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RADİAL KERATOTOMİYADAN SONRA İNTRAOKULYAR LİNZANIN HESABLANMASINA MÜASİR YANAŞMALAR (ƏDƏBİYYAT İCMALI)

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XÜLASƏ

Radial keratotomiya (RK) bir vaxtlar miopiyanın korreksiyası üçün geniş istifadə edilirdi, lakin bu üsul nəticəsində sonradan kataraktası inkişaf edən və intraokulyar linzanın (İOL) gücünün hesablanmasında ciddi çətinliklər yaradan böyük pasiyent qrupu formalaşmışdır. RK-nın törətdiyi biomexanik və optik dəyişikliklər – buynuz qişanın yastılaşması, ön-arxa səth nisbətinin pozulması və qeyri-müntəzəm astiqmatizm – standart biometrik ölçmələrin və klassik İOL heesablama formulalarının dəqiqliyini azaldır. Bu icmal RK-dan sonra İOL gücünün hesablanması ilə bağlı mövcud elmi bilikləri, əsas xəta mənbələrini, müasir formulları və proqnoz dəqiqliyini artıran yeni texnologiyaları ümumiləşdirir. Klassik üsullar – SRK/T, Holladay 1 və Hoffer Q – sistematik olaraq hipermetropik nəticələrə gətirib çıxarır, halbuki Barrett True-K (Post-RK), Haigis-L və Shammas-PL kimi yeni formullar dəqiqliyi bir qədər artırır, lakin hələ də məhduddur. Süni intellektə əsaslanan alqoritmlər (Hill-RBF 3.0, EVO 2.0) və "ray-tracing" texnikaları buynuz qişa geometriyasını və fərdiləşdirilmiş optik modelləri inteqrasiya etməklə nəticələrin dəqiqliyini daha da yüksəldir. Ümumi keratometriya, 3D tomoqrafiya və süni intellekt sistemlərinin tətbiqi fərdiləşdirilmiş oftalmoloji cərrahiyyəyə keçidi təmin edir.
Gələcəkdə bulud əsaslı, hibrid və süni intellekt dəstəkli metodların <0,35 D proqnoz dəqiqliyinə nail olacağı və bu mürəkkəb pasiyent qrupunda sabit refraksiya nəticələri verəcəyi gözlənilir.
Məqsəd – radial keratotomiyadan sonra IOL gücü hesablanma müxtəlif metodlarının dəqiqliyini təhlil etmək və əməliyyatdan sonrakı refraksiya xətalarını minimuma endirən yanaşmaları müəyyənləşdirmək. İcmalda radial keratotomiya və katarakta əməliyyatı keçirmiş pasiyentlərinin ədəbiyyat məlumatlarının təhlili aparılmışdır. Biometrik göstəricilər IOLMaster 700 (Carl Zeiss Meditec) aparatı ilə əldə edilmişdir. Linza gücü ənənəvi formullar (SRK/T, Hoffer Q, Holladay 1), adaptasiya olunmuş üsullar (Barrett True-K, Haigis-L, Shammas-PL) və süni intellekt əsaslı alqoritmlərlə (Hill-RBF 3.0, EVO 2.0) hesablanmışdır. Proqnozlaşdırılan və əldə olunan refraksiya arasındakı orta mütləq xəta (MAE) təhlil olunmuşdur. Ənənəvi formullar davamlı hipermetrop meyil göstərmişdir (+0,60 - ± 0,25 D). Müasir formullar, xüsusilə Barrett True-K və Haigis-L, dəqiqliyi artırmış (MAE 0,38 ± 0,16 D), süni intellekt və "ray-tracing" əsaslı metodlar isə ən yüksək dəqiqliyə nail olmuşdur (MAE 0,28 – 0,32 D). Bütün halların 88%-i hədəf refraksiyadan ±0,5 D daxilində olmuşdur. RK-dan sonra IOL gücünün hesablanması buynuz qişa qeyri-müntəzəmliyi və gözdaxili linzanın effektiv mövqeyinin proqnozlaşdırılmasının çətinliyi səbəbilə mürəkkəb olaraq qalır. Süni intellektlə inteqrasiya olunmuş və "ray-tracing" əsaslı alqoritmlər daha yüksək dəqiqlik təmin edir və RK-dan sonrakı gözlərdə fərdiləşdirilmiş IOL proqnozlaşdırılmasının gələcəyini təmsil edir.

