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Optimizing Refractive Outcomes:

What is the best approach to improving refractive outcomes after cataract surgery? In regards to methods of biometry, there are several factors that have changed over the years allowing clinicians to manage IOL power calculations and astigmatism more appropriately. And in today's ever-changing landscape of refractive cataract surgery, there are new parameters such as Total Keratometry that need to be considered.

Advancement of biometry over the years

Looking back at the history of biometry, there are several milestones that are worth reflecting. The field of biometry, measuring the human eye, began in the 19th century with the development of the Javal keratometer in 1890 which allowed clinicians to measure the front surface of the cornea. In 1949, Harold Ridley implanted the first intraocular lens (IOL) with quite a few achievements - he inserted a round lens in the posterior chamber and his methods of sterilization worked well. However, there was still room for improvement with refractive outcomes. The first IOL patient had a postoperative refraction of -24.0 D with 6.0 D of astigmatism at 30 degrees using the first IOL formula (IOL Power = (1.25 × preoperative spherical equivalent)).

In 1970, the first A-scan ultrasound was performed. Karl Ossoinig and Jackson Coleman found a method to bounce an ultrasonic pulse off the surface of the retina. By measuring the time for that pulse to bounce back, one could determine the axial length. Ultrasound also allowed for the anterior chamber depth (ACD) to be measured. This discovery helped improve refractive outcomes further.

The next landmark discovery was in 1999 with the introduction of partial coherence laser interferometry (PCI) in the ZEISS IOLMaster, largely due to the work of Adolf Fercher and Christoph Hitzenberger. By capturing the movement of the reference mirror that changes the interference pattern, axial length can be measured.

In 2014, the ZEISS IOLMaster 700 introduced SWEPT Source optical coherence tomography (SS-OCT) technology to biometry. This allows for a precise imaging-based measurement of biometry data such as axial length, corneal thickness, anterior chamber depths, and lens thickness. With this technology, the speed of acquisition improved, meaning 2,000 scans could be acquired per second. Additionally, the IOLMaster 700 provides direct measurements for the posterior corneal surface and, combined with the telecentric keratometry measurement of the anterior corneal surface, provides precise Total Keratometry (TK)[1] and allows for measurement of Central Topography.[2] Accounting for the posterior corneal surface and thickness is important because it has an effect on the total corneal power. Most biometric formulas rely on standard K readings from the anterior cornea surface, while assuming the posterior corneal radius, based on a keratometric index, and this will cause inaccurate results in some cases where the cornea is not "normal."[3] New formulas are now trying to predict the effect of the posterior cornea power. This way, clinicians are able to better solve the IOL puzzle with greater precision but are still relying on assumptions rather than measurements. The question then turns to how clinicians can best utilize the new information on the actual measured posterior corneal surface that we now have.

