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Original Article

Comparing Predictability of SRK/T, Barrett Universal II, and Kane Formulas on High Myopia Phacoemulsification

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ABSTRACT

Introduction: The refractive outcomes of phacoemulsification surgery have improved significantly in recent years, but it is still challenging to obtain good outcomes in eyes with long axial lengths. This study compares the difference between the predicted and manifest refraction outcomes between Sanders Retzlaff Kraff theoretical (SRK/T), Barrett Universal II (BU-II), and Kane formula in high myopia patients undergoing uncomplicated phacoemulsification surgery. Methods: This cross-sectional design study includes eyes with high myopia (axial length ≥26.0 mm) that undergo uncomplicated phacoemulsification surgery with intraocular lens implantation between January 2024 and January 2025 at Semarang Tertiary Hospital. The one-month post-surgery mean absolute prediction errors (MAE) difference between SRK/T, BU-II, and Kane formula are calculated and analyzed using the Wilcoxon Sign Rank Test. Result: Thirty-seven eyes meeting the criteria were analyzed, with a mean axial length of 29.07±2.42 mm. The MAE and percentages of eyes within 0.50 diopters (D) refractive prediction errors of the three formulas are as follows: SRK/T (0.68 D, 60%), BU-II (0.41 D, 73%), and Kane (0.37 D, 76%). There is a statistically significant difference in MAE between SRK/T vs BU-II ($p < 0.05$) and SRK/T vs Kane ($p < 0.05$). Conclusion: The Kane and BU-II formula has better accuracy in predicting refractive outcome (lower MAE and higher percentages of eyes within 0.5 D refractive prediction errors) than the SRK/T formula in patients with high myopia who undergo uncomplicated phacoemulsification surgery.

Introduction

High myopia, as defined by an axial length (AL) exceeding 26 mm or a refractive error of at least −6 diopters (D), represents a significant portion of refractive errors worldwide.[1] High myopia affected approximately 4% of the global population in 2010, a figure anticipated to rise to 10% (925 million people) by 2050.[2] This condition is not merely a matter of increased refractive power. However, it is frequently associated with a higher prevalence of other ocular conditions, including a notably elevated risk and accelerated progression of cataract development.[3,4] The anatomical characteristics of these eyes, such as exceptionally long axial lengths, often deeper anterior chambers, and the frequent presence of posterior staphyloma, can significantly impact the predictability of the effective lens position (ELP) that are primary contributors to inaccuracies in intraocular lens (IOL) power calculation.[5]

For decades, third-generation formulas, such as the Sanders-Retzlaff-Kraff/Theoretical (SRK/T) formula, have been widely used. The SRK/T formula, a regression-based formula utilizing AL and keratometry (K) readings, incorporates a theoretical framework to estimate the effective lens position (ELP) and has been a mainstay in clinical practice. While generally reliable for average eyes, its accuracy can diminish in eyes with very long axial lengths.[5–7]

More contemporary formulas have been developed to address these limitations. The Barrett Universal II (BU-II) formula is a vergence formula that uses AL, K, anterior chamber depth (ACD), lens thickness (LT), and white-to-white (WTW) distance as optional input parameters. It aims to provide a more accurate ELP prediction by considering the IOL's principal plane of refraction through a "lens factor". It is designed for accuracy across a wide range of axial lengths.[8]

Recently, newer generation formulas incorporating artificial intelligence (AI) and large datasets have emerged. The Kane formula is one such example, which combines theoretical optics with AI and regression analysis, utilizing data from a vast number of cases to refine its predictions. It typically uses AL, K, ACD, and patient biological sex as compulsory inputs, with optional parameters including LT and central corneal thickness (CCT). The Kane formula has shown particular promise in eyes with non-average biometry, including those with long axial lengths, by leveraging its extensive dataset and sophisticated algorithms.[9]

The current literature indicates ongoing evolution in IOL power calculation formulas, with newer methods promising improved accuracy in challenging cases such as high myopia. Therefore, the primary objective of this study was to compare the predictive accuracy, as measured by the mean absolute error, of the SRK/T, BU- II, and Kane formulas in patients with high myopia undergoing phacoemulsification surgery at Semarang Tertiary Hospital. Secondary objectives included comparing the proportion of eyes achieving postoperative refractive outcomes within ±0.25 D, ±0.50 D, and ±1.00 D of the target refraction for each formula.