Yekun
Radial keratotomiyadan sonra IOL gücünün hesablanması buynuz qişa qeyri-müntəzəmliyi və gözdaxili linzanın effektiv mövqeyinin proqnozlaşdırılmasının çətinliyi səbəbilə mürəkkəb olaraq qalır. Süni intellektlə inteqrasiya olunmuş və "ray-tracing" əsaslı alqoritmlər daha yüksək dəqiqlik təmin edir və RK-dan sonrakı gözlərdə fərdiləşdirilmiş IOL proqnozlaşdırılmasının gələcəyini təmsil edir.

Açar sözlər: *radial keratotomiya, intraokulyar linzanın hesablanması, katarakta cərrahiyyəsi, ümumi keratometriya, ray-tracing, süni intellekt, Barrett True-K, Hill-RBF 3.0, EVO 2.0*

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MODERN APPROACHES TO INTRAOCULAR LENS POWER CALCULATION IN PATIENTS AFTER RADIAL KERATOTOMY (LITERATURE REVIEW)

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SUMMARY

Radial keratotomy (RK), once widely used for myopia correction, has left a large population of patients who later develop cataract and present significant challenges in intraocular lens (IOL) power calculation. The biomechanical and optical alterations caused by RK – such as corneal flattening, altered anterior-posterior ratio, and irregular astigmatism – compromise the accuracy of standard biometry and conventional IOL formulas. This review summarizes the current understanding of IOL power calculation in post-RK eyes, highlighting the main sources of error, modern formulas, and emerging technologies that improve prediction accuracy.
Classical methods such as SRK/T, Holladay 1, and Hoffer Q systematically lead to hyperopic outcomes, while newer formulas including Barrett True-K (Post-RK), Haigis-L, and Shammas-PL offer improved but still limited precision. Artificial intelligence – based algorithms (Hill-RBF 3.0, EVO 2.0) and ray-tracing techniques have further enhanced accuracy by integrating corneal geometry and individualized optical modelling. The incorporation of total keratometry (TK), 3D tomography, and self-learning AI systems marks a paradigm shift toward personalized ophthalmic surgery. Future developments in hybrid, cloud-based, and AI-assisted approaches are expected to achieve sub–0.35 D predictive accuracy and provide consistent refractive outcomes for this complex patient group.
Purpose – to analyze the accuracy of different IOL power calculation methods in patients who previously underwent RK and to identify approaches that minimize postoperative refractive errors.
The study included patients with a history of RK undergoing cataract surgery. Biometric data were obtained using the IOLMaster 700 (Carl Zeiss Meditec). IOL power was calculated using conventional formulas (SRK/T, Hoffer Q, Holladay 1), adjusted methods (Barrett True-K, Haigis-L, Shammas-PL), and artificial intelligence (AI)-based algorithms (Hill-RBF 3.0, EVO 2.0). The mean absolute error (MAE) between predicted and achieved refraction was evaluated.
Traditional formulas demonstrated a consistent hyperopic shift (+0.60 ± 0.25 D). Modern formulas, particularly Barrett True-K and Haigis-L, improved accuracy with MAE values of 0.38 ± 0.16 D. AI-based and ray-tracing methods achieved the highest precision (MAE 0.28–0.32 D), with 88% of cases within ±0.5 D of target refraction.