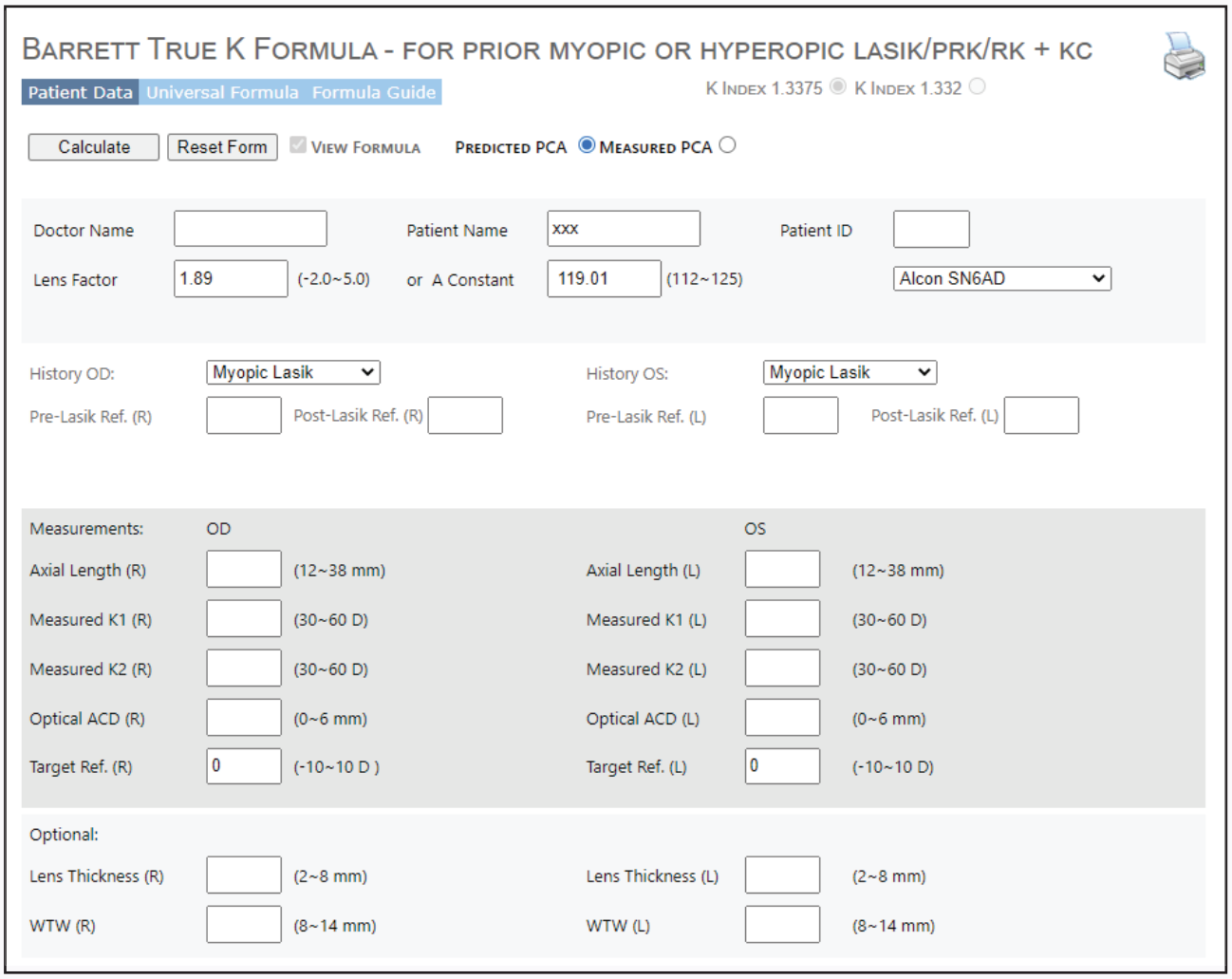
Accurate IOL power calculations utilizing both anterior and posterior corneal surface

With the ability to measure both the anterior and posterior corneal surface, it is also important to choose a formula that will not only deal with real measured values but also provide the most accurate IOL power. Professor Graham Barrett of the Lions Eye Institute has developed formulas that are utilized in the IOLMaster 700. The Barrett Suite comprises of the Barrett Universal II, Barrett Universal II TK, Barrett Toric, the Barrett Toric TK, the Barrett True K, and the Barrett True TK formulas. The Barrett Universal II formula uses up to five different variables: axial length, keratometry, anterior chamber depth, lens thickness, and white to white measurement. Dr. Barrett himself says, "For every lens that you implant, [the Barrett Universal II] works out the principle plane [of refraction] for those optics. This is the reason why it maintains its accuracy in unusual situations such as high myopia."

The Barrett Toric Calculator, on the other hand, gives the option of using the predicted posterior cornea power by implementing nomograms or directly using the measured posterior cornea power. Clinicians need to take into consideration that the original Barrett Toric Calculator does indeed use standard K and includes the standard nomogram to address posterior corneal surface effects. Using TK values with this calculator would compensate twice for the posterior corneal astigmatism and thus may result in inaccurate outcomes. If the TK and posterior keratometry (PK) values are available as measured with the IOLMaster 700, they can be used directly in the online calculator though, by choosing and entering measured instead of predicted values. The online calculator will then replace the posterior surface nomograms with the actual measurements.

