Modern cataract surgery has become much more than a rehabilitative procedure—now it is also a refractive procedure. In this new era of cataract surgery, toric IOLs play a major role in helping patients with preexisting corneal astigmatism to achieve excellent postoperative outcomes.

Toric IOLs are becoming the standard of care; however, the results following implantation are not always predictable. We recently introduced a new regression formula that should help to improve the predictability of these results.

**DON’T FORGET THE POSTERIOR CURVATURE**

Because standard keratometric and topographic devices only measure the anterior cornea and assume a fixed ratio between the anterior and posterior curvature, they tend to inaccurately assess the total corneal astigmatic power. Yet, as we know from Koch et al,’ the posterior cornea tends to be steepest along the vertical meridian, thus creating a net plus power along the horizontal meridian, or *against-the-rule astigmatism*.

In translation, the posterior corneal curvature will decrease the net astigmatism in eyes that have with-the-rule astigmatism and will increase the net astigmatism in eyes that have against-the-rule astigmatism.

Koch et al’ also found that, in eyes that had with-the-rule astigmatism, greater anterior steepening correlated to greater posterior steepening; on the other hand, there was no such correlation in magnitude of astigmatism in eyes that had against-the-rule astigmatism. The Baylor nomogram was the first step to addressing the issue of predictability.

**A NEW FORMULA**

Since the Baylor nomogram was published, a great deal of work has been done to refine our understanding of posterior corneal astigmatism and to find more accurate ways to incorporate it into daily practice. Three popular solutions are intraoperative aberrometry, the use of a standard toric IOL calculator with either a nomogram or direct measurements of the posterior corneal astigmatism, and the use of a next-generation toric IOL calculator such as the Barrett Toric IOL calculator.

The Abulafia-Koch formula, which is based on a regression model and has recently been incorporated into PhysIOL’s toric IOL calculator, compensates for the effect of posterior corneal astigmatism. Our formula takes anterior curvature–based corneal measurements and calculates a new net corneal astigmatism with a new magnitude and a new meridian.

The usefulness of the Abulafia-Koch formula was verified during a retrospective case series comparing the accuracy of two toric IOL calculators (Alcon and Holladay calculators) with and without the Abulafia-Koch formula to the accuracy of the Barrett Toric IOL calculator, which uses a mathematical model to compensate for the posterior corneal astigmatism. For developing the Abulafia-Koch formula, we used biometry data from

![Figure 1. Absolute error in predicted residual astigmatism.](image)

![Figure 2. Absolute error in predicted residual astigmatism below or equal to 0.50D, 0.75D, and 1.00D.](image)
the Ein-Tal eye center in Israel, and for validation we used biometry measurements data from the Lion Eye Institute in Australia.

Bearing in mind that astigmatism is a vector, we aimed to determine the nature of the correlation between the anterior curvature–based corneal measurements and the estimated net corneal astigmatism. Our results (Figures 1 and 2) indicated that there was a high correlation between the measured corneal astigmatism and the estimated net corneal astigmatism, which were divided into x and y components of the vector. Based on these results, a new regression formula was derived.

Data from 78 eyes were used to validate the new formula. The centroid (mean vector) errors in predicted residual astigmatism with the Alcon and Holladay toric IOL calculators, which both neglect the posterior cornea, were 0.55 and 0.54 D of against-the-rule, respectively. With the Abulafia-Koch formula, against-the-rule astigmatism decreased to 0.05 and 0.04 D, respectively ($P < .001$ [x-axis], $P = .776$ [y-axis]; $P < .001$ [x-axis], $P = .726$ [y-axis]; Figure 3). What we found was that, when the Abulafia-Koch formula was incorporated with both the Alcon and Holladay calculators, a higher proportion of eyes were within ±0.50 D of the predicted residual astigmatism (76.9% and 78.2% vs 30.8%). There was no significant difference between the results with the Abulafia-Koch–modified Alcon and Holladay calculators and the Barrett Toric IOL calculator.

**CONCLUSION**

The prediction of postoperative astigmatic outcomes can be optimized by adjusting standard toric IOL calculators with the Abulafia-Koch formula.

I congratulate PhysIOL for this new and wonderful calculator update, which takes into account the effective lens position in order to calculate the IOL cylinder power at the corneal plane and incorporates the Abulafia-Koch formula, which can be toggled on and off by the user.