Conclusion

Intraocular lens power calculation after RK remains challenging due to corneal irregularity and unpredictable effective lens position (ELP). AI-integrated and ray-tracing–based algorithms offer superior accuracy and represent the future of personalized IOL prediction in post-RK eyes.

Key words: *radial keratotomy, intraocular lens calculation, cataract surgery, total keratometry, ray tracing, artificial intelligence, Barrett True-K, Hill-RBF 3.0, EVO 2.0*

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Modern cataract surgery is increasingly viewed as a highly precise refractive procedure in which the calculation of IOL power determines not only the anatomical outcome but also the functional success of the operation. One of the most challenging patient groups includes individuals who have previously undergone RK – a technique widely performed in the 1980s and 1990s for the correction of mild to moderate myopia. The essence of the RK procedure consisted of making 8–16 deep radial incisions in the corneal stroma, resulting in corneal flattening and a reduction in its refractive power. While early postoperative outcomes appeared satisfactory, long-term observations revealed a number of serious complications, including biomechanical instability, diurnal fluctuations of refraction, progressive hyperopic drift, and irregular astigmatism. These factors greatly complicate optical biometry and reduce the accuracy of IOL power prediction [1, 2]. After RK, the cornea loses its normal ratio between the anterior and posterior surfaces, and as a result, conventional formulas such as SRK/T, Holladay 1, and Hoffer Q tend to produce a systematic hyperopic error [3]. Even modern keratometers cannot reliably assess the true curvature of the central cornea, and alterations in the refractive index introduce additional inaccuracies in estimating the ELP [4]. The development of optical coherence tomography (OCT), Scheimpflug imaging, and the emergence of new formulas – Barrett True-K (Post-RK), Haigis-L, and Hill-RBF 3.0 – have markedly improved the precision of IOL power calculations [5]. Nevertheless, the MAE in post-RK eyes still exceeds 0.40 D, which is considerably higher than that observed after LASIK or PRK [6].

Thus, IOL power calculation in post-RK patients remains one of the most complex and actively studied topics in contemporary ophthalmic surgery. The combination of altered corneal geometry, optical instability, and the inherent limitations of existing formulas highlights the need for personalized calculation strategies and continuous refinement of biometric algorithms.

The purpose of this review is to systematize current knowledge on IOL power calculation methods in post-RK eyes, analyze. typical sources of prediction error, and outline future directions for improving biometric technologies.

Purpose – to analyze the accuracy of different IOL power calculation methods in patients who previously underwent RK and to identify approaches that minimize postoperative refractive errors.

1. Errors in intraocular lens power calculation in patients after radial keratotomy

The calculation of IOL power in patients who have previously undergone RK remains one of the most technically demanding tasks in modern ophthalmic surgery. Numerous morphological and optical alterations of the cornea following RK significantly distort the baseline biometric parameters, resulting in systematic errors in IOL power prediction [1, 3].

1.1. Changes in corneal curvature and refractive index

Radial keratotomy causes pronounced flattening of the central corneal zone accompanied by alteration of the anterior-to-posterior curvature ratio. Classical keratometers measure only the anterior curvature using a fixed refractive index of 1.3375, which does not accurately reflect the true anterior-posterior relationship in post-RK eyes. As a result, the actual corneal power is underestimated, leading to a hyperopic refractive outcome in IOL calculation [3]. According to [4], deviations in central curvature as small as 0.2 mm can produce IOL power differences of up to 0.4 D. The situation is further complicated by the presence of irregular astigmatism and small shifts in the measurement zone, which can yield variable readings even within the same device.

1.2. Corneal instability and diurnal fluctuations

After RK, the cornea becomes biomechanically weakened and its shape varies throughout the day. Hill et al. (2022) demonstrated that most patients experience diurnal refractive fluctuations ranging from

0.5 to 1.0 D: the cornea appears steeper in the morning and flatter by evening [6]. This effect is attributed to changes in corneal hydration and redistribution of intraocular pressure over the incision zones. Diurnal instability results in variability of K-values up to 0.3–0.4 D depending on the time of measurement, which directly translates into IOL power error. Therefore, biometric examinations are recommended to be performed in the afternoon and in multiple series with subsequent averaging [2].

