For more than 100 years, eye scientists and clinicians have recognized that there is a difference between the refractive and anterior corneal astigmatism of the human eye. Javal1 postulated an approximately linear relationship between corneal astigmatism and refractive astigmatism, which became known as Javal’s rule: refractive astigmatism = 1.25 × (keratometric astigmatism) − 0.50×90.1 For most eyes, this means that, compared with anterior corneal astigmatism, refractive astigmatism in most eyes has less net plus power along the vertical meridian. In traditional refraction terminology, refraction tends to have less with-the-rule (WTR) or more against-the-rule (ATR) astigmatism.

Until recently, the source of this difference was unknown. Many, myself included, assumed that the crystalline lens was solely responsible for creating a refractive ATR effect. Other candidates were the posterior cornea and the retina. The role of the posterior cornea was dismissed because of the small difference between the indices of refraction of the cornea and aqueous. For the posterior cornea to produce the same amount of refractive astigmatism as the anterior cornea, the difference in curvature between the steep and flat posterior corneal surfaces would have to be approximately 10 times greater. The retina was dismissed on the basis of theory and confirmed by a clever retinoscopic study by Flüeler and Guyton.2

The problem was the lack of a reliable clinical method for measuring posterior corneal or lenticular astigmatism. The elusive nature of these measurements is somewhat dumbfounding, considering that the ease with which we can visualize these tissues and surfaces. Fortunately, although we still lack clinical methods for measuring lenticular astigmatism, we now have several evolving technologies for measuring posterior corneal curvature, including slit-scan imaging, Scheimpflug imaging, optical coherence tomography, and light reflection analogous to keratometry.

What have we learned?

1. Posterior corneal astigmatism is often clinically relevant. Ho et al3 reported that posterior corneal astigmatism on average reduced total corneal astigmatism by 13.4% and that, in 28.8% of eyes, total corneal astigmatism differed from anterior corneal astigmatism by >0.5 diopters (D) or >10 degrees in meridian.

2. In more than 80% of eyes, the posterior cornea is steeper along the vertical meridian.4 Because the posterior cornea is a minus lens, this creates net plus refractive power horizontally, that is, ATR refractive astigmatism.

3. Our group found that the amount of posterior corneal astigmatism varies according to the amount of anterior corneal astigmatism, averaging approximately 0.5 D in corneas that have WTR anteriorly and 0.3 D in corneas that have ATR anteriorly. This was demonstrated using Scheimpflug technology and confirmed in our clinical study.4,5

4. The relationships between anterior and posterior corneal astigmatism are complex and follow certain trends. We found that, in eyes with increasing amounts of anterior WTR astigmatism, there is a corresponding increase in posterior corneal astigmatism, reaching values as high as 1 D. Thus, the posterior cornea tends to partially compensate for increasing amounts of WTR anterior corneal astigmatism. However, in eyes with increasing amounts of ATR astigmatism, mean posterior corneal astigmatism is relatively constant.6

In this issue of Ophthalmology (please see www.aaojournal.org/article/S0161-6420(15)00091-3/fulltext), Ueno et al6 used swept-source optical coherence tomography to further our understanding of posterior corneal astigmatism. They found that the cornea is thicker along the vertical meridian than the horizontal meridian, thus providing the anatomic correlate to the posterior corneal power data. They also report that this difference increases with age. In our study, we found essentially no change in the magnitude of posterior corneal astigmatism with age. Further studies are needed to clarify this discrepancy.

Ueno et al noted that the superior vertical thickness is greater than the inferior, indicating that the posterior cornea produces asymmetric astigmatism and undoubtedly some higher-order aberrations as well.

A limitation of their study is that there is no way to verify their findings. Regrettably, there is no gold standard for measuring posterior corneal astigmatism. Therefore, the only way to confirm the accuracy of these values is by refracting eyes and eliminating all other sources of refractive astigmatism, which is best done in pseudophakic eyes.5 Also, it would be valuable to see whether their anatomic findings fully explain the optical data.
Despite these advances, we still lack validated ways to accurately measure posterior corneal astigmatism on a patient-by-patient basis. Our clinical study showed mean prediction errors of 0.57 D in the WTR group and 0.12 D in the ATR group even using dual Scheimpflug technology. Fortunately, these technologies continue to improve with new hardware (reflective imaging [Cassini, iOptics, The Hague, The Netherlands] and swept-source optical coherence tomography as in the study by Ueno et al) and greatly improved software (for Scheimpflug). In the meanwhile, clinicians can also use regression approaches such as the Baylor nomogram and theoretic formulas such as the Barrett toric intraocular lens formula (www.ascrs.org) to address posterior corneal astigmatism.

Accurate measurement mean posterior corneal power will also improve our accuracy in selecting IOL spherical power. Currently, posterior corneal power is calculated with the assumption that there is a fixed ratio between the anterior and posterior curvatures. Our data show that this approach introduces errors of up to 0.5 D in the estimation of true corneal power. This problem is, of course, compounded in eyes that have undergone corneal refractive surgery, when this assumption breaks down completely.

So the posterior cornea is sitting right there in front of us, waiting to be better measured and understood. The good news is that, thanks to collaboration between clinicians and industry, technologies are emerging that will enable us to accurately measure posterior corneal astigmatism and spherical power as a routine part of intraocular lens calculations.

References

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