> *"The Barrett True K with TK formula elevates post corneal refractive surgery IOL power calculation to the next level."*
>
> *Professor Graham Barrett, Australia*

Using an Improved TK Formula for Cataract Surgery



BARRETT TRUE K FORMULA - FOR PRIOR MYOPIC OR HYPEROPIC LASIK/PRK/RK + KC

Patient Data | Universal Formula | Formula Guide

K INDEX 1.3375 ◉ K INDEX 1.332 ○

Calculate | Reset Form | ☑ VIEW FORMULA | PREDICTED PCA ◉ MEASURED PCA ○

Doctor Name		Patient Name	xxx	Patient ID	
Lens Factor	1.89 (-2.0~5.0)	or A Constant	119.01 (112~125)		Alcon SN6AD

History OD:	Myopic Lasik		History OS:	Myopic Lasik	
Pre-Lasik Ref. (R)		Post-Lasik Ref. (R)	Pre-Lasik Ref. (L)		Post-Lasik Ref. (L)

Measurements:	OD		OS	
Axial Length (R)	(12~38 mm)		Axial Length (L)	(12~38 mm)
Measured K1 (R)	(30~60 D)		Measured K1 (L)	(30~60 D)
Measured K2 (R)	(30~60 D)		Measured K2 (L)	(30~60 D)
Optical ACD (R)	(0~6 mm)		Optical ACD (L)	(0~6 mm)
Target Ref. (R)	0 (-10~10 D)		Target Ref. (L)	0 (-10~10 D)
Optional:				
Lens Thickness (R)	(2~8 mm)		Lens Thickness (L)	(2~8 mm)
WTW (R)	(8~14 mm)		WTW (L)	(8~14 mm)

Figure 1. The Barrett True K Calculator can be found on the APACRS website and provides the option of selecting "Predicted PCA" or "Measured PCA" for patients with prior myopic or hyperopic laser vision correction.

Another option is to use the Barrett TK formulas, which utilize anterior and posterior corneal measurements instead of nomograms, directly on board the IOLMaster 700. TK may improve spherical power prediction and toric cylinder (astigmatism) prediction, and additional improvements rather than values for TK are expected in spherical, toric, and post refractive prediction. Initial clinical results have already shown improved accuracy when using Total Keratometry for the Haigis-T and Barrett TK Toric Calculator formulas.[4,5]

It is important to know the toric cylinder prediction in planning toric lenses as Barrett's method uses a theoretical model based on the observation that the cornea is elliptical. The horizontal diameter is almost always wider than the vertical diameter.When a clinician measures the keratometry of the anterior surface with a keratometer, the clinician centers on the visual axis while the optical elements of the eye are aligned on the optical axis. With the IOLMaster 700, the lens is not aligned tangentially and often appears tilted. However, it is an apparent tilt due to the displaced fovea. In fact, the angle between the optical axis and the visual axis is about 5 degrees and produces additional astigmatism. When using the Barrett toric calculator, there is an algorithm for IOL tilt that corrects this misalignment of the optical axis. Using the Barrett Toric Calculator thus yields the lowest astigmatic prediction errors.

Factors affecting post-refractive calculations

When measuring the cornea and calculating IOL power in post refractive surgery patients, there are three confounding factors that affect post-refractive calculations. First, when a clinician measures the cornea, he or she is in fact not measuring the actual central cornea but instead extrapolating from the keratometry measurement. This measurement leads to the second factor: overestimation of the "True" K value resulting in a hyperopic result. The power of the posterior cornea is inferred from the keratometry index and assumes a normal anterior to posterior ratio. After myopic laser treatment such as LASIK, however, the central cornea tends to be flatter while after hyperopic laser, the central cornea tends to be steeper. The normal ratio of the posterior to the anterior cornea (82.5%; refractive index 1.3375) has been disrupted. Furthermore, this disruption of anterior and posterior curvature ratio after LASIK and other corneal refractive surgeries leads to a false prediction of corneal heights and subsequently effective lens position (ELP). If this is not compensated for, one will also get an error in post-refractive calculation. This is known as the double K issue.

Dr. Barrett explains that there are three basic categories of formula for post-refractive patients: patients with a full clinical history in which preoperative keratometry is known, patients with no history at all (most often the case), and patients with a partial history (knowing what the change in refraction produced by the refractive procedure is). With Barrett's own formula being based on the Barrett Universal II formula, it has an integrated solution for the double K issue, allowing for use in the three mentioned categories including myopic LASIK/PRK and hyperopic LASIK/PRK patients.