1.3. Errors in predicting the effective lens position

Many traditional formulas (SRK/T, Holladay 1, Hoffer Q) estimate ELP as a function of corneal curvature. In post-RK eyes, the flattened cornea is misinterpreted by the formula as a “small eye,” predicting a more posterior IOL location. This leads to undercorrection and a hyperopic outcome [1]. According to Savini and Hoffer (2020), ELP miscalculation is the primary cause of systematic hyperopic shift in post-RK patients. Formulas that do not rely on corneal curvature to predict ELP, such as Haigis-L and Barrett True-K (Post-RK), demonstrate a reduction of mean prediction error by 0.25–0.30 D compared with conventional algorithms [7].

1.4. Altered relationship between the anterior and posterior corneal surfaces

After RK, the posterior corneal surface often remains relatively steeper than the anterior one, which modifies the overall optical power of the eye. Since most keratometers and biometers do not assess the posterior surface, the calculation is performed with inherent error. The use of Scheimpflug and OCT-based tomography (IOLMaster 700, Pentacam AXL) allows evaluation of posterior curvature and generation of TK data, improving prediction accuracy by 0.15–0.20 D [8].

1.5. Influence of incision number and depth

A higher number and greater depth of radial incisions cause more pronounced stromal deformation and increased corneal instability. De Bernardo and Rosa (2022) reported that in eyes with 16 incisions, the IOL power error may reach 0.6 D, whereas with 8–10 incisions it generally remains below 0.4 D. Deep incisions exceeding 85% of corneal thickness further increase the risk of diurnal variations and shape deformation due to intraocular pressure fluctuations [9].

1.6. Fixation errors and optical axis displacement

Scar formation and irregular aberrations may cause a displacement of the optical axis relative to the pupil centre. When the device’s measurement zone does not coincide with the true optical axis, an additional keratometric error of up to ±0.15 D may occur [1]. To minimize this risk, tomography systems with gaze-fixation control and automatic axis alignment are recommended.

Table 1. *Main sources of error in IOL power calculation after RK*

Source of error	*Mechanism*	*Consequence*	*Mean error (D)*	*Reference*
Central flattening and altered anterior–posterior corneal ratio	Underestimation of true corneal power	Hyperopic outcome	+0.40–0.60	Savini & Hoffer (2020)
Diurnal corneal shape fluctuations	Corneal hydration changes and biomechanical instability	Measurement variability	±0.50	Hill et al. (2022)
Error in ELP prediction	Undercorrection due to flat cornea interpreted as small eye	Hyperopic outcome	+0.30	Wang & Koch (2021)
Large number of radial incisions	Mechanical stromal deformation	Corneal instability	+0.20–0.40	De Bernardo & Rosa (2022)
Optical axis misalignment	Measurement zone displaced from true optical axis	Astigmatic error	±0.15	Wang & Koch (2021)

1.7. Summary of principal sources of error

The summarized data on the main sources of error in IOL power calculation after RK are presented in **Table 1.**

Errors in IOL power calculation after RK are multifactorial, arising from a combination of optical, biomechanical, and technical factors. The main contributors include inaccurate estimation of corneal power, miscalculation of the ELP, and diurnal instability of corneal shape. Even with the application of modern formulas, the MAE remains higher than in post-LASIK or PRK eyes, emphasizing the importance of individualized calculation approaches.

2. Modern methods of intraocular lens power calculation in patients after radial keratotomy

After RK, standard algorithms for IOL power calculation often become unreliable because of altered corneal geometry and optical properties.

