



Evaluating the Predictive Accuracy of the Kane and SRK/T Formulas in Keratoconus Patients Undergoing Cataract Surgery

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Abstract

Objectives: To compare the predictive performance of the SRK/T and Kane formulas in eyes with keratoconus undergoing cataract surgery.

Materials and Methods: A consecutive series of keratoconic eyes that underwent cataract surgery were retrospectively analyzed. Intraocular lens power was calculated using the SRK/T and Kane Keratoconus formulas. Subjective refraction was evaluated 1 month postoperatively. The mean prediction error (MPE) and percentage of eyes with a prediction error within ± 0.50 diopters (D) and ± 1.00 D were calculated. Patients were divided into two categories: early-stage (stage 1) and advanced-stage (stage 2-3) keratoconus.

Results: Thirty eyes of 25 patients were included in the study. A comparison of MPE between the two formulas in the stage 1 keratoconus group revealed no statistical difference. However, the MPE for the SRK/T formula was found to be significantly higher ($p=0.005$) in the stage 2-3 group. In the stage 1 group, 84.6% of eyes were within the PE range of ± 1.00 D based on the Kane formula, while 76.9% of eyes fell within the ± 1.00 D range according to the SRK/T formula. In stage 2-3 group, 41.2% of eyes were within the PE range of ± 1.00 D based on the Kane formula, while 29.4% of eyes fell within the ± 1.00 D range according to the SRK/T formula.

Conclusion: A comparison of the two formulas showed no statistically significant differences in early-stage keratoconus. However, in advanced keratoconus cases, the Kane formula exhibited superior accuracy.

Keywords: Cataract surgery, Kane formula, keratoconus, optical biometry, SRK/T formula

Introduction

Keratoconus is a progressive corneal disorder that manifests with thinning of the cornea and the formation of a cone-shaped protrusion, resulting in a deterioration of visual acuity.¹ While early-stage management options (such as contact lenses and corneal cross-linking) can be effective in stabilizing the condition, advanced cases may require surgical intervention, including corneal transplantation.² Cataract formation also becomes increasingly common with age in patients with keratoconus, but performing cataract surgery in these individuals presents a significant challenge due to the difficulty in accurately predicting refractive outcomes.^{3,4}

The efficacy of cataract surgery is contingent on the selection of an appropriate intraocular lens (IOL). However, corneal irregularities and limitations in biometric measurements in keratoconic eyes create significant challenges in this process.^{5,6} Accordingly, selecting the most appropriate biometric formula is crucial to achieving optimal refractive results after cataract surgery on keratoconic eyes. Several formulas are commonly used for IOL power calculations, including SRK/T, Holladay, Haigis, and Kane.⁷ While the SRK/T formula is widely utilized, particularly in longer eyes, hyperopic deviations have been noted in eyes with keratoconus.⁸ The Kane formula is a more recent advancement reported to provide superior accuracy in cases with irregular corneal morphology.⁹

The purpose of this study was to evaluate the refractive outcomes of cataract surgery in eyes with keratoconus and to compare the performances of the SRK/T and Kane formulas in IOL power calculation. There remains limited comparative data on these formulas in advanced keratoconus. The present study

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Preliminary results of this study were presented as an oral presentation at the 58th TOA National Congress (November 20-24, 2024).

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aims to address this literature gap and thereby provide clinicians with guidance to improve the refractive success rate of cataract surgery in patients with keratoconus.

Materials and Methods

A retrospective analysis was performed with consecutive keratoconus patients who underwent cataract surgery at University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital between January 2022 and December 2024. Patients were included if corneal specialists diagnosed them with keratoconus based on corneal tomography findings (Sirius+, C.S.O., Florence, Italy). The exclusion criteria comprised a prior history of intraocular surgery, corneal scarring, intraoperative or postoperative complications, and postoperative spectacle-corrected visual acuity below 20/40. The study received approval from the University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Scientific Research Ethics Committee (protocol code: 2025-32, decision no: 32, date: 29.01.2025), and all participants provided written informed consent in compliance with the ethical principles outlined in the Helsinki Declaration.

A subsequent analysis was conducted to categorize patients based on keratoconus severity, according to the classification criteria defined by Krumeich et al.¹⁰ Eyes were designated as stage 1 if their maximum keratometry was less than or equal to 48 diopters (D), stage 2 if it ranged between 48 D and 53 D, and stage 3 if it exceeded 53 D. Because of the limited number of cases, patients with stage 2 and stage 3 keratoconus were combined and analyzed as a single group. For further evaluation, patients were classified as early stage (stage 1) and advanced stage (stages 2 and 3).

All patients underwent preoperative IOL power calculations using the same optical biometer (OA-2000, Tomey Corporation, Nagoya, Japan). In all cases, IOL power was selected as the closest myopic value to emmetropia according to the SRK/T formula. Standard phacoemulsification surgery with a temporal main incision was performed by experienced surgeons, and all patients received a one-piece hydrophobic acrylic IOL (Enova, VSY Biotechnology, Leinfelden-Echterdingen, Germany) with no additional astigmatism-correcting procedures performed. Postoperatively, all patients were treated with topical steroids and antibiotics.

