ZEISS IOLMaster 700
Total Keratometry

ZEISS

Seeing beyond

Replacing assumptions with measurements

Total Keratometry combines anterior and posterior corneal surface measurement as well as corneal pachymetry to assess each eye's individual corneal characteristics. TK® is designed to be equivalent to K readings, in order to enable use in standard IOL power formulas with existing constants in normal eyes.

Furthermore, Graham Barrett has developed three new IOL power calculation formulas which use posterior corneal surface measurements of the ZEISS IOLMaster 700:

- Barrett TK Universal II for non-toric IOLs
- Barrett TK Toric for toric IOLs
- Barrett True K with TK for post-LVC eyes

When to use TK?

Toric and non toric IOL

Studies showed a strong agreement between conventional K and TK for toric and non toric IOL calculation with a trend toward a higher prediction accuracy and better refractive outcomes using TK (Fabian E, Wehner W, 2019; Srivannaboon S, Chirapapaisan C, 2019)

Post refractive surgery eyes

When using the Barrett True K TK formula, which was specifically designed for TK, it outperformed any other non-history formula in post myopic LASIK eyes (Lawless et al. 2020; Yeo et al. 2020).

TK, providing total corneal power values by means of direct corneal measurements can serve as a significant clinical benefit for surgeons undertaking post-laser refractive IOL calculations.

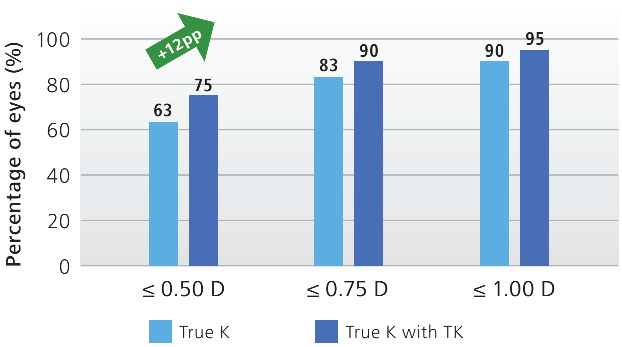


Figure 1: In post-myopic LASIK eyes, Barrett True K with TK improved the out come prediction compared to Barrett True K with classic K's within ±0.5 D by >12% (p = 0.04) (Source: Lawless et al. 2020)

"The Barrett True K with TK formula elevates post corneal refractive surgery IOL power calculation to the next level."

Graham Barrett, M.D.

Why create a new keratometry measurement?

"Total Keratometry has the potential to reduce refractive surprises to a minimum."

Graham Barrett, M.D.

Classic keratometry is based on anterior corneal surface measurements. A known limitation of classic keratometry is that the posterior surface of the cornea is considered via a keratometric index only. The famous Gullstrand eye model, for example, utilizes a fixed anterior posterior corneal curvature ratio (APR) of 0.883. Keratometry respects this fixed APR by modifying the corneal refractive index to the so-called keratometric index (e.g., 1.3315, Olsen 1986).

In recent years, however, several studies have confirmed that posterior corneal astigmatism magnitude and axis orientation cannot be adequately predicted by measuring the anterior corneal curvature alone (Tonn et al. 2014; Koch et al. 2012; LaHood et al. 2017).

Based on such insights, several researchers have created nomograms and mathematical models in order to predict the posterior surface astigmatism and optimize toric IOL power calculation (Koch et al. 2013; Abulafia et al. 2016; Canovas et al. 2018). One of the most prominent examples is the Barrett Toric Calculator (Abulafia, A., et al., 2015). Yet, these methods are based on theoretical assumptions of posterior corneal astigmatism and, therefore, generally cannot fully account for outliers and irregularities.

