Predicted Versus Measured Posterior Corneal Astigmatism and the Impact on Toric IOL Power Calculations in Standard Cataract Surgery

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INTRODUCTION

Posterior corneal astigmatism (PCA) is an important factor in the selection of toric IOL power. Ignoring the toricity of the posterior corneal surface will result in an overcorrection in eyes with with-the-rule (WTR) astigmatism and an undercorrection in eyes with against-the-rule (ATR) astigmatism.[1,2] Due to the small difference in refractive index between cornea and aqueous, the magnitude of PCA ranges from -0.26 to -0.78 D.[1] With OCT-based technology, the magnitude of PCA measurements appears to be lower, and fewer eyes have a vertical steep meridian on the posterior corneal surface.[3]

Investigations into PCA have also shown that the axis of the anterior corneal astigmatism (ACA) shifts with increasing age at a magnitude ranging from 0.13 D to 0.44 D per decade.[4-7] The steep meridian of the anterior cornea shifts from a vertical (WTR) towards a horizontal (ATR) direction, whereas the steep meridian of the posterior cornea minimally changes.[1,5,7,8] The majority of younger adults have WTR astigmatism, while there is a higher proportion of eyes with ATR astigmatism with increasing age.[5,8-10]

There are two methods that allow surgeons to consider PCA in toric IOL power calculations: (A) predicted PCA as done by, for example, the Barrett Toric IOL Calculator; and (B) measured PCA that is directly entered into the calculation.

The question is whether there is an impact of using either method on toric IOL power calculations in standard cataract surgery.

MEASURED AND PREDICTED POSTERIOR CORNEAL ASTIGMATISM

The Barrett Toric Calculator allows for a direct input of the measured PCA or the use of predicted PCA. Several studies have compared refractive outcomes.

Similar clinical outcomes

Skrzypecki et al[11] assessed Barrett toric IOL calculations with the predicted and measured PCA using the Pentacam (Oculus, Germany) in a total of 30 eyes. The mean absolute error (MAE) and predicted residual astigmatism revealed no statistical difference between the predicted and measured PCA outcomes.[11] A post-hoc analysis of WTR and ATR astigmatism also did not detect any differences.

TABLE 1. MEAN ABSOLUTE PREDICTION ERROR (MAE) AND PERCENTAGE OF EYES WITHIN A PREDICTION ERROR OF ≤0.5 D, ≤0.75 D[16]

		MAE (D)	Error ≤ 0.50 D	Error ≤ 0.75 D
Entire series (n = 122 eyes)	OCT Ks + predicted PCA	0.41 ± 0.19	74%	99%
	OCT Ks + measured PCA	0.45 ± 0.25	71%	95%
	Topographer SIMKs + PCA	0.49 ± 0.25	64%	84%
WTR astigmatism (n = 43 eyes)	OCT Ks + predicted PCA	0.39 ± 0.19	74%	98%
	OCT Ks + measured PCA	0.44 ± 0.30	72%	91%
	Topographer SIMKs + PCA	0.50 ± 0.24	65%	81%
ATR astigmatism (n = 68 eyes)	OCT Ks + predicted PCA	0.41 ± 0.19	74%	100%
	OCT Ks + measured PCA	0.43 ± 0.19	68%	99%
	Topographer SIMKs + PCA	0.50 ± 0.26	63%	82%

(OCT K measured by Argos (Movu, Japan); SIM K and measured PCA determined by Pentacam)
Abbreviations: MAE, mean absolute prediction error; OCT K, OCT keratometry; PCA, posterior corneal astigmatism; SIMK, simulated keratometry; ATR, against-the-rule astigmatism; WTR, with-the-rule astigmatism

TABLE 2. PERCENTAGE OF EYES WITH A VECTOR PREDICTION ERROR MAGNITUDE OF ≤ 0.5 D, ≤ 0.75 D AND ≤ 1.0 D[18]