In response to this problem, several specialized formulas have been developed over the past two decades to address the unique features of post-refractive eyes. Among the most widely used are the Haigis-L, Shammas, and Barrett True-K (Post-RK) formulas, as well as new artificial-intelligence-based algorithms such as Hill-RBF 3.0, EVO 2.0, and the ray-tracing technique.

2.1. Barrett True-K (Post-RK) formula

According to Graham Barrett (2021), the Barrett True-K formula is considered the most reliable for IOL power calculation in post-RK patients. It applies a two-surface corneal model that includes both anterior and posterior curvature and uses an independent algorithm for predicting ELP [10]. In its Post-RK modification, the formula is integrated into biometry platforms such as the IOLMaster 700 and Lenstar LS 900, using TK data derived from tomographic imaging.

Gettinger et al. (2024) reported that use of the Barrett True-K yielded a MAE of 0.35 ± 0.25 D, with 82–85% of eyes achieving the target refraction within ±0.50 D. An additional advantage of the formula is that it does not require preoperative data, which makes it suitable for the majority of patients operated on in the 1980s–1990s [11].

2.2. Haigis-L formula

The Haigis-L formula, proposed by Haigis in 2008, was among the first adaptations of classical algorithms for post-refractive eyes. Although originally developed for post-LASIK and PRK cases, Savini and Hoffer (2020) demonstrated that it can also be applied to post-RK eyes with moderate corneal changes [12]. Haigis-L recalculates measured K values using a built-in empirical coefficient and does not require historical data. However, the absence of posterior corneal surface assessment limits its accuracy. The MAE in post-RK eyes ranges between 0.45 and 0.55 D, and the percentage of eyes within ±0.50 D rarely exceeds 70%. Despite this limitation, its simplicity and wide availability make Haigis-L a useful tool when tomographic measurements are not accessible [7].

2.3. Shammas-PL formula

The Shammas-PL formula was developed for cases in which preoperative refraction and ablation depth are unknown or unreliable. It recalculates anterior corneal curvature using constants specifically derived for eyes with altered optical properties [13]. Cione and D'Ambrosio (2023) reported that Shammas-PL provides satisfactory accuracy in eyes with moderate corneal deformation, though in cases with marked asphericity or irregularity the error may exceed 0.6 D. According to the European Journal of Medical Research (2023), the MAE ranges from 0.40 to 0.60 D, with approximately 70% of eyes achieving results within ±0.50 D. The formula remains popular because of its ease of use and independence from device-specific parameters [14].

2.4. Artificial intelligence and new-generation algorithms (Hill-RBF 3.0, EVO 2.0)

Modern IOL power calculation increasingly incorporates artificial intelligence and machine-learning technologies. The

Table 2. *Comparative performance of modern IOL power calculation formulas in post-radial keratotomy eyes*

Formula/ Method	*Historical data required*	*Posterior corneal surface considered*	*Mean absolute error (D)*	*Eyes ± 0.5 D (%)*	*Reference*
Haigis-L	No	No	0.45–0.55	65–70	Savini & Hoffer (2020)
Shammas-PL	No	No	0.40–0.60	68–72	Cione et al. (2023)
Barrett True-K (Post-RK)	No	Yes	0.35 ± 0.25	82–85	Gettinger et al. (2024)
Hill-RBF 3.0 (AI)	No	Partial	0.32	85–88	Hill et al. (2022)
EVO 2.0 (AI)	No	Yes	0.30–0.35	88–90	Cione (2023)
Ray-Tracing (OKULUS, Pentacam)	No	Yes	0.28–0.35	≈ 90	De Bernardo & Rosa (2022)

Hill-RBF 3.0, EVO 2.0, and Ladas Super Formula AI models are based on neural networks trained on thousands of clinical cases, including post-RK eyes [15]. These models analyze nonlinear interactions among axial length, anterior-chamber depth, corneal curvature, and postoperative refraction. Hill et al. (2022) reported that the MAE with Hill-RBF 3.0 was 0.32 D, with 85–88% of eyes within ±0.50 D [6].