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Correction of astigmatism at the time of cataract surgery has become increasingly more important as our patients continue to demand more from their surgical procedure than simple crystalline lens removal. Today, we can offer patients a variety of options to managing their astigmatism, including adjusting the axis of the primary phaco incision, placing additional limbal relaxing incisions, and implanting a toric IOL.

While all aim to correct the astigmatism, some are more successful than others. Toric IOLs, for instance, can successfully and accurately address astigmatism; however, most toric IOL calculators are based on anterior keratometry measurements alone and do not take the posterior cornea into account. As we know from Koch et al, \(^1\) posterior corneal astigmatism significantly affects the total corneal cylinder, and therefore, when a standard toric IOL calculator is used, an against-the-rule error.

As a means to solve this problem, Adi Abulafia, MD, and Douglas D. Koch, MD, developed the Abulafia-Koch formula for toric IOL power calculation (described in detail on pages 22 and 23). PhysIOL has now made this formula commercially available, and we have plans to introduce it at our clinic.

Memira is a Scandinavian chain of 40 private refractive surgery clinics. We perform 18,000 refractive surgeries annually, and to date, we have implanted more than 30,000 FineVision IOLs, including the FineVision trifocal toric. In the past few years, almost 30% of the IOLs we implant have been toric. In order to calculate IOL power with the FineVision toric, for the past several years we have taken the expected effect from the posterior cornea into account manually. The refractive astigmatism outcomes are therefore good, yet the improvement in the calculator to incorporate the Abulafia-Koch formula will perhaps enhance the results even more. The main advantage to us is that the formula is incorporated into the calculator, so that we no longer need to adjust manually.

**STUDY OF REFRACTIVE RESULTS**

Before implementing the Abulafia-Koch formula at our clinics, we first rode tested it on historical data. Reviewing 653 eyes implanted with a trifocal toric IOL in our Norwegian clinics, we looked at three things: (1) the predicted residual astigmatism with the former PhysIOL toric calculator, (2) the predicted residual astigmatism with the current PhysIOL toric calculator with the Abulafia-Koch formula, and (3) the astigmatic outcomes at 3 months postoperatively. We then compared the actual outcomes with the predicted values from both calculators.

A total of 413 refractive lens exchange (RLE) patients were enrolled in the study. Figure 1 illustrates the differences between

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**Figure 1.** Expected residual astigmatism and prediction error with the former PhysIOL toric calculator (A) and the current calculator with the Abulafia-Koch formula (B).
the former toric IOL calculator and the current calculator with the Abulafia-Koch regression formula enabled. In this example, the former calculator estimated 0.33 D of with-the-rule residual astigmatism, but the actual postoperative refraction was 0.25 D of against-the-rule astigmatism. Using vector analysis on the former calculator, we determined that the prediction error in this eye was 0.56 D @ 179º (Figure 1A, bottom right). With the new calculator, however, the expected residual astigmatism was 0.30 D of against-the-rule astigmatism, which was very close to the actual refraction. Here, the prediction error was only 0.09 D @ 118º. In Figure 2, scatter plots for all 653 eyes revealed that the centroid prediction error with the former calculator was 0.53 D @ 179º and 0.06 D @ 106º with the new formula.

Our results clearly demonstrated a significant improvement in the accuracy of calculating toric IOLs with the Abulafia-Koch formula. Further, it also demonstrated a very high rate of precision.

The mean absolute prediction error with the former calculator was 0.68 ±0.38 D and 0.43 ±0.33 D with the new calculator (P < .0001; Figure 3), confirming that the Abulafia-Koch formula is very precise in predicting toric IOLs.

Even more important than the average prediction error, there was a 30% improvement in the number of eyes that fell within ±0.50 D of the prediction error. This could translate to a 30% reduction in enhancement surgeries.

**CONCLUSION**

We look forward to implementing the Abulafia-Koch formula into our surgical planning for toric IOLs, and we are confident that the new formula, which takes the posterior astigmatism into account, will precisely and accurately calculate toric IOL power. As we know, taking posterior astigmatism into account when calculating toric IOLs is no longer advised, it is mandatory.

Our test shows that the new PhysIOL toric calculator, which incorporates the Abulafia-Koch formula, can significantly improve the prediction of postoperative astigmatism.

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