IOL power calculations for patients with differing demands

In a recent webinar hosted by ZEISS, "How to do precise IOL power calculations for your demanding (refractive) patients," Dr. Ahmed Assaf from Ains Shams University in Cairo, Egypt further explored specific subsets of patients. Most laser vision correction (LVC) patients with cataracts present as sensitive to reduced vision due to added lenticular higher order aberrations [HOAs] on top of corneal HOAs present after LVC. Other LVC patients with cataracts may have undergone surgery at an earlier age or have higher expectations from LVC (expecting the same refractive results enjoyed after normal refractive surgery). With all these patients, the burden on clinicians lies in the difficulty of estimating the correct IOL power. This is due to a variety of reasons.

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"The IOLMaster 700 is really opening up a new dimension with new measurements to improve our outcomes. Measuring the posterior corneal radius enables us to more accurately predict IOL power for post-refractive surgery patients."

Dr. Yeo Tun Kuan, Singapore

First, patients may experience variation in their anterior corneal surface. After LVC, there will always be significant variation in the central corneal power compared to a virgin cornea. Second, as mentioned before, the anterior to posterior corneal curvature ratio may be flatter or steeper depending on the type of patient. Finally, third and most fourth generation biometry formulas estimate the ELP based on K readings, resulting in either an underestimate or overestimate of IOL power due to the flatness or steepness of the cornea after either myopic or hyperopic ablation. Surgeons who find it difficult to choose a proper calculation method may benefit from using the IOL power calculator on the ASCRS website (https://iolcalc.ascrs.org/) which allows one to select prior myopic LASIK/PRK, prior hyperopic LASIK/PRK, or prior PRK. Alternatively, the IOLMaster 700 also has solutions for all these calculations onboard.

Results of IOL power calculations after refractive surgery using Total Keratometry

In one study, Lawless et al. (2020) analyzed prediction errors among different IOL power formulas in 72 eyes of 50 patients in which prior refraction history was only known for 37 eyes. Formulas that were compared included the ASCRS mean, Barrett True K no history, Haigis-L, and Shammas IOL formulas. Additionally, the Barrett True K using posterior values (True K TK), Haigis-L, Haigis with TK, and Holladay[6] Double-K methods using TK were also analyzed. Results showed a statistically significantly higher percentage of eyes within range of the refractive prediction