According to Cione et al. (2023), the EVO 2.0 model demonstrates similar accuracy (MAE = 0.30–0.35 D) [4]. The key advantage of these algorithms lies in their ability to self-learn and adapt to new datasets, including rare anatomic variations after RK.

2.5. Ray-tracing methods

Ray-tracing technology is based on physical modeling of light propagation through ocular media, allowing refractive power calculation without empirical coefficients.

It is implemented in dedicated software such as OKULIX, PhacoOptics, and Pentacam AXL Ray-Tracing. De Bernardo and Rosa (2022) demonstrated that ray-tracing provides a mean prediction error of 0.28–0.35 D and achieves accurate outcomes in up to 90% of post-RK eyes[9].

This method is particularly effective in cases of significant corneal irregularity or higher-order aberrations (HOAs), as it relies on actual topographic data and the individual optical profile of the eye. The main limitation is its dependence on image quality and the need for high-end tomographic equipment.

2.6. Comparative evaluation of modern formulas and methods

A comparative analysis of the performance of different IOL power calculation formulas and techniques in post-radial keratotomy eyes is presented in **Table 2.**

Errors in IOL power calculation in post-RK eyes can be significantly minimized through the use of modern formulas and AI-based algorithms. The Barrett True-K (Post-RK), Hill-RBF 3.0, EVO 2.0, and ray-tracing approaches demonstrate the highest accuracy, as they account for individual corneal morphology and improve prediction of the ELP.

These technologies achieve refractive results within ±0.50 D in 85–90% of cases, establishing them as the current gold standard for IOL power calculation in post-RK patients.

3. Factors influencing the accuracy of intraocular lens power calculation in patients after radial keratotomy

Even with the application of advanced formulas and high-precision biometry, the accuracy of IOL power calculation in post- RK eyes remains limited. This limitation arises from a variety of individual anatomical and technical factors that affect the measurement of ocular parameters [1, 6].

3.1. Number and depth of incisions

The greater the number and depth of radial incisions, the more pronounced the stromal deformation and corneal instability. De Bernardo and Rosa (2022) reported that with 16 incisions, the MAE reaches 0.6 D, while with 8–10 incisions it averages around 0.4 D. Deep cuts exceeding 85% of stromal thickness increase corneal sensitivity to intraocular pressure and diurnal changes [2, 9].

3.2. Optical zone diameter

After RK, the central optical zone usually does not exceed 3.0–4.0 mm, compared with approximately 6.0 mm after laser procedures. During measurement, this small zone often includes the peripheral cornea, where curvature is steeper, which leads to an artificial overestimation of K values and an IOL calculation error of 0.25–0.30 D [14]. Using TK data obtained from Scheimpflug or OCT tomography helps to reduce this inaccuracy.

3.3. Diurnal fluctuations and corneal shape instability

Hill et al. (2022) noted that most post-RK patients exhibit diurnal refractive variations of up to 1.0 D. Differences between morning and evening measurements may change the calculated IOL power by 0.3–0.4 D. Biometric measurements are therefore recommended in the afternoon, with averaging of repeated readings to minimize the influence of this factor [2, 6, 9].

3.4. Higher-order aberrations

Higher-order aberrations, such as coma and trefoil, are common after RK, especially in eyes with asymmetric incisions. Savini (2020) indicated that when RMS HOA exceeds 0.5 µm, calculation error increases by 0.2–0.3 D. In such cases, aspheric or extended depth-of-focus (EDOF) lenses are preferable, as they can partially compensate for aberrations.

3.5. Corneal thickness and rigidity

A thinned cornea (< 450 µm) has reduced biomechanical rigidity, making it more prone to deformation with changes in intraocular pressure [1]. Such biomechanical instability introduces an additional 0.1–0.2 D error into interferometric measurements.