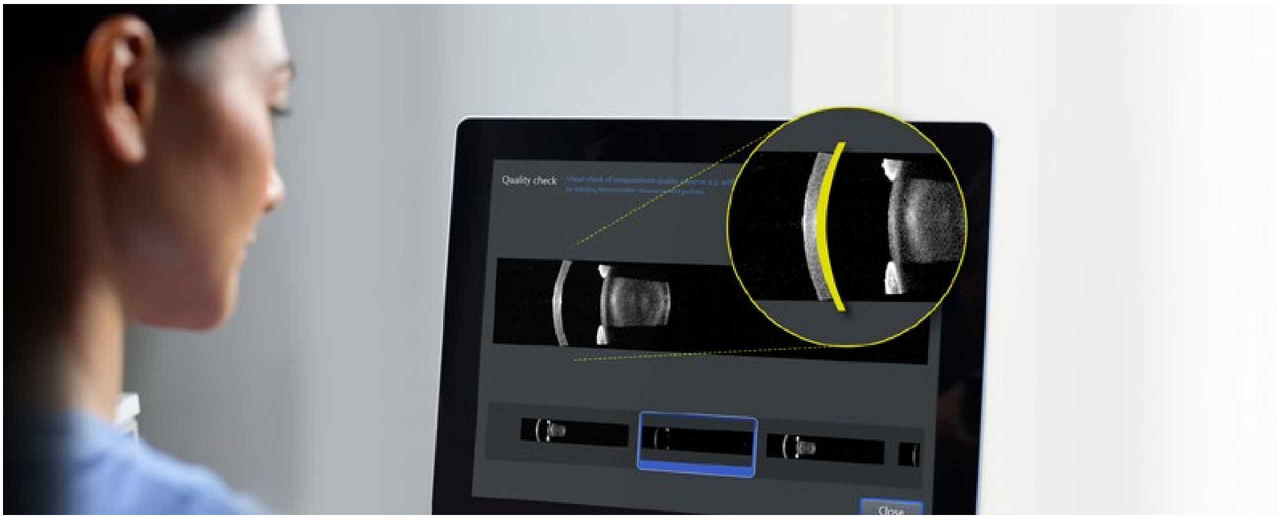
The imprecision of these previous estimations led to the development of technology able to measure, not estimate, the posterior curvature. This is Total Keratometry (TK®).

The Keratometry Transformation

Posterior corneal curvature cannot adequately be predicted by anterior corneal curvature alone.
A more effective method is necessary to produce better results and reduce outliers.

ABSTRACT

How is Total Keratometry different?



Total Keratometry differs from most established methods for total corneal power assessment. It considers corneal thickness and posterior corneal curvature in addition to the anterior corneal curvature measurements. It combines the proven and trusted telecentric 3-Zone Keratometry of the ZEISS IOLMaster 700 with its patented SWEPT Source OCT Cornea-to-Retina Scan (Akman A., Asena L., Güngör SG. 2016; Srivannaboon S. et al. 2015; Kunert KS. et al. 2016). This way, each eye's posterior curvature is considered individually rather than based on general model eye assumptions. Because of this, outliers in IOL calculation can be minimized.

Total Keratometry has been designed by ZEISS optical engineers to match the Gullstrand ratio in normal eyes. However, it still is capable of detecting the impact of posterior astigmatisms in individual eyes, such as eyes with post corneal laser vision correction. This is how Total Keratometry values differ from the many total cornea values provided by other instruments.

An additional significant advantage of Total Keratometry is that it can be directly incorporated in classic IOL power calculation formulas, while existing optimized IOL constants, such as ULIB and IOLCon.org constants, can still be used (Haigis W. et al. 2014).

Savini et al (Savini et al 2020) assessed the repeatability of Total Keratometry and standard keratometry measurements provided by ZEISS IOLMaster 700. 69 previously unoperated eyes and 51 eyes with previous myopic laser refractive surgery were prospectivelly enrolled and analyzed. They conclude that TK(R) measurements offer high repeatability in unoperated and post-excimer laser surgery eyes.

The Total Keratometry Difference
Total Keratometry combines corneal pachymetry with anterior and posterior corneal surface measurement to assess each eye's individual corneal characteristics.