Optical biometry was utilized to calculate the SRK/T formula, while the Kane keratoconus formula was computed using the Kane online calculator (<https://www.iolformula.com>). In both formulas, the IOL power was selected as the nearest myopic value to emmetropia. Prediction errors were calculated by subtracting the expected postoperative refraction from the spherical equivalent measured 1 month after surgery. For each formula, the mean absolute prediction error (MAPE), the mean prediction error (MPE), the median absolute prediction error, and the standard deviation of prediction error were determined. Furthermore, the percentage of eyes with prediction errors within ± 0.50 D and ± 1.00 D was assessed for each formula.

Statistical Analysis

Statistical analysis was performed using SPSS 22.0 for Windows (IBM Corp., Armonk, NY, USA). The normality of the data distribution was assessed using the Kolmogorov-Smirnov test and histogram analysis. Descriptive data were presented as mean $\pm$ standard deviation. Differences between dependent variables were analyzed using the Wilcoxon rank test. A p value of less than 0.05 was considered statistically significant.

Results

The study included a total of 30 eyes from 25 patients. The mean age was 61.2 ± 11.4 years (range, 39 to 82) and 17 (68%) patients were female. The mean postoperative spherical equivalent was -0.79 ± 1.70 D (range, -6.25 to +3.25). In accordance with the modified Krumeich classification scheme, 13 eyes were categorized as stage 1 and 17 eyes were classified as stage 2 or 3. The demographics of the study cohort are presented in [Table 1](#).

The mean values for the selected IOLs according to the Kane formula and the SRK/T formula were 20.45 ± 2.21 D (range, 16.50 to 24.00) and 20.21 ± 2.24 D (range, 16.50 to 23.50) in stage 1 eyes and 18.50 ± 4.70 D (range, 11.50 to 26.00) and 17.61 ± 5.00 D (range, 9.00 to 25.00) in stage 2-3 eyes, respectively. In stage 1 keratoconus, no significant difference was observed between the SRK/T and Kane formulas with respect to mean IOL power. However, in stage 2-3 keratoconus, the mean IOL power selected according to the SRK/T formula was significantly lower ($p=0.007$).

The prediction error for each group is displayed in [Table 2](#). In the stage 1 keratoconus group, the MPE and MAPE were comparable across the two formulas. An analysis of the stage 2-3 keratoconus group revealed a hyperopic shift when using the SRK/T formula. The MPE was found to be more

Table 1. Demographic and ocular data of the patients according to keratoconus stage

	Stage 1 (n=13)	Stage 2-3 (n=17)
Age (years)	63.8 ± 12.3 (39 to 78)	59.2 ± 10.7 (46 to 82)
Gender (female), n (%)	9 (69.2)	11 (64.7)
Postoperative SE (D)	-0.38 ± 1.47 (-2.75 to +1.25)	-1.12 ± 1.85 (-6.25 to +3.25)
K1 (D)	42.81 ± 1.51 (40.23 to 45.07)	46.40 ± 2.15 (42.59 to 57.76)
K2 (D)	45.39 ± 1.40 (41.53 to 47.83)	49.36 ± 3.33 (44.71 to 59.31)
ACD (mm)	3.29 ± 0.44 (2.67 to 4.04)	3.26 ± 0.55 (2.74 to 4.21)
Axial length (mm)	23.63 ± 0.56 (21.89 to 26.59)	22.63 ± 1.30 (21.65 to 28.81)

D: Diopters, SE: Spherical equivalent, K1: Flat keratometry value, K2: Steep keratometry value, ACD: Anterior chamber depth

hyperopic with the SRK/T formula compared to the Kane formula ($p=0.005$). However, the MAPE was comparable across the two formulas in stage 2-3 keratoconus. Among all cases, 12 eyes (40%) fell within the prediction error range of ± 0.50 D based on the Kane formula, while 9 eyes (30%) fell within the ± 0.50 D range based on the SRK/T formula. For the error range of ± 1.00 D, these values were 18 eyes (60%) and 15 eyes (50%), respectively. The rates of prediction error within ± 0.50 D and ± 1.00 D according to keratoconus stage are presented in Table 3.