Method

This study was an analytical observational investigation employing a retrospective, cross-sectional design. This approach to data collection, spanning from January 2024 to January 2025 at Semarang Tertiary Hospital, from high myopia patients (AL ≥26.0 mm) undergoing phacoemulsification surgery. Data, including biometric measurements and postoperative outcomes, as well as details of the implanted IOL power, were obtained from the patient's medical records. All surgeries were performed by three experienced attending surgeons utilizing standardized phacoemulsification techniques. The one-month postoperative endpoint was chosen to ensure the stability of the final refractive outcome, as the eye typically stabilizes from surgically induced inflammation and early corneal changes by this time point.[5,7,10]

The study's inclusion criteria comprised patients who underwent phacoemulsification with in-the-bag IOL implantation, had valid biometric eye measurement data obtained via the IOL Master 500 or 700, documented records of the implanted IOL power, and completed a follow-up visit one month postoperatively. The study's exclusion criteria included patients with a history of previous corneal or intraocular surgery, those experiencing intraoperative and postoperative complications that affected refractive outcomes, individuals with central corneal abnormalities, patients with macular disorders, patients with retinal traction, and those with a history of glaucoma.

This study's data encompasses demographic information, including age and gender, as well as biometric measurements of the eye, such as preoperative axial length (AL) in mm, anterior chamber depth (ACD) in mm, flat keratometry (K1) in D, steep keratometry (K2) in D, and white to white (WTW) in mm. Additionally, it includes implanted IOL power in D from medical records, refractive prediction calculations using the SRK/T, BU-II, and Kane formulas, and the patient's manifest refractive spherical equivalent (SE) in D one month post-surgery. High myopia is defined as an axial length of 26 mm or more. The axial length is determined from the corneal apex to the retina utilising the IOL Master 500 or 700 biometry systems. Refractive outcomes are assessed one month post-surgery using the best corrected visual acuity, with the SE value determined by adding the patient's spherical value to half of the cylindrical value. Prediction error (PE) are calculated as manifest postoperative SE minus the predicted postoperative SE. Absolute error (AE) is the absolute value of the PE (AE = |PE|). The Mean Absolute Prediction Error (MAE) represents the arithmetic mean of the absolute errors for each formula. This was the primary outcome measure for comparing formula accuracy. This study analyses the differences in refractive predictions among the SRK/T formula, BU-II formula, and Kane formula, in relation to the patient's spherical equivalent one month postoperatively.

To minimize selection bias, all consecutive patients who meet the inclusion criteria during the study period will be included.

Gender as potential confounding factor are explored by using subgroup analysis. Statistical analyses were conducted utilizing IBM SPSS Statistics 26 software. Only eyes with complete data for all variables required for the calculation of prediction error were included in the final analysis. Eyes with any missing data for these key variables were excluded. Numeric variables are presented as means and standard deviations (SD), whereas categorical variables are expressed as counts and percentages. The

Mann-Whitney test is used to determine whether the differences in refractive predictions and final refractive outcomes for each formula by gender are statistically significant. The Shapiro-Wilk test is utilized to assess data normality. The Wilcoxon Signed-Rank test assesses whether the differences between refractive predictions and final refractive outcomes in patients using various formulas are statistically significant ($p<0.05$).

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Results and Discussion

Results

A total of 37 eyes from 24 patients who satisfied all inclusion and exclusion criteria were enrolled and analyzed in this study. The demographic and baseline preoperative ocular characteristics of the study participants are presented in Table 1. The average age of the patients was 44.40 ± 10.74 years, with a range from 28 to 62 years. The cohort consisted of 9 male patients (37.5%) and 15 female patients (62.5%).

To determine whether gender can be a confounding factor, an analysis of the differences in refractive prediction accuracy between males and females was conducted. To assess the normality of the distribution of prediction errors for each formula, the Shapiro-Wilk test was conducted. At least one of the male or female groups of prediction errors of each formula was not normally distributed (male SRK/T: $p = 0.41$; female SRK/T $p < 0.05$; male BU-II $p = 0.17$; female BU-II $p = 0.66$; male Kane $p < 0.05$; female Kane $p < 0.05$). This finding justified the use of Mann-Whitney tests for comparing the MAEs between gender for each formula. There was no statistically significant difference in MAE between male and female groups for each formula (SRK/T: $p = 0.13$; BU-II: $p = 0.48$; Kane: $p = 0.82$).