ABSTRACT

How do I benefit from Total Keratometry?

With Total Keratometry, there is no need for a second device (LaHodd et al. 2018), third-party software or an online calculator to utilize posterior corneal curvature for IOL power calculation. Therefore, clinics and practices do not have to change their measurements or calculation workflows. The IOLMaster 700 will automatically measure Total Keratometry and incorporate it in current IOL calculations, if desired.

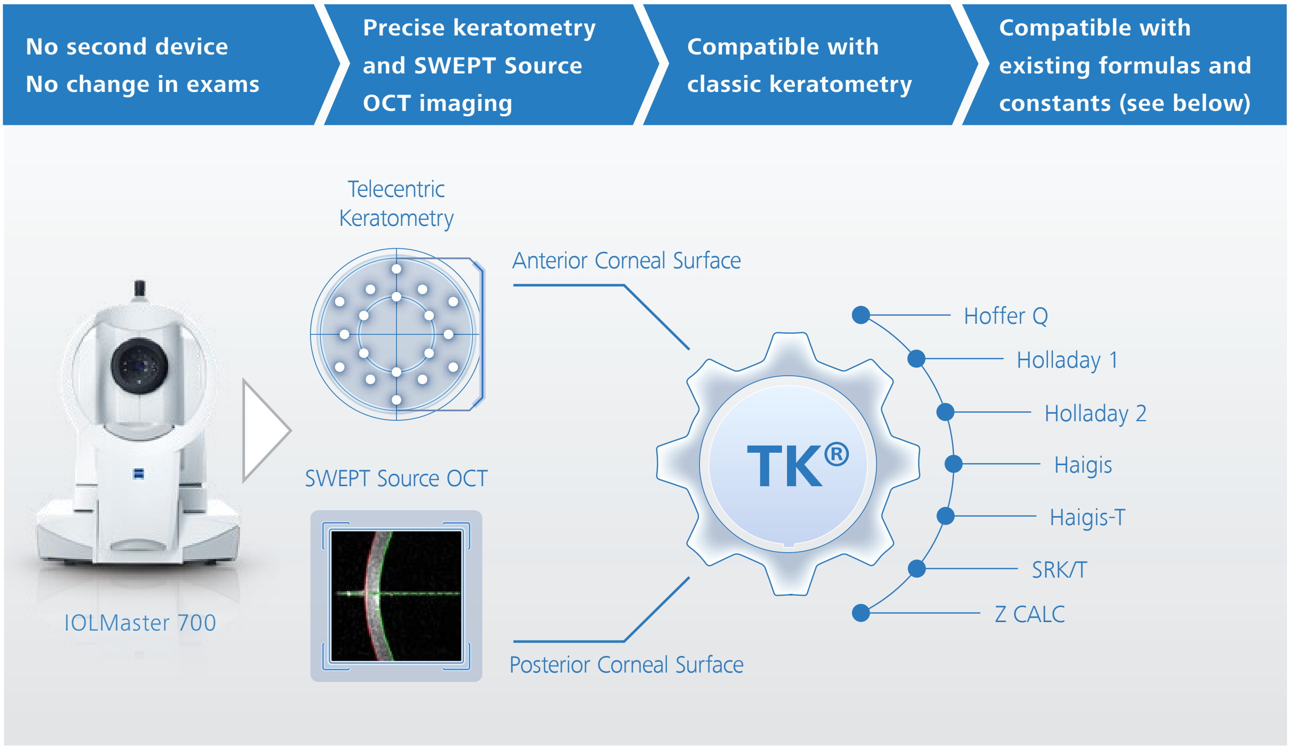


Figure 2: Total Keratometry overview

Ultimate Versatility
Total Keratometry offers clinics great flexibility. It can be used with classic IOL power calculation formulas and existing optimized IOL constants. Plus, there is absolutely no need for a second device, third-party software or an online calculator.

