Accuracy of toric intraocular lens formulas with measured posterior corneal astigmatism of different orientations

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Background

The correction of astigmatism at the time of cataract surgery is paramount when aiming for optimal unaided visual acuity postoperatively.[1,2] Formulas for calculating toric IOL power have evolved significantly since the initial description of meridional analysis.[3] A major development has been the recognition of the contribution of posterior corneal astigmatism (PCA) to total corneal astigmatism and therefore postoperative refractive astigmatism.[4]

The majority of eyes have PCA with a vertically orientated steep axis.[5] As current toric IOL formulas, via theoretical or regression methods, generally assume PCA to have a vertically orientated steep axis, this may produce a prediction error in eyes where the measured posterior cornea has a steep axis that is in an oblique or horizontal orientation. Therefore, the primary aim of our study was to test the hypothesis that when the orientation of the steep axis of posterior corneal is non-vertical, using measured PCA in toric IOL power calculations will improve prediction accuracy.

Methods

418 eyes of 344 patients were included in this retrospective observational cohort study. Prediction errors (PE) for postoperative refractive astigmatism at 4 weeks postoperatively were determined using vector analysis and compared for the following toric intraocular lens power formulas: Barrett Toric with predicted posterior corneal astigmatism (PPCA); Barrett Toric with measured posterior corneal astigmatism (MPCA); EVO Toric PPCA; EVO Toric MPCA; Holladay I with Abulafia-Koch regression. Subgroup analysis compared PEs for eyes with a vertically orientated steep axis of PCA (60-120°) to eyes with a non-vertically orientated steep axis of PCA.

Results

Standard keratometry was with-the-rule in 48% of eyes, while the steep PCA axis was vertically orientated in 91% of eyes. For all eyes, EVO-PPCA had a smaller mean absolute error than Barrett-MPCA, Barrett-PPCA and Abulafia-Koch ($p < 0.01$ for all). EVO-PPCA had the highest percentage of eyes within 0.50D of predicted postoperative astigmatism for eyes with vertical PCA (61%), while EVO-MPCA had the highest percentage for eyes with non-vertical PCA (54%). EVO-MPCA had the smallest centroid error for all eyes, and the subgroups ($p < 0.01$ for all).

Table 1: Refractive predictive outcomes for each formula

Formula	MAE (D) ± SD	tr-Centroid (D @ degrees)	% of eyes within vector prediction error magnitude			
			≤0.25	≤0.50	≤0.75	≤1.00
All eyes (n = 418)						
Abulafia-Koch	0.53 ± 0.37	0.17 @ 97°	22.5%	53.8%	78.9%	90.7%
Barrett PPCA	0.53 ± 0.38	0.15 @ 98°	22.1%	57.7%	79.0%	90.4%
Barrett MPCA	0.54 ± 0.38	0.18 @ 87°	23.0%	55.5%	78.9%	89.7%
EVO PPCA	0.51 ± 0.36	0.15 @ 95°	24.6%	59.6%	82.1%	92.1%
EVO MPCA	0.52 ± 0.37	0.06 @ 125°	24.2%	59.8%	80.4%	91.6%
Vertically orientated steep axis of PCA (n = 381)						
Abulafia-Koch	0.52 ± 0.37	0.16 @ 100°	22.6%	55.4%	80.3%	91.3%
Barrett PPCA	0.52 ± 0.38	0.13 @ 101°	22.6%	58.8%	79.8.%	91.3%
Barrett MPCA	0.53 ± 0.38	0.17 @ 89°	22.6%	55.9%	80.1%	90.8%
EVO PPCA	0.50 ± 0.36	0.14 @ 98°	24.9%	61.2%	83.2%	92.9%
EVO MPCA	0.51 ± 0.37	0.07 @ 128°	23.9%	60.4%	81.4%	92.1%
Non-vertically orientated steep axis of PCA (n = 37)						
Abulafia-Koch	0.63 ± 0.36	0.40 @ 84°	21.6%	37.8%	64.9%	83.8%
Barrett PPCA	0.64 ± 0.37	0.41 @ 84°	16.2%	40.5%	64.9%	81.1%
Barrett MPCA	0.59 ± 0.37	0.31 @ 71°	27.0%	45.9%	70.3%	81.1%
EVO PPCA	0.60 ± 0.36	0.33 @ 81°	21.6%	43.2%	70.3%	83.8%
EVO MPCA	0.56 ± 0.34	0.13 @ 60°	27.0%	54.1%	70.3%	86.5%

Eyes with non-vertical PCA had a lower percentage within 0.50D than eyes with vertical PCA when using PPCA (43% vs 61%, $p = 0.034$), but there was no significant difference between these groups when MPCA is used for eyes with non-vertical PCA (54% vs 61%, $p = 0.40$).

Conclusions

This study demonstrates that PCA-predicting toric formulas have reduced performance in eyes with a non-vertically orientated steep axis of PCA. For the Barrett and EVO toric formulas, this can be ameliorated by using measured PCA instead of predicted PCA. It is therefore recommended to examine the steep axis of measured PCA and enter measured posterior keratometry values into calculations in eyes where the steep axis of the posterior cornea is non-vertically orientated.

References

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