

# Intraocular Lens Calculation: Toric and Multifocal Intraocular Lenses



Nino Hirschall and Oliver Findl

## Introduction

The use of toric IOLs for corneal astigmatism has become the gold standard [1, 2]. Hoffmann et al. have shown that corneal astigmatism of 1.5 D and 2.0 D occurs in approximately 17% and 8% in the cataract population [3]. For the calculation of toric IOLs, the accurate measurement of the cornea plays a decisive role [4–6]. Therefore, it is strongly recommended to rely on different corneal measurement techniques.

## Posterior Surface of the Cornea

The methods of measuring the cornea can be divided into two groups. Either only the front surface of the cornea is measured and the influence of the back surface of the cornea is estimated. This method includes, for example, keratometry (either from one ring, 2 rings or a telecentric figure [7]) and Placido disc-based procedures. In the second group, the back surface of the cornea (and the corneal thickness) is measured as well as the front surface. This measurement is quite susceptible to interference, however, so eye drops prior to the measurement should be avoided (except for artificial tears) [8]. Both methods have their advantages and disadvantages and the current recommendations from the literature are contradictory [9–11].

---

N. Hirschall (✉)

Department of Ophthalmology and Optometry, Johannes Kepler University, Linz, Austria  
e-mail: [nino.hirschall@kepleruniklinikum.at](mailto:nino.hirschall@kepleruniklinikum.at)

O. Findl

VIROS-Vienna Institute for Research in Ocular Surgery, Hanusch Hospital, Vienna, Austria

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023

203

M. Shajari et al. (eds.), *Cataract and Lens Surgery*,

[https://doi.org/10.1007/978-3-031-05394-8\\_29](https://doi.org/10.1007/978-3-031-05394-8_29)

Estimation of the astigmatism of the posterior surface of the cornea is possible, because it shows an astigmatism with the rule in approximately 85% of all cases [12–14]. This results in the following important characteristic: if only the front surface of the cornea is measured and astigmatism with the rule is found, then the total astigmatism of the cornea is less than that measured on the front surface. This is because astigmatism with the rule on the front surface and negative astigmatism with the rule on the back surface of the cornea cancel [15]. Consequently, if the astigmatism is against the rule on the anterior surface of the cornea, the total astigmatism of the cornea is larger than measured purely from the anterior surface. It is important to note, however, that in the studies, a corneal posterior astigmatism was defined relatively generously ( $60^{\circ}$ – $120^{\circ}$ ) with the rule, but about 15% of the patients did not follow this pattern [13, 16].

Due to the different measurement methods, there are also different terms for how the refractive power of the cornea is represented. These terms include conventional keratometry (=simulated keratometry, or simK), true net power, total corneal refractive power and total keratometry (TK). Conventional keratometry (simK) is based on measuring the anterior corneal surface and the posterior corneal surface is calculated using a fixed ratio. The other terms measure the total cornea and indicate the refractive power in different ways. For example, true net power is a measurement of the corneal front and back surface and the refractive power is then calculated using Gaussian optics. Total corneal refractive power uses ray tracing using Snell's law to determine the total refractive power of the cornea. The TK value is a modified keratometry parameter that is used specifically for a biometric device and also describes the total corneal refractive power. The special feature of the TK value is that it can be directly transferred to any IOL formula without transversion [9].

All calculation models for toric IOLs, where the back surface of the cornea is estimated, could be replaced in the future as better measurement methods become available. For example, high-resolution OCT allow significantly better measurements compared to more conventional measurement techniques [5]. In the meantime, there are various OCT devices that can produce high-resolution corneal images (Anterior (Heidelberg Engineering, Germany) [17], Casia ss-1000 [5, 18] (Tomey, Japan), MS-39 (CSO, Italy)).

It is essential to always use at least 2, better 3, different measurement methods for the calculation of toric IOLs. There is no gold standard for the fusion of the different measurements. It is important to repeat the measurements in case of deviations and to choose undercorrection rather than overcorrection in case of doubt and, above all, to inform the patient if the different measurement methods differ. As already mentioned above, tomography also measures the back of the cornea and therefore a deviation from topographic methods should be expected. It should also be remembered that differences between different measurement methods often have a relevant impact on the quality of measurements, such as tear film problems, an irregular cornea or other problems.