ABSTRACT

Barrett TK formulas

The current Barrett Toric Calculator uses a unique eye model to predict the posterior corneal surface. Using Total Keratometry with the Barrett Toric Calculator would thus lead to overcompensation of posterior corneal astigmatism.

Because of this, Graham Barrett has developed three new IOL power calculation formulas: the Barrett TK Universal II for non-toric IOLs, Barrett True K with TK for post-LVC eyes and the Barrett TK Toric for toric IOLs. All three new formulas use posterior corneal surface measurements of the ZEISS IOLMaster 700 instead of the eye model used by the Barrett Toric Calculator.

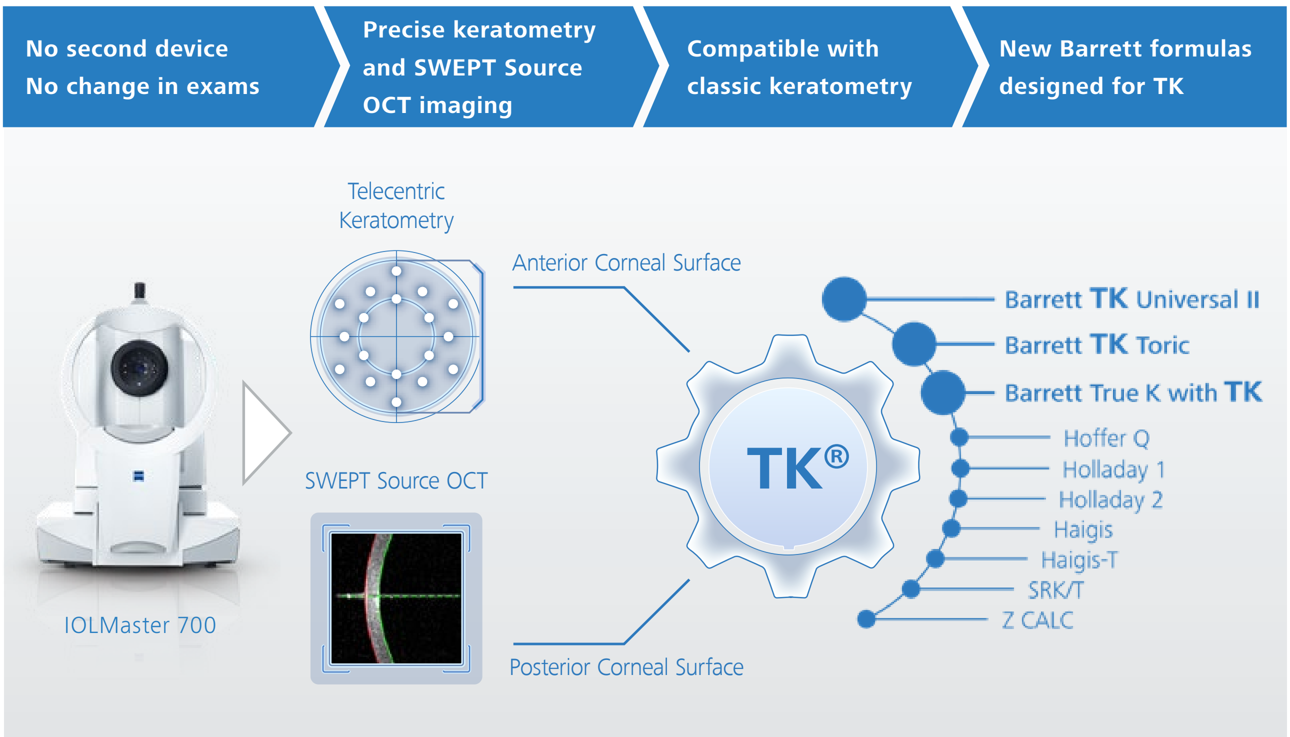


Figure 3: Barrett TK Formulas overview

New Barrett Formulas
To further improve his classic formulas, Graham Barrett has developed three new ones for use with Total Keratometry. They use ZEISS IOLMaster 700 posterior corneal surface measurements instead of the eye model used by the previous formulas.

