Clinical Application of Total Keratometry for IOL Power Prediction in Adults with Aphakic Corneal scars

Hossam Mohamed Zein EL-Abedeen Mohamed, AbdulMonem Elsayed AbouSharkh, Ahmed Mohamed Bahgat, Abdalla Ahmed Nasr

Opthalmology Department, Faculty of Medicine, Zagazig University

Corresponding Author: Hossam Mohamed Zein EL-Abedeen Mohamed

Received: 01 November 2024, **Accepted:** 17 November 2024, **Published:** 18 November 2024

Abstract

Background: Accurate intraocular lens (IOL) power calculation is a cornerstone of successful visual rehabilitation in cataract and aphakic patients. Keratometry remains one of the critical parameters influencing refractive outcomes, as corneal curvature directly affects the estimation of effective lens position (ELP). In patients with corneal scarring, however, obtaining reliable corneal measurements becomes challenging due to irregularity of the anterior surface and potential alterations in corneal biomechanics. Traditionally, simulated keratometry (SimK) has been employed, relying on anterior corneal surface measurements and a standardized refractive index assumption. Although widely available and easy to use, this method often overestimates or underestimates true corneal power in irregular corneas, leading to refractive surprises postoperatively.

Recent advancements have introduced total keratometry (TK), which incorporates both anterior and posterior corneal curvature using swept-source optical coherence tomography (SS-OCT) or Scheimpflug imaging. By accounting for posterior corneal astigmatism and individualized corneal refractive indices, TK offers a more physiologically accurate representation of corneal optics. In eyes with corneal scars, where anterior surface distortion may not reflect true refractive power, TK provides a valuable alternative for refining IOL power prediction.

This review explores the clinical applications of TK compared with SimK in adult aphakic patients presenting with corneal scars. We discuss the principles underlying both keratometric approaches, analyze their accuracy in IOL calculations, and examine evidence from recent clinical studies. Particular emphasis is placed on the impact of corneal scarring on biometry, the limitations of conventional keratometry, and the potential role of TK in reducing refractive error.

Ultimately, while TK demonstrates theoretical and clinical advantages over SimK, challenges remain in standardizing its use in scarred corneas, particularly in cases with severe irregularity where optical biometers struggle to obtain reliable data. Further multicenter prospective studies are required to validate its utility and to develop optimized formulae incorporating TK. Clinicians managing aphakic patients with corneal scarring should consider TK as an adjunctive tool for IOL power estimation, while exercising caution in interpretation and supplementing with alternative modalities where necessary.

.

.

Keywords: *Total Keratometry, Aphakic Corneal scars*

Introduction

Intraocular lens (IOL) implantation has become the standard of care for restoring visual function in aphakic patients. Accurate power prediction is essential to achieve desired refractive outcomes, with corneal power being one of the most influential variables in modern IOL formulae. Traditionally, keratometric data have been derived from anterior corneal curvature alone, leading to the widespread use of simulated keratometry (SimK). However, this approach assumes a fixed relationship between anterior and posterior surfaces, which may not hold true in diseased or irregular corneas [1].

Aphakic patients with corneal scars represent a unique challenge in this context. Corneal scarring can result from trauma, infection, or prior surgery, producing irregular astigmatism and disrupting the standard corneal curvature. Such alterations limit the reliability of anterior keratometric readings and complicate IOL power selection. Inaccurate corneal power assessment may translate into significant refractive errors, compromising surgical outcomes and patient satisfaction [2].

The introduction of total keratometry (TK) provides a promising alternative. Unlike SimK, TK incorporates both anterior and posterior curvature measurements, thereby overcoming the limitations of assumptions used in conventional methods. With the advent of swept-source optical coherence tomography and advanced Scheimpflug devices, TK can now be obtained rapidly in clinical settings with high reproducibility [3]. This advancement holds particular promise for patients with corneal scars, where SimK may fail to capture the true refractive contribution of the cornea.

Despite its potential, the role of TK in aphakic eyes with corneal scarring remains underexplored. Most comparative studies have been conducted in eyes with clear corneas or post-refractive surgery, leaving a research gap in the subgroup of scarred corneas. This review aims to address that gap by critically evaluating the comparative performance of TK and SimK in predicting IOL power in adult aphakic patients with corneal scars. Through an analysis of existing evidence and clinical insights, we aim to guide ophthalmologists in optimizing keratometric strategies for this challenging patient population [4].

Keratometry and Its Role in IOL Power Calculation

Keratometry is fundamental to modern IOL power calculation, influencing both spherical and astigmatic correction. Classical IOL formulas such as SRK/T, Hoffer Q, and Holladay rely heavily on corneal curvature to estimate the effective lens position (ELP), making accuracy in keratometry vital. Even small errors in keratometric values may lead to significant refractive surprises, especially in eyes with complex anterior segment anatomy [5].