In terms of eye distribution, 19 participants (51.35%) had right eyes, while 18 participants (48.65%) had left eyes. The mean axial length (AL) of the study eyes was 29.07±2.42 mm, ranging from 26.03 mm to 35.00 mm, thereby confirming the high myopia status of the cohort. The average implanted intraocular lens (IOL) power was 4.82±5.43 D, with a range from -7.00 D to 13.00 D, indicating the generally low or negative IOL powers needed for highly myopic eyes. Additional biometric parameters are presented in Table 1.

The refractive prediction accuracy metrics for the SRK/T, BU-II, and Kane formulas are presented in Table 2. The Kane formula achieved the lowest MAE (0.37±0.35 D), followed by the BU-II formula (0.41±0.37 D), and then the SRK/T formula (0.68±0.66 D). A similar trend was observed for the MedAE, with the Kane formula yielding the lowest MedAE (0.28 D), followed by BU-II (0.34 D) and SRK/T (0.45 D).

The Kane formula demonstrated the highest accuracy regarding the percentage of eyes within specific refractive prediction error ranges. Specifically, 48.6% of eyes were within ±0.25 D of the predicted refraction with the Kane formula, compared to 37.8% with BU-II and 29.7% with SRK/T. For the ±0.50 D target, the percentages were 75.7% for Kane, 73.0% for BU-II, and 59.5% for SRK/T. For the ±1.00 D target, the percentages were 97.3% for Kane, 94.6% for BU-II, and 67.6% for SRK/T.

The Shapiro-Wilk test was used to assess the normality of the distribution of prediction errors for each formula. The results indicated that the prediction errors for all three formulas were not normally distributed (SRK/T: $p < 0.05$; BU-II: $p < 0.05$; Kane: $p < 0.05$). This finding justified the use of non-parametric tests for comparing the MAEs (See table 1).

The Wilcoxon Signed-Rank Test was performed to compare the MAEs between the formulas. The MAE of the SRK/T formula was statistically significantly higher than that of the BU-II formula ($p < 0.05$). The MAE of the SRK/T formula was statistically significantly higher than that of the Kane formula ($p < 0.05$). There was no statistically significant difference in MAE between the BU-II formula and the Kane formula ($p = 0.14$).

Although the Kane formula exhibited a numerically lower MAE (0.37 D) compared to the BU-II formula (0.41 D), this difference of 0.04 D did not reach statistical significance with the current sample size. This suggests that while a trend towards better performance with the Kane formula exists, both the Kane and BU-II formulas provide a comparably high level of accuracy that is significantly superior to SRK/T. However, the clinical impact of achieving a higher percentage of eyes within the tightest error margin of ±0.25 D (Kane: 49% vs. BU-II: 38%) may be noteworthy for patients and surgeons aiming for the most precise refractive outcomes

Table 1. Patients Demographics and Characteristic

Characteristic	Value	P Value
Number of Patients	24	
Gender		0,13*
Male, n (%)	9 (37.5%)	0.48**
Female, n (%)	15 (62.5%)	0.82***
Age (years), Mean ± SD (Range)	44.40±10.74 (28 - 62)	
Number of Eyes	37	
Right Eye, n (%)	19 (51.35%)	
Left Eye, n (%)	18 (48.65%)	
Axial Length (AL) (mm), Mean ± SD (Range)	29.07±2.42 (26.03 - 35.00)	
Flat Keratometry (K1) (D), Mean ± SD (Range)	43.88±1.24 (41.79 - 46.81)	
Steep Keratometry (K2) (D), Mean ± SD (Range)	45.06±1.50 (42.43 - 48.35)	
Mean Keratometry (Km) (D), Mean ± SD	44.47±1.29	
Anterior Chamber Depth (ACD) (mm), Mean ± SD (Range)	3.60±0.29 (2.78 - 4.06)	
White to White (mm), Mean ± SD (Range)	12.16±0.45 (11.4 - 13.6)	
Implanted IOL Power (D), Mean ± SD (Range)	4.82±5.43 (-7.00 - 13.00)	

[a]Mann-Whitney test (*SRK/T; **BU-II; ***Kane; significant if p<0.05)

Ophthalmologica Indonesiana
Vol. 52 No. 1 2026, 27-34

Table 2. Comparison of Refractive Prediction Accuracy Metrics for SRK/T, BU-II, and Kane Formulas

Accuracy Metric	SRK/T	BU-II	Kane
Mean Absolute Error (MAE) ± SD (D)	0.68±0.66	0.41±0.37	0.37±0.35
Median Absolute Error (MedAE) (D)	0.45	0.34	0.28
Eyes with AE ≤±0.25 D, n (%)	11 (29.7%)	14 (37.8%)	18 (48.6%)
Eyes with AE ≤±0.50 D, n (%)	22 (59.5%)	27 (73.0%)	28 (75.7%)
Eyes with AE ≤±1.00 D, n (%)	25 (67.6%)	35 (94.6%)	36 (97.3%)