ABSTRACT

Clinical results

Results in toric or non-toric IOL power calculation

As mentioned before, TK is designed to be equivalent to classic K readings when comparing measurements in large normal patient cohorts. This equivalence is required in order to make TK compatible with existing formulas and IOL constants. However, while TK values are equivalent to K values in normal eyes, they will differ in eyes with an unusual ratio of anterior to posterior corneal curvature or in patients with an unusual posterior astigmatism. In these cases, the classic posterior corneal astigmatism nomograms cannot detect these outliers, while TK can.

Therefore, one can expect that TK and K will overall perform relatively similar in terms of mean refractive outcomes after cataract surgery in normal eyes. However, TK will be able to help surgeons avoid outliers or refractive surprises in the unusual cases mentioned above.

Currently published studies confirm this behavior with respect to spherical equivalent and cylinder prediction errors.

Fabian and Wehner (Fabian E, Wehner W, 2019) demonstrated that in comparison to the conventional keratometry, a notable trend in lowering the absolute prediction errors (Mean absolute- and median absolute errors) was observed by applying Total Keratometry (TK) input into the Haigis-T and the Barrett Universal II/Toric TK formulas. They conclude: *"In comparison to standard K, a higher prediction accuracy can be expected by using TK values along with the two newly developed formulas. TK values are compatible with standard IOL power calculation formulas and existing optimized IOL constants."*

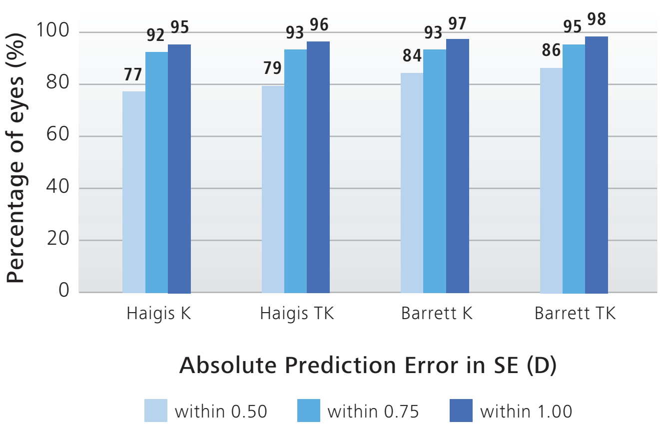


Figure 4: Cumulative percentage of eyes within the specified range of absolute prediction error [APE] in spherical equivalent [SE] (diopters [D]) for the different formulas. (Source: Fabian E, Wehner W, 2019)

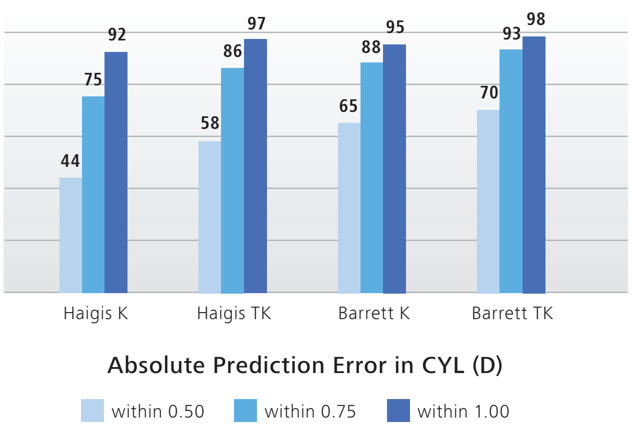


Figure 5: Cumulative percentage of eyes within the specified range of absolute prediction error [APE] in cylinder [CYL] (diopters [D]) for the different formulas. (Source: Fabian E, Wehner W, 2019)

