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Mini Review

Posterior Corneal Astigmatism and It's Importance in Selection of Toric Intraocular Lens

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Abstract

This mini review focuses on the current knowledge on posterior corneal astigmatism based on the latest research. In the first part the definition, the magnitude as well as methods and devices for its evaluation are presented. Posterior corneal astigmatism measurement is improving as new technologies are evolving. It is now shown that the posterior corneal surface acts as a negative lens and as a result the total corneal power is overestimated in eyes with the rule anterior astigmatism and underestimated in eyes with against the rule when only the anterior corneal surface is taken in account. In the second part emphasis is given to the effect of posterior corneal astigmatism on toric intraocular lens calculations. The available nomograms and formulae that can be used and their accuracy are discussed. Finally the steps needed to be taken for the best possible result when calculating toric intraocular lenses are presented.

Keywords: *Posterior Corneal Astigmatism; Toric Intraocular Lens*

Over 100 years ago ophthalmologists have noticed the difference between refractive astigmatism and anterior corneal astigmatism in the human eye.

This difference was first described by Javal with the rule: refractive astigmatism=1,25x (keratometric astigmatism)-0.50@ 90, implying the impact of posterior corneal astigmatism (PCA). The assumption was confirmed on refraction as less with the rule astigmatism (WTR) and more against the rule (ATR) astigmatism. The importance of PCA later was neglected mainly because of the difficulty in it's measurement, until refractive surprises with the introduction of toric intraocular lenses turned surgeon's attention back to the posterior corneal surface [1]. Lately with the technological advances in diagnostic tools, it is possible to measure with accuracy posterior corneal curvature.

Definition of posterior corneal astigmatism

Untill recently the contribution of posterior corneal astigmatism in the refractive power of the cornea was underestimated because of the small difference in the refractive index between the cornea and the aqueous humor. So for the posterior corneal surface to produce the same amount of refractive astigmatism to the anterior, the difference in curvature between the steepest and the flattest meridian should be 10 times larger.

Initially the estimation of corneal power was done with the keratometer where four spots were measured in a circular area of 3 - 4 mm diameter. The keratometric astigmatism was then calculated with the use of keratometric index (1,3375) that is based on the fact that anterior and posterior astigmatism have a standard and linear relationship, a fact that is not true for many eyes.

Corneal topography became possible with next generation devices that were based on projection of a Placido ring over the cornea such as the EyeSys topographer, the Humphrey and later the Orbscan. The measurement of posterior corneal astigmatism was only achieved

with the development of corneal tomography as performed with Scheimpflug devices, such as Pentacam, Sirius as well as swept source optical coherence tomography of the anterior segment.

In an initial study by Koch., *et al*. [2] they found that the magnitude of posterior corneal astigmatism has a mean value of -0,30D with the higher value (0,50D) in eyes with the rule (WTR) anterior astigmatism. In more than 80% of eyes the posterior astigmatism was steeper in the vertical meridian, while it's magnitude remained stable over the years. In eyes with WTR astigmatism PCA increases when anterior corneal astigmatism (ACA) increases. On the contrary in eyes with ATR astigmatism PCA remains relatively constant.

The study concluded that when only anterior corneal astigmatism is used in calculations the total corneal astigmatism is underestimated by 0,50@180 while the error is over 0,50D in 5% of eyes.

Tonn B., *et al.* [3] in a similar study found that in corneas with WTR anterior astigmatism the posterior astigmatism is also vertical in 97% of cases and corneal power is overestimated by almost 0,11D. In eyes with ATR anterior corneal astigmatism only 18% have concomitant horizontal PCA therefore SimK's underestimate the total corneal power by almost 0,26D.

Savini G., *et al.* [4] investigated the relationship between posterior corneal astigmatism and total corneal astigmatism in eyes with moderate and high astigmatism over 1D. They found that the percentage of eyes with PCA > 0,50D was much larger than the one found in previous studies. According to the authors keratometric astigmatism overestimates WTR astigmatism by 0,22 ± 0,32D, underestimates ATR by 0,21 ± 0,26D and finally overestimates oblique astigmatism by an average 0,13 ± 0,37D. In 20% of eyes the opposite is true. Overall in the total sample of eyes the difference between keratometric astigmatism and total corneal astigmatism was 0,50D in 16,6% of cases and the difference between the steepest axis was greater than 10o in 3,8% of cases.

Zheng T., *et al.* [5] studied 374 eyes of patients aged between 45 and 84 years old. They concluded that four parameters namely the difference between the anterior and the posterior axis of astigmatism, the size of posterior astigmatism, the amount of keratometric astigmatism and the axial length, were related to the value of absolute difference between keratometric and total corneal astigmatism as measured with Scheimpflug device. The absolute error in value and angle increases with higher values of PCA, with higher keratometric astigmatism, older age, while is reduced with larger difference between anterior and posterior astigmatic axis and increase of axial length.

Ueno Y., *et al*. [6] estimated that corneal is thicker in the vertical compared to the horizontal meridian. That results in PCA being more ATR than what is calculated based on the anterior corneal surface. This asymmetry is more prominent in older ages.

In summary posterior cornea surface works as a negative lens that counteracts anterior corneal astigmatism to an extend. Mean power is -0,30D and in the majority of cases it has a vertical axis. Use of Simk's leads to over estimation of total corneal power in eyes with WTR astigmatism and underestimation in eyes with ATR astigmatism. The vector difference between total corneal astigmatism and keratometric astigmatism ranges between 0,22@180 and 0,28@177,2.

In patients with keratoconus posterior corneal astigmatism shows a large variation and high values. Mean value of PCA in those eyes is around 1D [7].