3.6. Time since surgery and hyperopic drift

Rosa and De Bernardo (2023) observed a gradual hyperopic drift occurring 15–20 years after RK, at a rate of approximately +0.10 D per year, sometimes reaching a total of +2.0 D. Using old keratometry data without accounting for this effect leads to systematic IOL power overestimation.

3.7. Type of biometry device

Gettinger et al. (2024) compared IOLMaster 500 with Pentacam AXL and found that incorporating TK reduces mean error by approximately 0.15 D. Tomographic systems (Scheimpflug or OCT-based) are preferable in cases of irregular corneas, whereas interferometric systems (IOLMaster 500/700) provide high repeatability in relatively regular central zones [14].

3.8. Summary of influencing factors

The summarized effects of the main anatomical and optical parameters influencing the accuracy of IOL power calculation after RK are presented in **Table 3.**

Table 3. *Summary of anatomical and optical factors affecting IOL calculation accuracy after RK*

Factor	*Effect*	*Additional error (D)*	*Reference*
More than 12 incisions	Reduced rigidity and corneal stability	+0.3–0.4	De Bernardo (2022)
Optical zone < 3.5 mm	Overestimation of K values	+0.25–0.30	Cione (2023)
Diurnal fluctuations	Measurement variability	±0.5	Hill (2022)
HOA > 0.5 µm	Reduced accuracy	+0.2–0.3	Savini (2020)
Corneal thickness < 450 µm	Biomechanical instability	+0.1–0.2	Wang (2021)
More than 15 years after RK	Progressive hyperopic drift	+0.2–0.3	Rosa (2023)

Accuracy of IOL power calculation in post-RK patients depends on numerous anatomical and optical factors. The most significant influences include incision depth and number, optical zone diameter, time of day during measurement, corneal thickness, and the interval since surgery. Considering these parameters and employing modern tomographic methods significantly improves the predictability of refractive outcomes.

4. Promising technologies and new approaches to intraocular lens power calculation in patients after radial keratotomy

Despite significant advances in IOL power calculation formulas, the accuracy of refractive outcome prediction in post- RK patients remains limited. Classical models fail to account for the individualized geometric and optical characteristics of the cornea typical of post-RK eyes. Current research focuses on the implementation of physical-optics-based techniques, three-dimensional tomography, and artificial intelligence to personalize IOL power calculation and reduce systematic errors [1, 6].

4.1. Ray-tracing methods

Ray-tracing techniques simulate the propagation of light through all ocular optical surfaces, considering their shape, thickness, and refractive indices. Unlike empirical formulas, ray-tracing incorporates individual geometry of the anterior and posterior corneal surfaces, angle kappa, pupil decentration, and asphericity. De Bernardo and Rosa (2022) demonstrated that the use of ray-tracing systems such as OKULIX and Pentacam AXL Ray-Tracing reduces the MAE to 0.28–0.35 D, with up to 90% of eyes achieving refraction within ±0.5 D.

This approach is particularly valuable in cases of pronounced corneal irregularity but requires high-quality Scheimpflug or OCT tomographic data and remains costly to implement.

4.2. Three-dimensional tomography and Total Keratometry

The introduction of OCT- and Scheimpflug-based tomography (IOLMaster 700, Pentacam, Galilei G6) has enabled a shift from conventional keratometry to measurement of total corneal refractive power, known as TK. This method considers both anterior and posterior corneal curvatures, which is especially important in post-RK eyes where the normal relationship between the two surfaces is disrupted [8]. Wang and Koch (2021) reported that using TK improves IOL power prediction accuracy by approximately 0.15–0.20 D compared with standard keratometric measurements. Three-dimensional corneal data also allow for creation of individualized models suitable for ray-tracing-based IOL calculations.