Srivannaboon and Chirapapaisa (Srivannaboon S, Chirapapaisan C, 2019) find similar results. Their conclusion: *"Conventional K and TK for IOL calculation showed strong agreement with a trend toward better refractive outcomes using TK. The same IOL constant can be used for both K and TK."*

Performance of TK in post laser vision correction IOL power calculation

Eyes after refractive corneal laser surgery are the most prominent example of unusual anterior and posterior corneal curvature ratio, as the anterior surface has been altered. In these eyes TK becomes very beneficial, as it does not rely on assumptions on the posterior surface but is a measurement of total corneal power taking actual posterior corneal curvatures into consideration.

Wang et al (Wang et al. 2019) have shown for example, that TK can be used in classic IOL power calculation formulas such as the Haigis formula, resulting in overall similar results like specifically designed post LVC formulas as the Barrett True K without taking historical refraction data into account.

They conclude: *"The performance of the combination of Haigis and TK in refractive prediction was comparable with Haigis-L and Barrett True K in eyes with previous corneal refractive surgery."* (Wang et al. 2019)

Thus, they proved the principle of TK as stated above. Table 6 highlights the outcomes specifically for post myopic LASIK, where Haigis TK and Barrett True K (using K) show similar results in mean absolute errors in patients treated for hyperopia and myopia, as well as for patients who underwent RK.

Parameter	Haigis	Haigis-L	Barrett True K	Haigis-TK
Myopic LASIK/PRK				
MNE (D) ± SD	+0.57 ± 0.68	-0.42 ± 0.61	-0.02 ± 0.73	+0.19 ± 0.59
Range (D)	-0.81, +2.87	-1.66, +0.76	-1.48, +3.04	-0.83, +1.78
MAE (MedAE) (D)	0.72 (0.65)	0.61 (0.53)	0.54 (0.37)	0.50 (0.44)
± 0.5 D (%)	35.8	45.3	52.8	58.5
± 1.0 D (%)	73.6	81.1	92.5	90.6
± 2.0 D (%)	98.1	100.0	98.1	100.0

Table 6: Refractive prediction errors using User Group for Laser Interference Biometry lens constants and percentage of eyes within certain ranges of prediction errors. (Source: Wang et al. 2019)

Lawless et al (Lawless et al. 2020) **(including Graham Barrett)** have shown in their publication, that when using the Barrett True K TK formula, which was specifically designed for TK, it outperformed any other non-history formula in post myopic LASIK eyes evaluated in this study. They also confirm, that Haigis with TK provides similar results as Barrett True K with K and no history.

They conclude based on the formulas evaluated in the paper: *„The Barrett True-K (TK) provided the lowest mean refractive prediction error (RPE) and variance for both prior myopes and hyperopes undergoing cataract surgery. The Barrett True-K (TK) exhibited the highest percentages of eyes within ±0.50D, ±0.75D and ±1.00D of the RPE compared to other formulae for prior myopic patients."*