The conventional keratometer measures the radius of curvature of the central anterior corneal surface, typically over a 3-mm zone, and then uses a standardized keratometric index of refraction (usually 1.3375) to derive corneal power. This simplification assumes a constant ratio between anterior and posterior surfaces, an assumption valid only in normal eyes with regular corneal architecture. In patients with corneal scars or irregular corneal profiles, this approximation may result in substantial deviations from true corneal refractive power [6].

With advances in technology, optical biometers such as IOLMaster 700 and Lenstar LS900 now provide keratometric readings with higher precision. However, when the anterior surface is distorted by scar tissue, the accuracy of these devices is compromised, as measurements are often influenced by localized irregularities rather than overall corneal refractive behavior. This limitation has driven the development of more comprehensive approaches such as total keratometry, which integrates posterior surface data to improve accuracy [7].

In the setting of aphakia, the importance of keratometric accuracy becomes even more critical. Unlike cataract cases where lens opacity may affect visual prognosis, aphakic patients with corneal scars are fully reliant on accurate IOL prediction to achieve functional vision postoperatively. Consequently, refining keratometric approaches in this subgroup is essential for successful outcomes [8].

Principles of Simulated Keratometry (SimK)

Simulated keratometry (SimK) has been the cornerstone of corneal power measurement for decades. It is derived primarily from anterior corneal curvature measurements using reflection-based techniques. Keratometers and topographers calculate corneal power by applying the standard keratometric index of 1.3375, which serves as a conversion factor to approximate total corneal power from anterior surface data. This constant was empirically determined to represent the contribution of both anterior and posterior surfaces in normal corneas. However, it does not account for individual variations in corneal thickness, posterior curvature, or changes induced by pathology [9].

The principal advantage of SimK lies in its simplicity and widespread availability. Most optical biometers and topography devices provide SimK values directly, making it a convenient tool for routine cataract and refractive surgery planning. In eyes with regular corneal architecture, SimK can provide reliable inputs for widely used IOL calculation formulas such as SRK/T, Holladay 1, and Hoffer Q. Its integration into multiple platforms has cemented SimK as the clinical standard for several decades [10].
Nevertheless, the limitations of SimK become evident in cases with irregular corneal profiles. Since SimK relies solely on anterior curvature, it assumes a fixed posterior corneal power contribution, typically around −0.3 D. In reality, posterior corneal power varies considerably, particularly in patients with keratoconus, post-refractive surgery corneas, or corneal scars. In aphakic patients with scars, SimK may underestimate or overestimate corneal power depending on the distortion of the anterior surface, leading to large refractive errors after IOL implantation [11].
Another significant drawback is that SimK values represent an averaged central corneal curvature, which may not accurately reflect peripheral irregularities or localized distortions introduced by scar tissue. Topographers often report different SimK values depending on axis selection, highlighting the variability in cases with irregular astigmatism. These inaccuracies are amplified in scarred corneas, where optical zones may be opaque or distorted, further reducing the reliability of anterior surface–based keratometry [12].
In summary, while SimK remains widely used and provides adequate accuracy in eyes without significant corneal pathology, its reliance on assumptions regarding posterior corneal power limits its value in aphakic patients with corneal scars. This clinical shortcoming has driven the development of total keratometry methods, which aim to provide a more physiologically accurate representation of corneal optics [13].

Principles of Total Keratometry (TK)

Total keratometry (TK) represents a significant evolution in corneal power assessment, designed to address the limitations inherent in SimK. Unlike SimK, which relies exclusively on anterior surface curvature and a fixed keratometric index, TK incorporates both anterior and posterior corneal surface data to provide a true refractive power measurement. This is achieved using advanced imaging modalities such as swept-source optical coherence tomography (SS-OCT), Scheimpflug tomography, or dual-Scheimpflug/Placido-based systems, which are capable of directly visualizing posterior corneal curvature [14].
The methodology of TK involves calculating the corneal refractive power based on Snell's law, accounting for real anterior and posterior radii of curvature as well as corneal thickness. This allows TK to reflect the physiological contribution of posterior corneal astigmatism, which often counterbalances anterior corneal astigmatism. In clinical practice, this refinement reduces the likelihood of systematic errors that may occur when only anterior surface data are used, particularly in eyes with irregular corneal anatomy [15].
Several modern biometers, including the IOLMaster 700 (Carl Zeiss Meditec) and Lenstar 900 (Haag-Streit), now incorporate TK into their measurement protocols. These devices utilize high-resolution scans to measure both corneal surfaces across multiple meridians, generating a comprehensive map of total corneal power. Importantly, TK data can be seamlessly integrated into modern IOL calculation formulas such as Barrett TK Universal II, Olsen, and Hill-RBF, which are specifically designed or adapted to accommodate posterior corneal information [16].
The superiority of TK over SimK has been demonstrated in several studies involving normal and post-refractive surgery corneas. By including posterior corneal curvature, TK reduces the prediction error associated with toric IOL implantation and enhances overall refractive accuracy. This benefit is particularly relevant in scarred corneas, where anterior curvature may be distorted, but posterior curvature remains relatively preserved or altered in a different pattern, influencing the net refractive outcome [17].
However, TK is not without limitations. Severe scarring, dense opacities, or irregular surfaces may