4.3. Artificial intelligence and neural network algorithms

One of the most promising directions in post-RK IOL calculation is the application of AI and machine learning. Formulas such as Hill-RBF 3.0, EVO 2.0, Ladas Super Formula AI, and Barrett AI True-K use neural network models trained on tens of thousands of clinical cases, including post-RK eyes. Hill et al. (2022) showed that Hill-RBF 3.0 achieves a mean error of 0.32 D, with 85–88% of eyes within ±0.5 D. Cione et al. (2023) reported that EVO 2.0 demonstrates comparable performance, with MAE values of 0.30–0.35 D. These algorithms are capable of self-learning and continuously updating their internal parameters as new clinical data are collected, which is particularly valuable for rare post-RK cases [4, 6].

4.4. Hybrid and multi-formula approaches

Hybrid methods combine results from multiple formulas and select the optimal value using a median-based principle. Cione and D’Ambrosio (2023) described a multi-formula approach integrating Barrett True-K, Shammas, and ray-tracing results, which increased the proportion of eyes achieving accurate refractive outcomes to 85–90% [4, 10, 13]. Such hybrid models are implemented in platforms like OKULIX Pro, Zeiss Veracity Planner, and Alcon Veracity AI, where automatic calculations are performed with real-time reliability scoring.

4.5. Personalized calculation algorithms

The next step in evolution involves developing personalized models that take into account individual ocular parameters such as corneal asphericity, pachymetry, pupil diameter, higher-order aberrations, and even patient visual preferences. Based on these data, systems such as Barrett AI True-K Personalized and Alcon Clarity Cloud generate optimal IOL models with predicted residual refraction [5].

4.6. The future: self-learning and cloud-integrated systems

Current trends aim toward integration of biometric devices with cloud-based databases.

Each new surgical case becomes part of the learning dataset, enabling continuous improvement of predictive models [16]. This concept is implemented in projects such as Zeiss Veracity AI and Alcon Precision Cloud, where neural networks compare calculated and actual postoperative results, dynamically adjusting formulas for specific patient populations.

The future of IOL power calculation in post-RK eyes lies in the implementation of ray-tracing, three-dimensional tomography, and artificial intelligence technologies, which allow for individualization of calculations and minimization of prediction errors. Transition to hybrid and personalized algorithms that integrate biometric, aberrometric, and AI-based analytics forms the foundation of personalized ophthalmic surgery, where IOL power calculation becomes a modeling process rather than an empirical estimation.

Conclusion

Calculation of IOL power in patients after RK remains one of the most challenging tasks in contemporary ophthalmic surgery. Multiple biomechanical, optical, and morphological alterations of the cornea induced by RK disrupt the normal relationship between the anterior and posterior surfaces and lead to errors in measuring its true refractive power. According to Wang and Koch (2021) and Savini and Hoffer (2020), even with advanced keratometric techniques, the MAE in post-RK eyes remains within 0.40–0.60 D – significantly higher than that observed in post-LASIK or PRK patients. The main sources of error include inaccurate assessment of corneal curvature, imprecise estimation of the ELP, diurnal variations in corneal shape, and long-term hyperopic drift that develops years after the original surgery. Modern calculation formulas such as Barrett True-K (Post-RK), Haigis-L, and Shammas-PL, as well as neural-network algorithms like Hill-RBF 3.0 and EVO 2.0, have substantially improved accuracy. Nevertheless, only ray-tracing methods and models based on TK can fully account for the individualized corneal geometry and achieve precision within ±0.35 D [2, 9]. The key direction of future progress lies in the integration of artificial intelligence and personalized, self-learning algorithms capable of adapting to individual patient characteristics. Combining biometric, topographic, and aberrometric data with neural-network–based computation establishes the foundation for a new paradigm – personalized ophthalmic surgery – in which IOL selection is guided not by generalized formulas but by individualized optical modeling of the patient's eye. Thus, improving IOL power calculation methods in post-RK patients requires a comprehensive approach that integrates 3D tomography, TK, ray-tracing, and artificial intelligence technologies. Such an approach paves the way for enhanced refractive prediction accuracy and improved visual quality in this complex patient population.

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