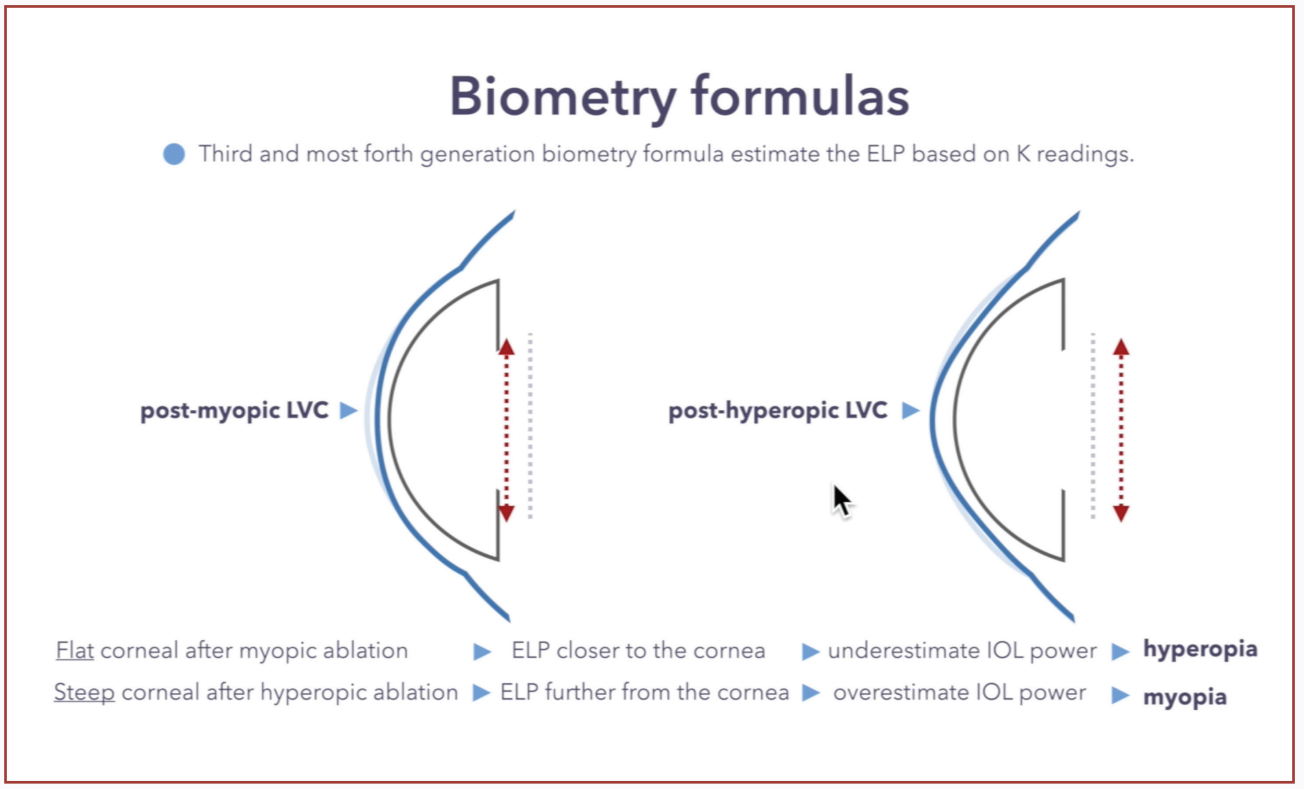

Figure 2. Third and fourth generation biometry formulas estimate the ELP based on K readings, resulting in either an underestimate or overestimate of IOL power due to the flatness or steepness of the cornea after either myopic or hyperopic ablation.]

Zeiss IOLMaster 700

Zeiss IOL and OVD Portfolio

when using the Barrett True K with TK compared to the Shammas, Haigis-L, and ASCRS Average formulas. In fact, the highest number of eyes that came within 0.5 D utilized the Barrett True K with TK formula, indicating that using TK values may supplement outcomes when prior refraction history is not known.[7]

Dr. Tun Kuan Yeo of Tan Tock Seng Hospital in Singapore also shared his thoughts in the webinar on Total Keratometry in post-refractive surgery IOL power prediction. He reiterated the previous message that the sources of error in myopic post-refractive surgery patients come from mismeasuring the anterior corneal radius, ignoring the posterior corneal power measurement, and predicting the ELP. Dr. Yeo also reemphasized that the IOLMaster 700 combines both the telecentric anterior corneal radius measurement, which reduces noise and improves accuracy, and swept-source OCT, providing total corneal power.

Dr. Yeo conducted his own study at Tan Tock Seng Hospital and assessed the accuracy of different formulas using TK in post-myopic laser refractive surgery patients in 64 eyes from 49 patients.[8] Biometric measurements were taken with the IOLMaster 700 one month after uneventful phacoemulsification. The formulas utilized in this study included post-LASIK no-history formulas (Barrett True K, Haigis-L, Shammas-PL) and conventional formulas with TK (Barrett True K TK, EVO TK, Haigis TK, Hoffer Q TK, Holladay I TK, and SRK/T TK). The findings from the study showed that without TK, Barrett True K performed better than the Haigis-L and Shammas-PL formulas. Barrett True K TK further improved results, and among the formulas with TK, Barrett True K TK, EVO TK, and Haigis TK formulas performed the best.