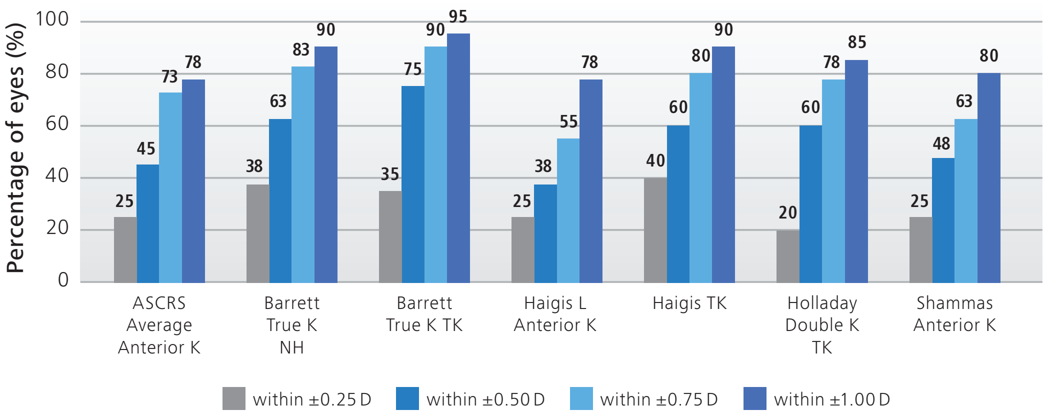


Figure 7: Percentage of eyes within ±0.25 D, ±0.50 D, ±0.75 D and ±1.00 D of refractive prediction error in previously myopic eyes. (Source: Lawless et al. 2020)

It is a common problem, that refraction data of patients prior to refractive surgery is often not known or of unknown quality. TK, providing actual corneal power values by means of direct corneal measurement can serve as a significant clinical benefit for surgeons undertaking post-laser refractive IOL calculations.

Yeo et al (Yet et al 2020) analyzed in this open access paper 64 eyes with previous myopic laser refractive surgery by comparing the prediction error on different formulas. In their analysis EVO TK followed by Barrett True-K TK and Haigis TK achieved the highest percentages of patients with absolute prediction error within 0.50 and 1.00 D. For formulas utilizing the ELP, "reverse double-K" method was applied successfully, allowing also conventional formulas to be used for IOL calculation on eyes with previous refractive surgery.

They conclude: *"Formulas combined with TK achieve similar or better results compared to existing no-history post-myopic laser refractive surgery formulas."*

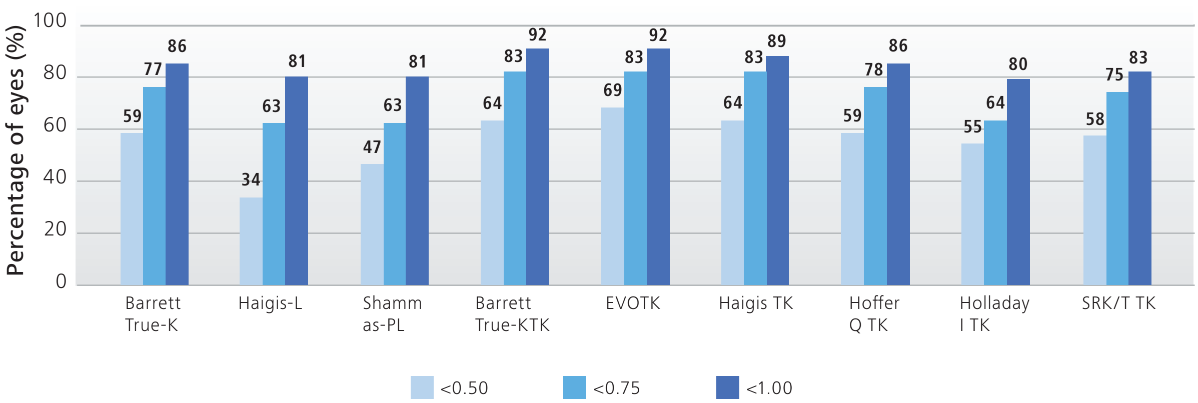


Figure 8: Percentage of eyes within 0.50 D, 0.75 D, and 1.00 D of absolute prediction error; no-history formulas followed by formulas using TK.

Summary of clinical results

- TK is designed to be equivalent to K readings, in order to enable use in standard IOL power formulas with existing constants in normal eyes. Therefore the results are expected to be the same. However, it will help minimizing refractive surprises by directly measuring the power/curvature of unusual posterior corneas, instead of relying on nomograms.
- In post-LVC eyes, TK can either be used with classic formulas, such as Haigis, which are not using K values for ELP prediction, to achieve similar results as formulas specifically designed for post-LVC cases. When used in the new Barrett True K TK formula (available on the ZEISS IOLMaster 700 in 2020), it can outperform other commonly used formulas. Also, the use of historical data is not required.

SUMMARY

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