## Formulae for Toric IOLs

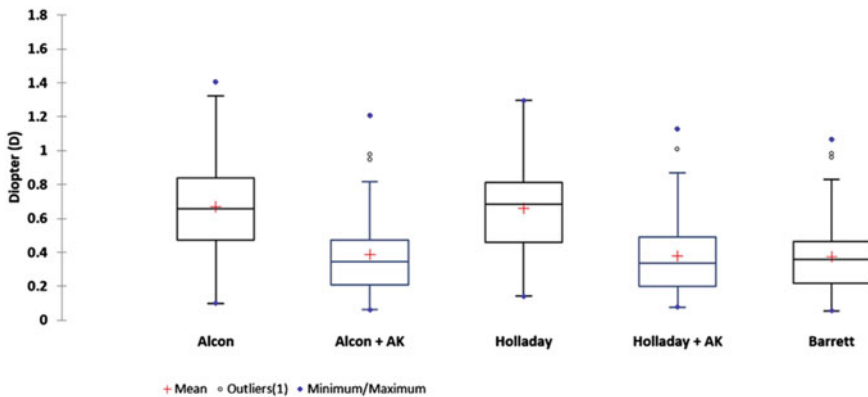
Toric IOL power calculation formulae vary depending on the method of measurement used for corneal measurement. Abulafia et al. [16] clearly showed that a pure measurement of the corneal anterior surface without estimating or measuring the posterior surface performs significantly worse. In the same study it was shown that the Abulafia-Koch formula (AK correction) can be used directly for most toric online calculators to achieve better post-operative toric refraction results (Fig. 1).

An important point is that it would be a mistake to measure and additionally estimate the posterior corneal surface, as otherwise the posterior corneal surface would be included twice in the formula. This has to be taken into account, especially with the companies' online calculators.

Most companies that offer toric IOLs have recently adapted their online calculators and offer a correction method for the posterior surface of the cornea. In most cases the AK (Abulafia, Koch [16]) correction (formerly Baylor Nomogram) is applied to estimate the influence of the posterior surface of the cornea.

Alternatively, the Barrett Toric Calculator on the APACRS website or on the ASCRS website can be used (Fig. 2). This calculator uses a very similar concept, is not a correction option for existing other formulae, but rather an independent formula. In the meantime, the Barrett calculator has also integrated the function of using the measured corneal back surface.

Another alternative is the EVO calculator, which also offers a calculation of toric IOLs. One advantage of this calculator is that it also offers a calculation of toric IOLs after myopic LASIK/PRK.



**Fig. 1** Abulafia et al. [16] have developed the Abulafia-Koch formula (AK correction). The aim of this correction is to estimate the influence of the posterior corneal surface and to correct the resulting error



**Fig. 2** Barrett Toric calculator. **a** shows a 3 D astigmatism of the corneal anterior surface with the rule (90°). However, due to the influence of the posterior corneal surface, the total corneal astigmatism is only 2.17 D (bottom left in the figure). In **b** the same data are used, only the astigmatism of the anterior surface is now against the rule (180° instead of 90°). The total corneal astigmatism has increased to 3.18 D

Finally, ray tracing concepts are also useful to calculate toric IOLs [19–21]. Ray tracing concepts are especially relevant for cases after refractive surgery, or if IOL tilt should be included in the calculation [22]. Another important advantage of ray tracing is that irregular astigmatism can be better calculated and corrected.

### Author's recommendation

From our point of view, it is essential to measure the back surface of the cornea with a modern measurement technique, such as OCT. On the one hand, this is to exclude anticipated corneal ectasia, and on the other hand, to determine the orientation and extent of astigmatism of the corneal surface. In cases where the posterior corneal surface has a classical orientation with the rule, estimation methods (AK correction, Barrett toric calculator) can be used, in all other cases it is better to use the measured value and choose a formula where the measured posterior corneal surface can also be used.