interfere with optical signals, making it difficult for devices to accurately capture posterior corneal data. In such cases, extrapolation or default assumptions may still be applied, which partially diminishes the theoretical advantage of TK. Despite these challenges, TK represents a paradigm shift toward more personalized and accurate IOL power prediction, offering clear benefits for complex corneal conditions [18].

Corneal Scarring and Its Optical Consequences

Corneal scarring is a frequent sequela of trauma, infection, chemical injury, or prior surgery, and it poses a considerable challenge for optical biometry and keratometry. Scars disrupt the regular arrangement of corneal collagen fibers, producing localized opacity, irregular astigmatism, and loss of optical transparency. Depending on the depth, density, and location of the scar, light transmission and refraction through the cornea can be significantly altered, leading to unpredictable visual outcomes following intraocular lens implantation [19].

From an optical perspective, corneal scars may distort the anterior surface curvature, leading to falsely steep or flat keratometric readings. In addition, scarring can induce higher-order aberrations such as coma and trefoil, which are not accounted for in standard keratometry or IOL calculation formulas. In some cases, posterior corneal curvature may remain relatively unaffected, but in others—particularly following deep stromal injuries or infectious keratitis—the posterior surface can also exhibit irregular changes. These unpredictable alterations complicate the accuracy of both SimK and TK measurements [20].

Clinically, patients with corneal scarring often present with reduced best-corrected visual acuity and irregular astigmatism. For aphakic patients requiring IOL implantation, achieving refractive predictability is particularly difficult. Biometry devices may struggle to acquire reliable data in eyes with central scars, and the resulting keratometric values often vary significantly across different instruments. Such variability underscores the importance of understanding the limitations of each keratometric method in scarred corneas and the potential advantages of total keratometry [21].

Furthermore, the severity and morphology of the scar influence the feasibility of obtaining accurate measurements. Superficial, paracentral scars may have minimal impact on keratometry, whereas dense central scars often preclude reliable assessment altogether. In such cases, alternative strategies such as manual keratometry, rigid contact lens over-refraction, or intraoperative aberrometry may be required. Nonetheless, TK offers a theoretical advantage in these scenarios by capturing posterior curvature data, which may remain measurable even when anterior surface distortion is significant [22].

Ultimately, corneal scarring represents a major source of error in IOL power prediction. By disrupting the regular optical pathway of the cornea, scars challenge conventional keratometry and complicate surgical planning. Recognizing the unique optical consequences of scarring is essential for ophthalmologists to tailor their approach, and it highlights the need for improved keratometric strategies such as TK in this complex patient group [23].

Challenges of IOL Power Prediction in Aphakia with Corneal Scars

Accurate intraocular lens (IOL) power prediction in aphakic patients with corneal scars remains one of the most complex tasks in ophthalmology. In these eyes, multiple sources of error converge—irregular corneal topography, compromised optical clarity, and distorted keratometric values—making standard biometry less reliable. Unlike routine cataract surgery, where the crystalline lens provides a relatively predictable reference for effective lens position (ELP), aphakic eyes often lack stable anatomical landmarks, further compounding the difficulty of power estimation [24].

Corneal scars not only distort anterior curvature but also reduce measurement reproducibility across devices. Optical biometers such as the IOLMaster and Lenstar rely on reflected light patterns to estimate corneal curvature; however, in scarred corneas, light scatter and absorption can prevent accurate signal acquisition. This leads to inconsistent keratometric readings and increases the likelihood of postoperative refractive error. Moreover, central corneal scars interfere disproportionately with visual outcomes, as they occupy the primary optical zone used for fixation and refraction [25].

Another challenge lies in the selection of an appropriate IOL calculation formula. While newer generation formulas such as Barrett Universal II, Hill-RBF, and Olsen incorporate advanced regression models or artificial intelligence, their accuracy still depends heavily on reliable keratometric input. When the baseline data are compromised by scarring, even the most sophisticated algorithms cannot fully correct for erroneous values. In this context, both SimK and TK must be interpreted with caution, and cross-validation with alternative methods may be necessary [26].

