

Calculating equivalent K readings

I congratulate Symes and Ursell¹ on their well-designed, well-executed study and their excellent discussion comparing automated keratometry (K) and Scheimpflug in the preoperative assessment of cataract patients. In their study, they confirmed almost exactly the results we found in the original article on equivalent K readings over a 4.5 mm zone,² with a difference of only -0.018 diopter (D), a 95.3% *r* value, and a standard deviation of 0.47 D (ours was 0.56 D for the laser in situ keratomileusis [LASIK] patients). I would like to comment on 2 points raised in the article.

In the introduction, Symes and Ursell state that “the Scheimpflug device... has found a place in the preoperative biometry of eyes with cataracts that have had refractive surgery,” with which we agree wholeheartedly. However, they then give 4 references, 3 of which agree with this statement but 1 of which, by Tang et al.,³ does not. Tang et al. said, “. . . the Holladay equivalent K readings calculated using version 1.16r04 of the Scheimpflug system software was inaccurate in virgin corneas (mean error +1.38 D) and in those with a history of LASIK, photorefractive keratectomy (mean error +1.84 D), or radial keratotomy (mean error +2.17) using current intraocular lens power (IOL) calculation formulas.” We were very alarmed by this statement until we found their mistake in the location of the thin lens principal plane (also known as the effective lens position [ELP]) by approximately 0.5 mm, which explained their mean errors. We addressed the issue in a letter⁴ but were disappointed that Tang et al. did not correct their mistake in their response,⁵ despite our 1998 publication of the explanation of the correct method for determining the ELP from direct measurements of the IOL.⁶ Symes and Ursell have helped remove this blemish in the equivalent K reading, as did the other 3 references given. It is unfortunate that Tang et al. did not admit their mistake in their response to our letter but instead stated, “This does not make sense.”

The second, more positive, point relates to the question at the end of the discussion as to why the equivalent K reading over the 4.5 mm zone would agree with the IOLMaster (Carl Zeiss Meditec) that measures an approximate 2.5 mm ring (on a 44.0 D cornea). The answer relates directly to the calculation of the equivalent K reading and the ellipsoid shape of the human cornea.⁷ If the cornea were a sphere (~ 7.7 mm), the radius would be the same at all points from the center to the periphery. The refractive power, however, would increase from the center to the periphery when using Snell law (this is the basis of spherical aberration). Although the cornea is an ellipsoid, it is only about halfway between the sphere and the perfect ellipsoid

(Q value = -0.54), with the average cornea having a Q value of -0.26 .⁷ The equivalent K reading is calculated using Snell law at each point and then a weighted average is computed based on the area represented by each point. The result of this computation is a gradual increase in corneal power (D) from the 1.0 to 7.0 mm zone, as shown in Table 1 of the Symes and Ursell article.¹ Because the keratometer measures only 4 points on a 2.5 mm ring (nothing smaller within the zone) and does not use Snell law, the result is that the keratometer overestimates the power within the zone below 4.5 mm (-0.96 D @ 1.0 mm) and then underestimates the zonal power above 4.5 mm ($+1.19$ @ 7.0 mm).¹ The intersection of the equivalent K reading and standard K nominally crosses near 4.5 mm, which was found in our original article and confirmed by Symes and Ursell. Because the zonal average value uses many more points (thousands) over the entire zone (effective refractive power—Eyesys [Eyesys Vision], equivalent K reading—Pentacam [Oculus], etc.), it is usually more accurate in representing the central refractive power of the cornea than standard keratometry (4 points).

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REPLY: We appreciate Holladay’s comments about our paper and his contribution to our discussion with respect to the agreement between automated K and

the equivalent K readings at 4.5 mm. Our study investigated virgin corneas prior to cataract surgery. In the introduction, we stated that “[t]he Scheimpflug device . . . has found a place in the preoperative biometry of eyes with cataract that have previously had refractive surgery.” These were carefully chosen words, since the choice of lens power for post-refractive-surgery patients with cataract still represents a significant challenge for the cataract surgeon. Scheimpflug imaging has certainly increased the options available with the advent of software such as the BESSt formula¹ and the Holladay equivalent K readings, but as correctly stated by Holladay et al.² in their paper describing the equivalent K readings, the historical method should always be calculated for comparison if preoperative refractive data are available and patients should be counseled prior to surgery regarding the risk for a secondary procedure to optimize their refraction.

Most cataract surgery, however, is performed in patients who have not had prior refractive surgery. As stated in our paper, with improvements over the years in axial length measurement techniques, keratometry is an important source of potential biometry error. The Pentacam (Oculus) is able to measure many more points on the cornea than a conventional keratometer and can also image the posterior curvature. The hope for cataract surgeons is that, in the future, this technology may become applicable to routine cataract surgery, increasing the accuracy of biometry and reducing the risk for refractive surprises. The equivalent K is a helpful innovation as it allows Scheimpflug K values to be substituted into conventional IOL power prediction formulas. Ultimately, prediction formulas may be modified to incorporate more corneal parameters, as a result of developments in corneal imaging such as Scheimpflug. Anecdotally, we would comment that in the mostly elderly cataract population from which our study sample was derived, we sometimes had difficulty obtaining results from the Pentacam with the “OK” quality statement, even when measurements were repeated (although all the data included in the study were OK). This may partly relate to the relatively long time required to acquire the images (approximately 2 seconds for our device), and it has been suggested this may be relevant even when the OK quality specification is obtained.³ As the technology evolves, this is likely to produce increased accuracy for the mathematical algorithms based on the Scheimpflug measurements.—Richard J. Symes, MRCOphth, Paul G. Ursell, MD

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Role of angle kappa in patient dissatisfaction with refractive-design multifocal intraocular lenses

We would like to congratulate de Vries et al.¹ for their retrospective study, which looked at multiple factors in patient dissatisfaction. The authors primarily evaluated 2 diffractive intraocular lens (IOL) models and noticed that residual ametropia and astigmatism, posterior capsule opacification, and large pupil were the 3 most significant etiologies in patient dissatisfaction.

In a recent prospective trial, we evaluated the visual acuity and quality-related satisfaction of patients with a refractive-design multifocal IOL and analyzed the factors that predicted dissatisfaction, including the role of angle kappa.^{2,A,B} A total of 50 eyes of 44 consecutive patients who had phacoemulsification with multifocal IOL implantation (Rezoom, Abbott Medical Optics, Inc.) were included. At 1 year, 37 patients (43 eyes) who completed the follow-up were asked to rate their unocular symptoms on a graded questionnaire (scale of 0 to 5 [good to bad] for 5 queries). Using regression analysis, we found that the occurrence of halos was predicted by the degree of angle kappa and diminution in uncorrected distance visual acuity ($R^2 = 0.26, P = .029$); the occurrence of glare was predicted by the degree of angle kappa ($R^2 = 0.26, P = .033$).²

Multiple issues are involved in the consideration of angle kappa in multifocal IOL implantation. Because of factors such as capsule contraction, memory of the haptics, and IOL rotation, it seems unlikely that a multifocal IOL intentionally decentered kappa-centrally toward the visual axis would stay in the same position during the postoperative period. Donnenfeld and Holladay^C performed pupilloplasty to center the pupil and improve the waxy vision in such cases with high angle kappa. In recent years, we have been working on fibrin glue-assisted sutureless posterior chamber IOL implantation with intrascleral tuck (“glued IOL”).³ The IOL itself can be adjusted in the case of a glued IOL for aphakia by adjusting the amount of tucking, centering it according to the kappa angle.^B A feasibility study of this with a glued IOL is underway in our institution, and the results may throw more light on this evolving concept.