## References

1. Visser N, Beckers HJ, Bauer NJ, Gast ST, Zijlmans BL, Berenschot TT, et al. Toric vs aspherical control intraocular lenses in patients with cataract and corneal astigmatism: a randomised clinical trial. *JAMA Ophthalmol.* 2014;132(12):1462–8.
2. Cohen T, Klaproth OK. Correction of astigmatism during cataract surgery. *Klin Monbl Ophthalmol.* 2009;226(8):596–604.
3. Hoffmann PC, Hutz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. *J Cataract Refract Surg.* 2010;36(9):1479–85.
4. Brain Sound N, Hoffmann PC, Draschl P, Maedel S, Findl O. Evaluation of factors influencing the remaining astigmatism after toric intraocular lens implantation. *J Refract Surg.* 2014;30(6):394–400.
5. Hoffmann PC, Abraham M, Hirschall N, Findl O. Prediction of residual astigmatism after cataract surgery using swept source Fourier domain optical coherence tomography. *Curr Eye Res.* 2014;39(12):1178–86.
6. Norby S, Hirschall N, Nishi Y, Findl O. Fluctuations in corneal curvature limit predictability of intraocular lens power calculations. *J Cataract Refract Surg.* 2013;39(2):174–9.
7. Shajari M, Cremonese C, Petermann K, Singh P, Muller M, Kohnen T. Comparison of axial length, corneal curvature, and anterior chamber depth measurements of 2 recently introduced devices to a known biometer. *At J Ophthalmol.* 2017;178:58–64.
8. Brain sound N, Crnej A, Gangwani V, Findl O. Effect of fluorescein dye staining of the tear film on Scheimpflug measurements of central corneal thickness. *Cornea.* 2012;31(1):18–20.
9. Fabian E, Wehner W. Prediction accuracy of total keratometry compared to standard keratometry using different intraocular lens power formulae. *J Refract Surg.* 2019;35(6):362–8.
10. Ferreira TB, Ribeiro P, Ribeiro FJ, O'Neill JG. Comparison of methodologies using estimated or measured values of total corneal astigmatism for toric intraocular lens power calculation. *J Refract Surg.* 2017;33(12):794–800.
11. Fityo S, Buhren J, Shajari M, Kohnen T. Keratometry versus total corneal refractive power: analysis of measurement repeatability with 5 different devices in normal eyes with low astigmatism. *J Cataract Refract Surg.* 2016;42(4):569–76.
12. Koch DD, Ali SF, Weikert MP, Shirayama M, Jenkins R, Wang L. Contribution of posterior corneal astigmatism to total corneal astigmatism. *J Cataract Refract Surg.* 2012;38(12):2080–7.

13. Koch DD, Jenkins RB, Weikert MP, Yeu E, Wang L. Correcting astigmatism with toric intraocular lenses: effect of posterior corneal astigmatism. *J Cataract Refract Surg.* 2013;39(12):1803–9.
14. Core C, Cortum K, Muller M, Kampik A, Priglinger S, Mayer WJ. Comparison of two toric IOL calculation methods. *J Ophthalmol.* 2018;2018:2840246.
15. Abulafia A, Barrett GD, Kleinmann G, Ofir S, Levy A, Marcovich AL, et al. Prediction of refractive outcomes with toric intraocular lens implantation. *J Cataract Refract Surg.* 2015;41(5):936–44.
16. Abulafia A, Koch DD, Wang L, Hill WE, Assia EI, Franchina M, et al. New regression formula for toric intraocular lens calculations. *J Cataract Refract Surg.* 2016;42(5):663–71.
17. Asam JS, Polzer M, Tafreshi A, Hirschall N, Findl O. Anterior segment OCT. In: Bille JF, editor. *High resolution imaging in microscopy and ophthalmology: new frontiers in biomedical optics.* Cham (CH);2019. pp. 285–99.
18. Fukuda S, Ueno Y, Fujita A, Mori H, Tasaki K, Murakami T, et al. Comparison of anterior segment and lens biometric measurements in patients with cataract. *Graefes Arch Clin Exp Ophthalmol.* 2020;258(1):137–46.
19. de Sanctis U, Donna P, Penna RR, Calastri MI, Eandi CM. Corneal astigmatism measurement by ray tracing versus anterior surface-based keratometry in candidates for toric intraocular lens implantation. *At J Ophthalmol.* 2017;177:1–8.
20. Hoffmann PC, election J, Hutz WW, Preussner PR. A ray tracing approach to calculate toric intraocular lenses. *J Refract Surg.* 2013;29(6):402–8.
21. Hirschall N, Buehren T, Trost M, Findl O. Pilot evaluation of refractive prediction errors associated with a new method for ray-tracing-based intraocular lens power calculation. *J Cataract Refract Surg.* 2019;45(6):738–44.
22. Brain sound N, Buehren T, Bajramovic F, Trost M, Teuber T, Findl O. Prediction of postoperative intraocular lens tilt using swept-source optical coherence tomography. *J Cataract Refract Surg.* 2017;43(6):732–6.