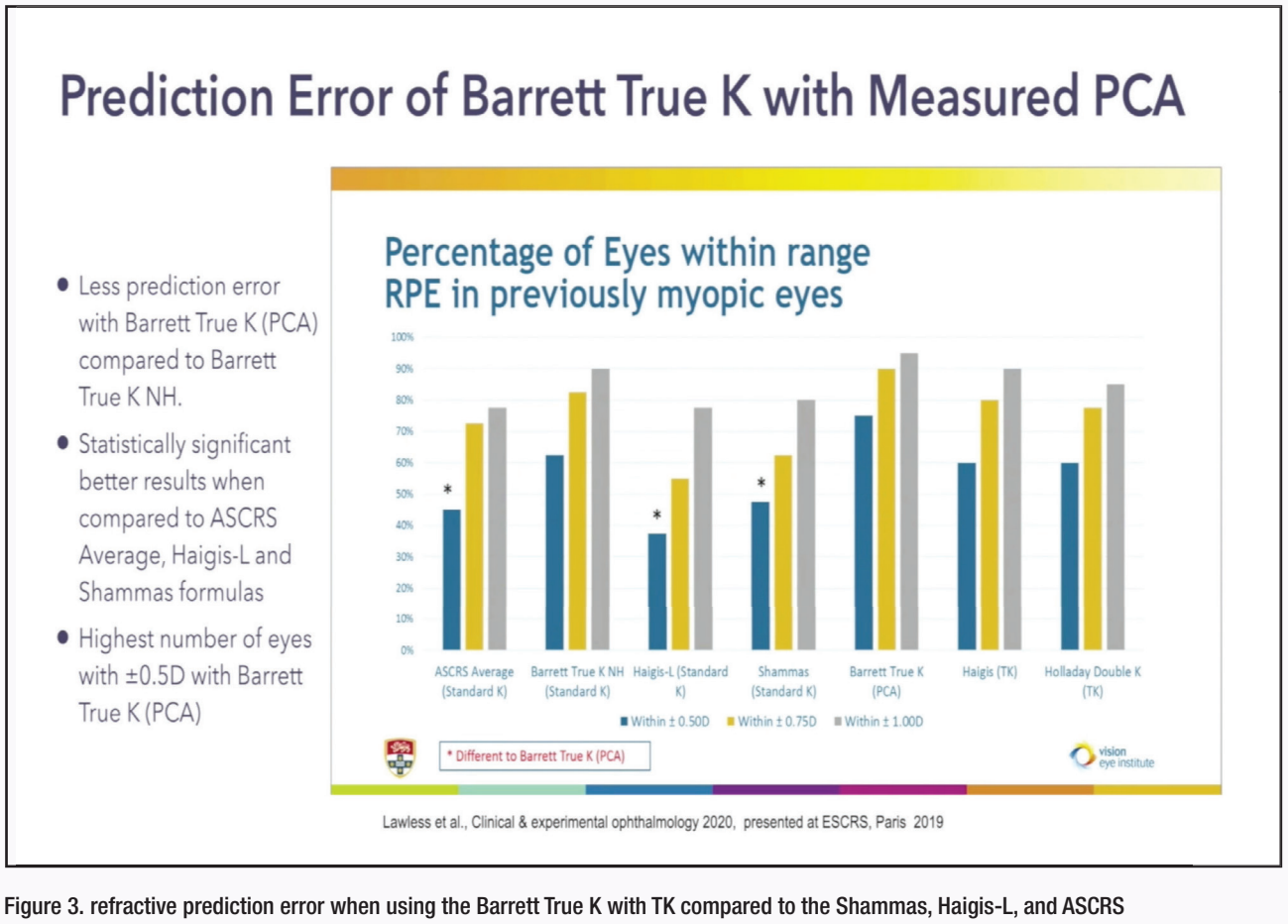

Figure 3. refractive prediction error when using the Barrett True K with TK compared to the Shammas, Haigis-L, and ASCRS Average formulas.]

Dr. Yeo concluded, "The IOLMaster 700 is really opening up a new dimension with new measurements to improve our outcomes. Measuring the posterior corneal radius enables us to more accurately predict IOL power for post-refractive surgery patients."

Key Take Home Messages:

The following points summarize the findings on IOL power calculations from various key refractive surgery leaders.

1. Measurement of the posterior corneal surface with the IOLMaster 700 is reliable and shall be used to further improve IOL power calculation, especially when it comes to patients with previous refractive surgery.

2. When combined with TK measurements, formulas such as the Barrett Univ. II (TK version), EVO, and Haigis take into consideration the measured posterior corneal curvature and can improve your results.

3. Including the measured posterior corneal power with the Barrett True K formula improves IOL calculation in post refractive corneal surgery cases.

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