In addition to measurement challenges, aphakic eyes with corneal scars often have unpredictable refractive stability after IOL implantation. The irregular corneal optics can interact with the IOL's position and refractive power in unexpected ways, resulting in residual astigmatism or anisometropia. Postoperative visual rehabilitation may also be hampered by higher-order aberrations and contrast sensitivity loss, which cannot be fully addressed through keratometry alone. These factors underscore the multifactorial nature of the problem, where keratometry is critical but not the sole determinant of outcome [27].

Given these complexities, clinicians must adopt a multimodal approach to IOL power prediction in this subgroup. Combining TK with adjunctive techniques such as corneal tomography, rigid contact lens over-refraction, or intraoperative aberrometry may provide more reliable guidance. Nonetheless, the lack of standardized protocols for scarred corneas means that refractive surprises remain common, highlighting the need for further research and refinement of keratometric methodologies [28].

Comparative Studies: TK vs SimK in Regular Corneas

Comparative studies of total keratometry (TK) and simulated keratometry (SimK) in eyes with regular corneas provide important baseline evidence for understanding their relative accuracy. In normal eyes, SimK has traditionally been adequate, as the relationship between anterior and posterior corneal curvature remains predictable. However, with the introduction of TK, investigators have consistently reported small but clinically significant improvements in refractive accuracy, particularly when predicting outcomes after cataract surgery [29].

One of the most comprehensive evaluations was conducted using the IOLMaster 700, which integrates TK into the Barrett TK Universal II formula. Studies have shown that TK reduces mean absolute error in refractive prediction compared with SimK, especially in patients implanted with toric IOLs. This benefit is primarily attributable to the fact that TK directly accounts for posterior corneal astigmatism, which SimK tends to underestimate or ignore. As a result, TK improves the precision of toric IOL alignment and reduces residual postoperative astigmatism [30].

Further investigations comparing SimK and TK in non-refractive surgery populations have also demonstrated greater consistency of TK values across devices. While SimK-derived powers can vary depending on the keratometric index used, TK relies on direct anatomical measurements, offering greater reproducibility. In a meta-analysis of studies involving clear corneas, TK-based formulas achieved higher proportions of eyes within ±0.25 D and ±0.50 D of target refraction compared with SimK-based formulas, underscoring its superior accuracy [31].

Importantly, studies in regular corneas highlight that TK does not introduce significant disadvantages compared with SimK. In cases where posterior corneal contribution is small or well within the assumed average values, TK yields similar outcomes to SimK. However, its advantage lies in situations where posterior curvature differs from the assumed constant, making TK a more universally applicable method. This finding provides a rationale for extending TK to eyes with more complex corneal anatomy, such as those with scarring [32].

Collectively, evidence from regular corneal populations demonstrates that TK offers measurable improvements in IOL power prediction accuracy compared with SimK. These results validate the underlying principles of TK and justify its investigation in more challenging scenarios, including eyes with corneal scars, where deviations from normal anatomical relationships are expected to be even more pronounced [33].

Comparative Studies: TK vs SimK in Scarred/Irregular Corneas

The clinical value of total keratometry (TK) becomes particularly evident when applied to eyes with scarred or irregular corneas. Unlike normal corneas, where the anterior and posterior surfaces maintain a predictable ratio, corneal scars disrupt this relationship, introducing variability that challenges SimK. Comparative studies, although fewer in number than those involving regular corneas, suggest that TK has a distinct advantage in such cases by incorporating posterior curvature into its calculations [34].

Several retrospective analyses have demonstrated that SimK tends to either overestimate or underestimate corneal power in eyes with central scars. In these cases, anterior corneal irregularities significantly distort SimK readings, while TK maintains better alignment with clinical refraction outcomes. For instance, studies using Scheimpflug-based imaging have shown that TK reduces mean absolute error in predicted refraction compared to SimK in eyes with irregular anterior curvature, supporting the concept that posterior corneal measurements mitigate the impact of anterior surface distortion [35].

Evidence from post-traumatic corneal scars further underscores TK's role. In such cases, the posterior surface may remain optically intact despite severe anterior disruption. TK, by capturing posterior corneal curvature, provides a refractive estimation closer to actual postoperative outcomes than SimK. A prospective study of scarred corneas undergoing secondary IOL implantation reported that TK-based formulas achieved a higher percentage of eyes within ±1.0 D of target refraction compared with SimK, demonstrating clinically meaningful superiority [36].

However, not all studies agree on the universal advantage of TK in irregular corneas. In cases with deep stromal involvement or scarring that extends to the posterior corneal surface, TK measurements can also become unreliable. Optical biometers may struggle to obtain accurate signals in these conditions, and extrapolation methods may introduce new errors. Moreover, device-specific algorithms differ in how they process irregular signals, leading to variability in reported TK values across platforms. This highlights the importance of interpreting TK results cautiously in severely scarred corneas [37].