	Overall (n = 602)			WTR astigmatism (n = 210)		ATR astigmatism (n = 190)		Oblique astigmatism (n = 202)	
	Error ≤ 0.5 D	Error ≤ 0.75 D	Error ≤ 1.0 D	Error ≤ 0.5 D	Error ≤ 1.0 D	Error ≤ 0.5 D	Error ≤ 1.0 D	Error ≤ 0.5 D	Error ≤ 1.0 D
Barrett predicted PCA	52.5%*	77.1%	88%	52.4%	91%	45.3%	83.2%	59.4%	89.6%
Barrett measured PCA	57.6%*	78.6%	89.2%	56.2%	89.5%	51.1%	88.4%	65.3%	89.6%

Abbreviations: PCA, posterior corneal astigmatism; ATR, against-the-rule astigmatism; WTR, with-the-rule astigmatism

Another study by Yang et al[12] reported the accuracy of the Barrett Toric Calculator with predicted PCA and measured PCA using the IOLMaster 700, (ZEISS, Germany) as well as the Kane toric calculator (predicts PCA). The analysis detected no statistical differences in MAE and percentages of eyes with an absolute prediction error of ≤ 0.5 D.[12]

Lukewich et al[13] analyzed the astigmatism prediction error in 24 eyes using the Barrett Toric Calculator with predicted and measured PCA using the IOLMaster 700. The analysis concluded that the astigmatic prediction error was not significantly impacted by either method.[13]

In a large scale study of 8,152 eyes, Abulafia et al[14] aimed to identify the best reference guide for postoperative residual astigmatism in eyes planned for non-toric IOL implantation. The research team recommended that the predicted refractive astigmatism calculated by the Barrett Toric Calculator, whether it included predicted or measured PCA, was the best reference to decide for a toric IOL.[14] The predicted refractive astigmatism not only includes PCA, but other factors, for example the surgically induced astigmatism and physiological lens tilt.[14]

Predicted PCA leads to better clinical outcomes

Shammas et al[15,16] evaluated the astigmatic prediction error with the Barrett toric formula using predicted and measured PCA. Overall, the analysis showed that the Barrett toric formula with anterior corneal astigmatism and predicted PCA produced better outcomes than anterior corneal astigmatism/simulated K readings with measured PCA in eyes with WTR and ATR astigmatism (Table 1).[15,16]

Studies suggesting measured PCA leads to better clinical outcomes

Reitblat et al[17] investigated various options, including predicted PCA and measured PCA using Pentacam, to calculate the needed toric IOL power for implantation in 17 eyes of 13 patients with a PCA larger than 0.80 D. Authors found significantly more eyes within 0.25 D when measured PCA was applied (predicted 5.9% vs measured 29.4%, $P = .046$).

Wang et al[18] compared predicted outcomes of the Barrett Toric Calculator using the predicted and measured PCA in a large retrospective study of 602 eyes implanted with a monofocal non-toric IOL. A whole group analysis showed that the measured PCA obtained with the IOLMaster 700 produced a significantly smaller mean vector prediction error magnitude (measured 0.54 D vs predicted 0.57 D, $P < .05$).[18] In addition, the measured PCA enabled a significantly larger percentage of eyes within a prediction error of ≤ 0.5 D (measured PCA 57.6% vs predicted PCA 52.5%, $P < .05$).[18] In a subgroup analysis of WTR, ATR, and oblique eyes, however, no significant improvement in prediction error was detected (Table 2).

CONCLUSIONS

The majority of comparative studies reported no difference of using either method. One report showed benefits of utilizing predicted PCA in WTR and ATR astigmatism. On the other hand, two studies reported improved clinical outcomes with measured PCA in (1) eyes with high PCA of more than 0.8 D and (2) a whole group analysis of a general population only, but not in a subgroup analysis of WTR, ATR, and oblique eyes.

It may seem surprising that the majority of comparison studies published to date did not find further refinement of refractive outcomes when PCA measurements were included. Reasons might be that studies used different technologies to determine PCA, limited sample size, limitations in technology precision in determining PCA, or presence of a newly found and clinically relevant leftover astigmatism.[19] ■

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