKR) can be calculated that is equivalent to the K-reading, but adjusted for the difference in the posterior radius from normal. This is necessary in present day IOL calculation formulas, which expect a K-reading, not equivalent power (or approximate true net power).

7. The histogram on page 864 (Fig 1), shows the exact frequency plot when we calculated the EKR for various sample zone diameters from 0.5 to 8.0 mm. There are no r, r², or P values in a histogram. The modal value of 4.5 mm was chosen as it is the optimal zone diameter from our data. In Figures 2 and 3, the standard deviation is given, which includes 67% of the data. As mentioned in the Discussion, 2 standard deviations would include 95% of the data (P=.05). It is true that significant variations in the optimal zone size from various studies range from a center value as reported by Kim et al to 4 mm reported by Srivannaboon et al with the Orbscan II. Our value is closer to the latter.

8. When referencing refractive error, the proper location for the power is the corneal vertex. A change in corneal power (or measurement error of 1.00 D) will have exactly 1.00 D of effect on the refraction at the corneal vertex. This would be no different than placing a 1.00-D contact lens on the cornea or having 1.00-D LASIK, where the change in refraction is exactly 1.00 D—axial length and other parameters are irrelevant.

9. We are grateful the typographical errors were found and agree that the two “±” signs at the end of the first paragraph (page 863), second column should be “−.” The equation at the end of paragraph 1 should be (1336−1376)/6.165, and in paragraph 3, the equation should be (1337.5−1000)/7.692 (indices of refraction ×1000 and radii in mm).
We appreciate the comments, queries, and opportunity to clarify the definition of EKR and our study on the Pentacam.

Jack T. Holladay, MD, MSEE, FACS
Bellaire, Texas
Warren E. Hill, MD, FACS
Mesa, Arizona
Andreas Steinmueller, MSc
Wetzlar, Germany

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