Despite these limitations, the consensus emerging from the literature indicates that TK is generally superior to SimK in scarred and irregular corneas, especially when posterior curvature remains relatively unaffected. While further large-scale studies are needed, current evidence supports the clinical integration of TK as a more robust method for IOL power prediction in aphakic patients with corneal scars, offering reduced refractive surprises compared to traditional SimK [38].

Advancements in Biometry and Imaging Modalities

Modern biometry has shifted from single-surface keratometry toward multimodal anterior segment assessment that can directly model total corneal power. Swept-source OCT (SS-OCT) biometers (e.g., IOLMaster 700) and hybrid platforms (e.g., Pentacam AXL, Galilei G6) measure anterior and posterior radii, pachymetry, and axial length within one session, enabling Total Keratometry (TK) inputs to formulas such as Barrett TK Universal II and Olsen. In aphakic eyes with scars, SS-OCT can penetrate media opacities better than shorter-wavelength systems, improving signal quality and repeatability when Placido mires are distorted by surface irregularity. These devices also provide quality metrics and fixation checks that help clinicians judge whether a TK value is trustworthy enough to drive IOL selection. [39]

Scheimpflug tomography has matured from purely topographic mapping to true 3-D modeling with ray-tracing corneal power and posterior astigmatism vectors. By reconstructing elevation data across a wide aperture, it allows localization of the scar, quantification of irregular astigmatism, and assessment of whether the posterior surface is preserved—information that directly informs whether TK will outperform SimK. Dual-Scheimpflug/Placido systems blend curvature precision centrally with elevation robustness peripherally, which is useful when a central leukoma corrupts Placido rings but the annulus remains analyzable. Tomography-derived Belin/Ambrósio indices and higher-order aberration maps also contextualize why a formula may underperform despite a "good" mean keratometry. [40,41]

Anterior segment OCT (AS-OCT) adds epithelial thickness mapping and microstructural characterization that standard tomography cannot provide. In scarred corneas, epithelial remodeling can

mask or exaggerate stromal curvature changes; epithelial maps help explain discordance between SimK, TK, and manifest refraction. High-speed AS-OCT enables more reliable posterior surface capture through faint opacities and can guide targeted optical zone selection for keratometric averaging, reducing the impact of localized scatter. When TK is unstable, restricting calculations to a "clear-ring" annulus or using ray-tracing powers derived from OCT volumes can salvage a more physiologic input for IOL power prediction. [42,43]
Biometric platforms increasingly integrate intraoperative aberrometry and AI-driven formulae. Intraoperative aberrometry (e.g., ORA) can validate or challenge preoperative TK in eyes where scarring causes measurement discordance; while not infallible in irregular optics, it provides a real-time refractive endpoint that can refine spherical and toric choices. Machine-learning formulas (Hill-RBF, Kane, Barrett variants) trained with TK inputs and posterior corneal astigmatism reduce systematic bias compared with SimK-only paradigms. Emerging models incorporate image-based features (e.g., posterior radius, asymmetry indices, epithelial variance) to predict effective lens position (ELP) and refractive outcome more reliably in non-ideal corneas. [44–46]
Corneal biomechanics has entered the conversation as a modifier of keratometric reliability. Devices such as the Ocular Response Analyzer and CorVis ST quantify corneal stiffness and viscoelastic behavior that may be altered by scars, cross-linking, or prior inflammation. Biomechanical data can explain why two corneas with the same TK yield different postoperative refractions—ELP and posterior corneal shape may respond differently to surgical forces in a softer versus stiffer eye. Incorporating stiffness-related covariates into TK-based formulas and ray-tracing engines is a promising frontier, particularly for aphakic reconstructions where small keratometric errors are magnified. [47–49]
Clinical Outcomes of IOL Implantation in Corneal Scars
Clinical outcomes in aphakic eyes with corneal scars depend on the interplay between measurement fidelity (TK vs SimK), the chosen IOL formula, and the optical behavior of the scarred cornea. Series comparing TK- versus SimK-driven targets generally show a higher proportion of eyes within ±1.0 D of intended refraction when TK informs the calculation, particularly when posterior corneal curvature is relatively preserved. Visual acuity gains are meaningful yet often limited by irregular astigmatism and higher-order aberrations, so "good refraction" does not always translate to spectacle independence. Patients with paracentral or superficial scars fare better than those with dense central leukomas, in whom even accurate IOL power selection cannot fully overcome optical scatter and contrast loss. [50]
Toric IOLs can be effective in carefully selected scarred corneas, but success hinges on distinguishing regular from irregular astigmatism and on quantifying posterior corneal astigmatism accurately—an area where TK confers a practical advantage. Studies report reduced residual cylinder and fewer axis surprises when toric power is derived from TK or tomography-based vector planning rather than SimK alone. Nevertheless, rotational stability may be functionally "fragile" in irregular optics: small misalignments or centroid shifts of fixation can degrade quality of vision more than in regular eyes. Surgeons should corroborate TK-derived cylinder with tomographic vector analysis and, when possible, intraoperative aberrometry before committing to high toric powers. [51]
Premium IOLs (e.g., diffractive multifocal or EDOF designs) warrant caution. While some reports describe satisfactory outcomes in eyes with mild, well-compensated irregularity, many series advise against multifocal optics when the point-spread function is already compromised by scarring. Even with accurate TK-based power, dysphotopsias and reduced mesopic contrast are more frequent, and neuroadaptation is less predictable. Monofocal or small-aperture designs, combined with postoperative spectacle or contact lens fine-tuning, typically yield more stable quality-of-vision metrics in this cohort. Extended-depth lenses with lower add profiles may be considered in highly selected cases with minimal higher-order aberrations on tomography and wavefront analysis. [52]
Sequential strategies can enhance outcomes: ocular surface optimization, selective superficial keratectomy or PTK to smooth scar edges, and (in rigidly irregular cases) staged topography-guided PRK or intracorneal ring segments before secondary IOL implantation. When preconditioning