The importance of posterior corneal astigmatism in cataract surgery

Toric intraocular lens use in cataract surgery has allowed correction of high levels of existing corneal astigmatism. In most studies the mean refractive astigmatism after the implantation of toric IOL ranged between -0,72D ± 0,43(SD) and -1,03D ± 0,79D [8].

D Koch and colleagues [8] compared 5 devices that measure corneal astigmatism. They concluded that WTR astigmatism was overestimated while ATR astigmatism was underestimated by IOL Master, LENSTAR, Atlas and manual keratometer. The most accurate measurements derived from those devices that evaluate the posterior surface of the cornea, in this particular study the Galilei, which is a Scheimpflug based device. When technologies that estimate the total corneal astigmatism based only on anterior corneal measurements

were used, WTR astigmatism was overestimated by 0,5 - 0,6D while the ATR astigmatism was underestimated by 0,2 - 0,3D. Based on these findings Koch et al proposed a nomogram based on the mean value of PCA. The nomogram targets postoperative WTR astigmatism of about 0,40D to account for the gradual shift of the astigmatism axis with age from WTR to ATR [Table 1].

Effective IOL Cylinder Power at Corneal Plane (D)	WTR (D)	ATR (D)
0.00	≤ 1.69 (PCRI if > 1.00)	< 0.39
1.00	1.70-2.69	0.40*-0.79
1.50	2.20-2.69	0.80-1.29
2.00	2.70-3.19	1.30-1.79
2.50	3.20-3.79	1.80-2.29
3.00	3.80-4.39	2.30-2.79
3.50	4.40-4.99	2.80-3.29
4.00	5.00	3.30-3.79

Table 1: *The Baylor Nomogram : Koch D. Journal of Cataract and Refractive Surgery 39 (2013): 1803-1809. The nomogram targets up to 0.40D of residual WTR astigmatism using an average 0.20D WTR surgical induced astigmatism.*

ATR: Against the Rule; IOL: Intraocular Lens; PCRI: Peripheral Corneal Relaxing Incision; WTR: With the Rule

**Especially if spectacles have more ATR*

Similar results are reported by Zhang., *et al.* [9]. They propose adjusting the toric IOL power based on the relationship between anterior and posterior corneal surface as this is measured with Scheimpflug technology.

Reitblat O., *et al.* [10] compared five different methods for their accuracy on toric IOL power prediction. The incorporation of PCA in the measurements changed the power of the toric intraocular lens in the majority of cases. They evaluated the Baylor nomogram. When the latter was used there was the largest change in toric IOL power in eyes with WTR astigmatism. The same study found that the axis of PCA was vertical in the majority of cases (96,8%) . In 15,7% of eyes the deviation of axis between anterior and posterior astigmatism was larger than 20o. The axis of the total corneal astigmatism had in most cases a negligible effect in toric IOL calculation. In certain eyes though when the axis of ACA and PCA were very different and the power difference is small, then the axis of total corneal astigmatism might change significantly. The eyes more influenced by this relationship were those with oblique astigmatism.

In clinical practice

Ideally the measurement of PCA should be performed for every eye planned for implantation of toric IOL. The technologies that show the most reliable results are the Scheimpflug cameras such as Pentacam, Galilei, Sirius as well as newest devices such as Cassini that is based on ray tracing imaging. In addition intraoperative abberrometry can assess the total corneal astigmatism during cataract surgery. Similar features are developed in swept source anterior segment OCT devices such as Avanti, Optovue. The devices and their software are constantly improving and offer individual measurements of PCA for use in IOL calculation. This is very important for eyes that had previous refractive corneal surgical procedures, where the relationship between anterior and posterior surface of the cornea is altered.

Alternatively, when planning the cataract surgery with toric intraocular lens the available nomograms can be used such as the Baylor nomogram, or other calculators such as the Barrett. The latter uses the effective lens position from Universal II Barrett formula combined with a mathematical model for posterior corneal astigmatism without measuring it's curvature, to calculate the axis and power of the toric IOL. This calculation tool is available on line. (www.ascrs.org/barrett-tori-calculator&www.apacrs.org)

The web based Alcon toric IOL calculator incorporated Barrett's algorithm for IOL calculation, thus improving accuracy.

Abufalia A., *et al*. [11] evaluated different methods of measuring and predicting postoperative astigmatism with toric intraocular lens implant. He concluded that the calculation based on Barrett toric calculator and use of Scheimpflug camera measurements gave the most accurate results, with more than 90% of the eyes falling within 0,75D from predicted residual astigmatism.

Defining steps for toric IOL calculation

- Anterior astigmatism needs to be measured with at least two reliable devices (automated keratometer, Lenstar, IOL Master, Placido topographers etc) for comparison and reproducible results should be used. Posterior astigmatism measurements should be incorporated. Alternatively the existing nomograms can be used. The astigmatic shift that occurs with the age [12] should be taken in consideration especially in young patients. According to studies is about 0,3D from WTR to ATR in ten years. In eyes with extreme axial length such as those with very short or very long ALs toric IOL calculations may be difficult due to the limitations of the current methods that use effective lens position (ELP) for power prediction. In short eyes the IOL toricity may need to be reduced. It's the opposite for long eyes. Finally each surgeon should know his surgical induced astigmatism (SIA). It is now easy to calculate using web based tools such as sia-calculator.com that requires pre and post surgical topography data.

Cataract surgery with toric intraocular lenses is a refractive procedure. The results will continue to improve with use of new technologies and available tools that will allow even more accurate measurements of the posterior corneal surface (Figure 1).

Figure 1: *The Barrett toric calculator available on line that incorporates posterior corneal astigmatism in toric IOL power prediction.*

Conclusion

Cataract surgery with toric intraocular lenses is a refractive procedure. The results will continue to improve with use of new technologies and available tools that will allow even more accurate measurements of the posterior corneal surface.

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