Discussion

The IOL power calculation process is considerably less accurate in eyes with keratoconus than in normal eyes, and most existing formulas typically lead to hyperopic refractive results in these patients.^{3,11,12,13,14,15} In this study, we compared the SRK/T formula, an older formula that has been reported as yielding favorable outcomes in keratoconus cases, with the newer Kane formula, which has also shown superior results in patients with keratoconus.^{9,11,12}

Previous studies have indicated that of the conventional formulas, the SRK/T formula demonstrates the highest accuracy in keratoconic eyes, with MPE and MAPE ranging from $+0.22$ to $+0.91$ D and from 0.47 to 1.00 D, respectively.^{3,11,12} Recent studies have documented that the MPE and the MAPE of the Kane formula range from -0.28 D to $+0.22$ D and from 0.49 D to 0.92 D, respectively.^{9,15,16} In a study by Kane et al.⁹, the MPE in eyes with stage 1 keratoconus was found to be -0.18 D and -0.23 D with the Kane and SRK/T formulas, respectively. In stages 2 and 3 keratoconus respectively, MPEs were 0.53

and 0.02 according to the Kane formula.⁹ Consistent with their findings, our stage 2-3 group also had MPE values within this range. Using the SRK-T formula, Kane et al.⁹ reported MPE values of 0.51 and 1.86 in the stage 2 and stage 3 keratoconus groups, respectively. In the present study, the MPE for the stage 2-3 group was 0.79 , again aligning with earlier established values.

In a study by Yokogawa et al.¹⁶, the Kane formula resulted in greater hyperopic outcomes in the stage 1 group, with a MPE of $+0.68 \pm 0.87$ D; in contrast, the SRK/T formula demonstrated a closer alignment with emmetropia in the same group, yielding an MPE of $+0.23 \pm 1.18$ D. One potential explanation for this finding is that the mean keratometry values of the patient cohort were slightly higher, as acknowledged in the article. Furthermore, after comprehensive evaluation of all cases in the study, the authors reported that the Kane formula yielded more successful results than the SRK/T formula.¹⁶

The superior performance of the SRK/T formula in keratoconus cases relative to other older-generation formulas is hypothesized to result from its tendency to overestimate IOL power in steep corneas, as evidenced in the study by Melles et al.¹⁷ This overestimation is believed to compensate for the hyperopic shift observed in most formulas in keratoconus patients.¹² In this context, the Kane keratoconus formula utilizes a modified corneal power that is based on the anterior corneal radius of curvature, offering a more accurate representation of the anterior/posterior ratio in eyes affected by keratoconus.⁹ Additionally, it reduces the impact of corneal power on the effective lens position calculation, leading to more precise estimates.

Study Limitations

The most significant limitation of our study is the single-center design and relatively small sample compared to those in the multicenter studies that dominate the literature on IOL calculations for patients with keratoconus. In addition, due to the limited number of patients with either stage 2 or stage 3 keratoconus, these cases were assessed collectively in this study. Furthermore, although the follow-up period lasted at least 1 month and the surgery was performed on patients with stable keratoconus, refractive stability may continue to improve for up to 6 months postoperatively, particularly in eyes with thin corneas affected by keratoconus.¹⁸

However, this study is distinct from multicenter studies in its use of a singular optical biometer and IOL across all patients, a feature that contributes to its methodological strength.

Conclusion

In the early stages of keratoconus, no significant differences were observed between the Kane and SRK/T formulas, and residual refraction showed comparable characteristics. In advanced stages of keratoconus, the Kane formula demonstrated significant alignment toward emmetropia, whereas the SRK/T formula tended to induce a hyperopic shift. It is imperative that future prospective studies include greater numbers of participants and patients with severe keratoconus in particular,

Table 2. The prediction error of the two formulas according to keratoconus stage

Formula	MAPE	MPE	STDEV	MedAPE
Stage 1				
Kane (D)	0.86	-0.04	1.20	0.55
SRK/T (D)	1.00	0.14	1.32	0.75
Stage 2-3				
Kane (D)	1.32	0.24	1.73	1.12
SRK/T (D)	1.51	0.79	1.67	1.27

D: Diopters, MAPE: Mean absolute prediction error, MPE: Mean prediction error, STDEV: Standard deviation of the prediction error, MedAPE: Median absolute prediction error

Table 3. Percentages of eyes with prediction error within ± 0.50 and ± 1.00 D according to keratoconus stage

	Stage 1 (n=13)		Stage 2-3 (n=17)	
	± 0.50 D	± 1.00 D	± 0.50 D	± 1.00 D
Kane	53.8%	84.6%	29.4%	41.2%
SRK/T	46.2%	76.9%	17.6%	29.4%
p value	1.000	1.000	0.688	0.720

D: Diopters

so as to more accurately assess the predictive capabilities of the formulas in these challenging cases.

Ethics

Ethics Committee Approval: The study received approval from the University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Scientific Research Ethics Committee (protocol code: 2025-32, decision no: 32, date: 29.01.2025).

Informed Consent: All participants provided written informed consent in compliance with the ethical principles outlined in the Helsinki Declaration.

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Declarations

Authorship Contributions

Surgical and Medical Practices: Y.B.A., F.O.A., A.C., Y.Y., Concept: Y.B.A., B.K.Y., A.C., Design: Y.B.A., H.D., B.K.Y., Data Collection or Processing: H.D., F.O.A., Analysis or Interpretation: B.K.Y., Y.Y., F.O.A., Literature Search: Y.B.A., A.C., Y.Y., H.D., Writing: Y.B.A., H.D., F.O.A., A.C., B.K.Y., Y.Y.

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