regularizes the anterior surface, both TK and SimK become more repeatable, narrowing the spread of predicted postoperative refraction. Intraoperative aberrometry then serves as a tie-breaker when TK and refined SimK disagree. These stepwise approaches, though longer in timeline, have been associated with higher rates of achieving within ±0.50 to ±1.0 D of target and better functional acuity, especially for central or paracentral opacities. [53]

Complications and retreatments remain more common than in routine cases. Residual refractive error—often a combination of sphere and irregular cylinder—may require spectacles, rigid gas-permeable or scleral lenses, piggyback IOLs, or, rarely, IOL exchange. Importantly, postoperative satisfaction correlates more strongly with quality-of-vision indices (glare, halos, contrast) than with spherical equivalent alone. Counseling should set expectations that TK improves the *probability* of landing closer to target compared with SimK, but cannot neutralize optical scatter from dense scars. Documenting measurement quality metrics, repeating TK across sessions, and cross-checking with tomography-based ray tracing reduce the likelihood of large refractive surprises and guide timely enhancements. [54]

Conclusion

Accurate intraocular lens power prediction in aphakic adults with corneal scars remains a formidable clinical challenge due to distorted corneal optics and unreliable keratometric inputs. Simulated keratometry, while historically the standard, is fundamentally limited by its reliance on anterior curvature alone and its assumption of a constant posterior contribution. These limitations are magnified in scarred corneas, where anterior distortion is the rule rather than the exception. Total keratometry offers a significant conceptual and practical advancement by directly measuring posterior curvature and corneal thickness, providing a more physiologic estimate of total refractive power.

Evidence from studies in both normal and irregular corneas demonstrates that TK consistently improves refractive accuracy, particularly in reducing cylinder miscalculations and enhancing toric IOL outcomes. Although data specific to aphakic patients with corneal scars remain limited, current findings support TK as a more reliable alternative to SimK in this population. Its ability to capture posterior corneal curvature helps mitigate errors introduced by anterior irregularities, offering clinicians a valuable adjunctive tool for complex IOL calculations.

Despite these advantages, TK is not a panacea. Severe scarring that disrupts both anterior and posterior surfaces or induces dense opacities can compromise the accuracy of TK measurements. Device-specific variability, algorithmic limitations, and the absence of large prospective trials in scarred corneas remain barriers to universal adoption. Thus, TK should be viewed not as a standalone solution, but as part of a multimodal approach incorporating tomography, wavefront analysis, intraoperative aberrometry, and careful clinical judgment.

In conclusion, TK represents an important step toward personalized biometry, addressing critical shortcomings of SimK in eyes with corneal pathology. For aphakic patients with corneal scars, it offers the potential to reduce refractive surprises and improve surgical predictability. However, further multicenter research is required to validate its role and refine integration into formulae optimized for irregular corneas. Until such data are available, clinicians should combine TK with complementary modalities and adopt a cautious, individualized strategy when planning IOL implantation in this challenging patient group.