Discussion

The principal finding of this study is that in patients with high myopia (AL ≥ 26.0 mm) undergoing uncomplicated phacoemulsification, the Kane and BU-II formulas demonstrated significantly better refractive prediction accuracy compared to SRK/T formula. The superior performance of the Kane and BU-II formulas is likely attributable to their more sophisticated approaches to estimating ELP. ELP is a critical determinant of postoperative refraction and is notoriously challenging to predict accurately, especially in eyes with non-standard anatomical dimensions such as long axial lengths.[7] The BU-II formula utilizes five biometric parameters (AL, K, ACD, LT, WTW) to model the eye and predict ELP, offering a more comprehensive assessment than the two primary variables (AL and K) used by the SRK/T formula.[11] The Kane formula further advances this by employing a hybrid model that combines theoretical optics with artificial intelligence and "big data" techniques, using AL, K, ACD, and gender as core inputs, with optional parameters like LT and CCT, to refine its predictions.[9]

The consistent outperformance of the SRK/T formula by both the BU-II and Kane formulas in this study strongly suggests that the incorporation of additional biometric parameters and/or more sophisticated modelling algorithms, including AI, is pivotal for addressing the anatomical complexities in long eyes. While the SRK/T formula was a significant advancement and remains a useful tool, its accuracy may be limited in these extreme cases.[5,7]

Our results are consistent with a growing body of literature demonstrating the enhanced accuracy of newer-generation IOL formulas in challenging cases, such as high myopia. Several studies have reported that formulas like BU-II and Kane outperform older formulas such as SRK/T in eyes with long axial lengths. For instance, a study comparing multiple formulas in high axial myopia found that Kane and EVO 2.0 achieved better results than SRK/T and BU-II, though BU-II also performed well.[12]

Similarly, research focusing on extremely long eyes (AL ≥ 29.0 mm) indicated that the Kane, BU-II, EVO 2.0, and Olsen formulas were comparable and significantly more accurate than the SRK/T formula.12 A systematic review and network meta-analysis also suggested that AI-based formulas, including Kane, tend to offer higher accuracy in highly myopic eyes compared to traditional vergence formulas.[14]

When comparing the Kane and BU-II formulas, the Kane formula showed a numerically lower MAE (0.37 D vs. 0.41 D) and a notably higher percentage of eyes achieving a refractive outcome within ±0.25 D of target (48.6% vs. 37.8%). However, the difference in MAE between these two leading formulas did not reach statistical significance (p=0.140). This outcome is not uncommon in comparative studies of modern, high-performing IOL formulas, where incremental improvements may require substantially larger sample sizes to demonstrate statistical significance for all metrics. The results for the Kane formula are consistent with a growing body of literature highlighting its robust accuracy, often positioning it as one of the most precise formulas available, particularly in eyes with atypical biometry.[9,11]

Strengths of this study include its dedicated focus on a challenging cohort of patients with high myopia, the direct comparison of a widely used traditional formula with two contemporary formulas — one of which incorporates artificial intelligence and the use of a standardized one-month postoperative refraction assessment protocol. Despite its strengths, this study has several limitations. While the sample of 37 eyes was sufficient to detect significant differences between SRK/T and the newer formulas, it might have been underpowered to reveal a statistically significant difference in MAE between the Kane and BU-II formulas. The findings originate from a single tertiary referral hospital. While this ensures consistency in surgical and assessment protocols, it may limit the generalizability of the results to other healthcare settings with varying biometry equipment or different surgical practices. Further study in multicentered settings with larger samples would offer a better chance to detect significant differences in MAE of newer formulas and broader applicability.

Conclusion

In patients with high myopia (axial length ≥26.0mm) undergoing phacoemulsification, the Kane and BU-II formulas demonstrate significantly superior predictive accuracy compared to the SRK/T formula. Both Kane and BU-II formulas offer comparable overall accuracy (p=0.14), with Kane yielding a numerically lower mean absolute error and the highest proportion of eyes achieving refractive outcomes within the highly precise ±0.25 D of target refraction. These findings strongly support the preferential use of newer generation formulas, specifically Kane and BU-II, for IOL power calculation in highly myopic eyes over the SRK/T formula.

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Ophthalmologica Indonesiana
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