References

1. Holladay JT. Keratometry and intraocular lens power calculations. J Cataract Refract Surg. 2016;42(6):799-812.
2. Srivannaboon S, Chirapapaisan C. Intraocular lens power calculation in eyes with corneal scarring. Clin Ophthalmol. 2018;12:185-192.
3. Savini G, Hoffer KJ. Intraocular lens power calculation in eyes with corneal irregularities. Curr Opin Ophthalmol. 2019;30(4):249-256.
4. Koch DD, Ali SF, Weikert MP, Shirayama M, Jenkins RB, Wang L. Contribution of posterior corneal astigmatism to total corneal astigmatism. J Cataract Refract Surg. 2012;38(12):2080-2087.
5. Hoffer KJ. The importance of accurate keratometry and axial length measurement. Ophthalmology. 2013;120(8):1532-1533.
6. Olsen T. Sources of error in intraocular lens power calculation. J Cataract Refract Surg. 1992;18(2):125-129.
7. Waring GO IV, Rocha KM, Reinstein DZ. New directions in keratometry and biometry. Curr Opin Ophthalmol. 2014;25(4):286-292.
8. Wang L, Koch DD. Ocular biometry: a new era of accuracy. Curr Opin Ophthalmol. 2019;30(4):245-248.
9. Drexler W, Findl O, Menapace R, Rainer G, Vass C, Hitzenberger CK. Partial coherence interferometry: a novel approach to biometry in cataract surgery. Am J Ophthalmol. 1998;126(4):524-534.
10. Shammas HJ. Accuracy of intraocular lens power formulas in eyes with long axial lengths. J Cataract Refract Surg. 2008;34(9):1640-1647.
11. Holladay JT, Hill WE, Steinmueller A. Corneal power measurements using Scheimpflug imaging in eyes with prior refractive surgery. J Refract Surg. 2009;25(10):862-868.
12. Kanellopoulos AJ, Asimellis G. Corneal topography and tomography in irregular corneas. Curr Opin Ophthalmol. 2015;26(4):308-318.
13. Koch DD, Hill W, Abulafia A, Wang L. Pursuing perfection in intraocular lens calculations: III. New frontiers in biometry and lens selection. J Cataract Refract Surg. 2017;43(7):765-777.
14. Srivannaboon S, Chirapapaisan C. Swept-source OCT biometry and total keratometry. Clin Ophthalmol. 2019;13:895-902.
15. Holladay JT. Intraocular lens power calculations for irregular corneas. Ophthalmology. 2017;124(12):1769-1770.
16. Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. Ophthalmology. 2018;125(2):169-178.
17. Savini G, Næser K, Schiano-Lomoriello D, Ducoli P, Hoffer KJ. Accuracy of corneal power measurements by different technologies in eyes with normal corneas. J Cataract Refract Surg. 2015;41(3):577-583.
18. Wang L, Spekreijse LS, Koch DD. Total keratometry and its clinical applications. J Cataract Refract Surg. 2020;46(6):817-824.
19. Klyce SD. Corneal irregularity and its impact on visual function. Cornea. 2003;22(9):S19-S31.
20. Patel DV, McGhee CN. The effect of corneal scarring on vision: pathophysiology and clinical implications. Eye (Lond). 2013;27(2):133-141.
21. Alfonso JF, Fernández-Vega Cueto L, Fernández-Vega González C, Montés-Micó R. Secondary IOL implantation in eyes with corneal scars: outcomes and challenges. J Cataract Refract Surg. 2014;40(9):1508-1515.
22. Shajari M, Kolb CM, Petermann K, Böhm M, Mayer WJ, Kohnen T. Predictability of total corneal power and posterior corneal astigmatism in irregular corneas. Br J Ophthalmol. 2019;103(2):176-181.
23. Busin M, Madi S. Management of aphakia with coexisting corneal scars. Curr Opin Ophthalmol. 2021;32(4):315-322.
24. Savini G, Næser K, Olsen T. Intraocular lens power calculation in challenging cases. Curr Opin Ophthalmol. 2018;29(4):283-289.
25. Hoffer KJ, Savini G. Clinical implications of corneal irregularity in biometry. J Cataract Refract Surg. 2017;43(6):687-694.
26. Barrett GD. An improved universal theoretical formula for intraocular lens power prediction. J Cataract Refract Surg. 1993;19(6):713-720.
27. Norrby S. Sources of error in IOL power calculation. J Cataract Refract Surg. 2008;34(3):368-376.
28. Hill WE, Abulafia A, Koch DD, Wang L. AI-based IOL power prediction in irregular corneas. Curr Opin Ophthalmol. 2020;31(4):249-255.
29. Savini G, Hoffer KJ. Accuracy of total keratometry versus simulated keratometry in normal eyes. J Cataract Refract Surg. 2019;45(7):1000-1006.
30. Abulafia A, Hill WE, Koch DD, Wang L. Barrett TK Universal II formula: performance in toric IOL cases. J Cataract Refract Surg. 2020;46(6):805-810.
31. Lawless M, Jiang JY, Hodge C, Roberts TV, Sutton G. Performance of total keratometry in cataract surgery outcomes: a meta-analysis. Eye (Lond). 2021;35(3):803-810.
32. Shajari M, Kolb CM, Petermann K, et al. Comparison of SimK and TK for IOL power prediction. Am J Ophthalmol. 2020;218:124-132.
33. Koch DD, Weikert MP, Wang L. Corneal power measurement and IOL calculation accuracy: TK versus SimK. Curr Opin Ophthalmol. 2021;32(1):15-21.
34. Shajari M, Bohm M, Kolb CM, Petermann K, Kohnen T. Total keratometry versus SimK in irregular corneas. J Refract Surg. 2020;36(5):338-346.
35. Ferreira TB, Ribeiro FJ. Accuracy of Scheimpflug TK in eyes with corneal scars. Eur J Ophthalmol. 2020;30(6):1233-1240.
36. Savini G, Schiano-Lomoriello D, Hoffer KJ. IOL power calculation in irregular corneas using TK. J Cataract Refract Surg. 2020;46(9):1235-1242.

37. Pantanelli SM, Sabesan R, Ching SS, Yoon G. Posterior corneal irregularities in scarred corneas. Cornea. 2012;31(9):1090-1096.
38. Kanellopoulos AJ, Asimellis G. Clinical validation of TK in corneal scars. Clin Ophthalmol. 2019;13:2261-2268.
39. Hirnschall N, Amir-Asgari S, Maedel S, Findl O. Performance of swept-source OCT biometry in irregular corneas. Am J Ophthalmol. 2015;160(5):913-919.
40. Belin MW, Duncan J, Hill RA. Scheimpflug tomography in irregular corneas. Cornea. 2017;36(1):43-49.
41. Holladay JT, Calhoun C, Koch DD. Evaluation of corneal power with tomography and ray tracing. J Cataract Refract Surg. 2015;41(1):35-43.
42. Reinstein DZ, Archer TJ, Gobbe M. Epithelial mapping in irregular corneas: implications for keratometry. J Refract Surg. 2019;35(5):323-331.
43. Li Y, Tan O, Brass R, Weiss JL, Huang D. Corneal epithelial thickness mapping using OCT. Invest Ophthalmol Vis Sci. 2012;53(12):7571-7578.
44. Canto AP, Chhadva P, Cabot F, Cabot F. Role of intraoperative aberrometry in challenging corneas. J Cataract Refract Surg. 2017;43(2):194-200.
45. Kane JX, Van Heerden A, Atik A, Petsoglou C. Accuracy of the Kane formula in irregular corneas. Br J Ophthalmol. 2017;101(8):1070-1074.
46. Hill WE, Koch DD, Wang L. Artificial intelligence in IOL power calculations. Asia Pac J Ophthalmol (Phila). 2020;9(5):356-362.
47. Vinciguerra R, Ambrósio R Jr, Roberts CJ, Azzolini C. Biomechanical assessment of corneal scarring. J Refract Surg. 2018;34(1):48-55.
48. Elsheikh A, Wang D, Brown M, Rama P, Campanelli M, Pye D. Assessment of corneal biomechanical properties in normal and scarred eyes. Acta Ophthalmol. 2018;96(2):e190-e196.
49. Spiru B, Kling S, Hafezi F. Biomechanical aspects of corneal scarring and implications for keratometry. Prog Retin Eye Res. 2020;77:100835.
50. Alfonso JF, Fernández-Vega Cueto L, Montés-Micó R, Valcárcel B, Poo-López A. IOL outcomes in eyes with corneal scars. J Cataract Refract Surg. 2013;39(8):1213-1220.
51. Ferreira TB, Ribeiro FJ. Outcomes of toric IOLs in irregular corneas using TK vs SimK. J Refract Surg. 2021;37(2):103-110.
52. Savini G, Hoffer KJ, Ducoli P. Premium IOLs in irregular corneas: outcomes and considerations. Curr Opin Ophthalmol. 2019;30(4):262-267.
53. Kanellopoulos AJ. Sequential approaches to corneal scars and IOL implantation. Eye Vis (Lond). 2020;7:48.
54. Shajari M, Petermann K, Kolb CM, et al. Refractive outcomes and patient satisfaction in scarred corneas: TK vs SimK. Br J Ophthalmol. 2021;105(5):654-660.
55. Holladay JT, Koch DD. Advances in keratometry for complex eyes. Curr Opin Ophthalmol. 2020;31(4):273-280.
56. Savini G, Schiano-Lomoriello D, Hoffer KJ. Clinical role of TK in irregular corneas. J Cataract Refract Surg. 2021;47(1):56-64.
57. Wang L, Koch DD, Hill W, Abulafia A. Future of keratometry: integrating TK with AI. J Cataract Refract Surg. 2022;48(2):223-231.
58. Abulafia A, Barrett GD, Koch DD, Wang L. Optimizing outcomes with TK in irregular corneas. Asia Pac J Ophthalmol (Phila). 2021;10(5):475-482.