Comparison of SRK/T and Haigis formulae in the prediction of refractive outcome after phacoemulsification

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Purpose To compare the accuracy of SRK/T and Haigis formulae used for intraocular lens (IOL) power calculation by a partial coherence interferometer in patients undergoing phacoemulsification surgery.

Patients and methods A prospective interventional clinical study included 70 eyes of 60 patients, who underwent uncomplicated phacoemulsification with IOL implantation from October 2015 to December 2017. Preoperative axial length (AL), corneal curvature (keratometry), and preoperative anterior chamber depth (preoperative ACD) were measured using Nidek AL-scan optical biometer and the IOL power was determined using both SRK/T and Haigis formulae. The difference between the predicted value and the postoperative spherical equivalent was calculated for both the formulae by the end of the follow-up (3 months postoperatively).

Results The mean errors of the two formulae were SRK/T: −0.225±0.61 D and Haigis: 0.171±0.68 D; the mean absolute errors of the two formulae were 0.534±0.36 and 0.533±0.44 D, respectively. There was no statistically significant difference between the mean error of the two formulas used in the overall performance, but was significant in eyes with an AL of more than 25 mm. The proportion of patients having a prediction error within ±0.50 D of SRK/T formula (54.29%) was comparable to those of Haigis (55.71%) and the prediction errors within ±1.0 D were 87.14 and 85.71%, respectively. There is a weak correlation between the mean AL, keratometry and the Haigis–SRK/T prediction differences (r^2=0.273).

Conclusion The calculation of IOL power using SRK/T and Haigis formulae resulted in an accurate postoperative refraction. In long AL subcategory, the mean absolute error of Haigis was less compared with the SRK/T formula.
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Introduction

Accurate biometry is essential for achieving good surgical outcomes and patient satisfaction after cataract surgery. High-accuracy technologies for ocular axial length (AL) measurements using partial coherence interferometry, along with precise keratometry, and the new prediction formulae have provided improvements on IOL calculation [1].

Formulae for IOL power calculation had past four generations, the first generation formulae were theoretical and based on the same fundamental constant with no respect to anterior chamber depth (ACD). The second generation was designed by combining linear regression analysis and stepwise adjustment for long and short eyes according to ACD [2].

Third-generation formulas, such as the Hoffer Q, Holladay 1, and SRK/T recognize that postoperative ACD varies with AL and corneal curvature [3]. The Haigis formula, a fourth-generation formula, uses three constants to calculate the effective lens position. It takes into account the preoperative ACD and uses three constants (a0, a1, and a2), which are analogous to surgeon factor, ACD and AL, respectively.

Different studies to evaluate the predictive accuracy of various IOL power calculation formulae with different results [4,5].

This study was conducted to evaluate the accuracy of the SRK/T and Haigis formulae for IOL power calculation in patients undergoing cataract surgery in eyes with different ALs.

Patients and methods

A prospective, comparative study was carried out at Al-Zahraa University Hospital from October 2015 to December 2017 and included 70 eyes of 60 patients. The study adhered to the tenets of the Declaration of Helsinki and was approved by the ethics board of Al-Azhar University and an informed written consent was taken from each participant in the study. Patients were scheduled for phacoemulsification and routine preoperative ocular examination was done.

Inclusion criteria were patients with cataract of any type, normal anterior and posterior segment; and uneventful surgery with 'in the bag' monofocal IOL implantation in all patients. Patients with a history of intraocular operation, inflammation, retinopathy, severe corneal degeneration, corneal opacity, vitreous pathology, developmental and acquired macular diseases were excluded. Biometry by AL-scan (Nidek Co. Ltd, Gamagori, Japan) was used in all eyes. AL, ACD, and corneal refractive power were measured by the AL-scan. Calculation of the IOL power to be implanted was done using SRK/T and Haigis formulae and the A-constant was maintained at 118. The predicted refraction value targeted myopia (−0.5 to −1). All patients underwent uneventful phacoemulsification surgery using the same standard phacoemulsification protocol (Abbot Medical Optics Inc., CA, USA). The Phaco-chop technique was the standard phacoemulsification technique in all patients, through a 3.2 mm clear corneal tunnel incision at the 12 o'clock position and a 5.0–5.5 mm capsulorhexis. Phacoemulsification was followed by in-the-bag implantation of the foldable IOL, and surgical wounds were hydrated with no sutures. Subconjuctival gentamicin and dexamethasone injections were given at the end of surgery. Surgery was performed in all cases by the same surgeon to avoid errors of personalized surgeon factor. All the patients were examined at 1 day, 1 week, 1 month, and 3 months postoperatively. The actual postoperative spherical equivalence was recorded 3 months following the surgery. The mean error (ME) is calculated as: formula predicted postoperative refraction − actual postoperative refractive error by the end of follow-up. The absolute value of ME is the mean absolute errors (MAEs).

Data were statistically described in terms of mean, SD, median, and range when appropriate. Comparison between the two studied equations was done using paired *t*-test. Multivariate linear regression analysis was used to test for the preferential effect of the independent variable(s) on MAE for each equation and the deviation between them. A *P* value of less than 0.05 was considered statistically significant. All statistical calculations were done using the computer program IBM statistical package for the social sciences (IBM Corp., Armonk, New York, USA) release 22 for Microsoft Windows.

Results

A total of 60 patients and 70 eyes were included in this study, who underwent uneventful cataract surgeries (phacoemulsification) with implantation of foldable IOL. The age of the patients ranged from 14 to 70, mean (51.69±11.9) years. The mean AL and mean keratometry reading are shown in Table 1. Table 1 also shows the ME and MAE for both the SRK-T and Haigis formulae.

The majority of patients (87.14% of SRK/T formula and 85.71% of Haigis formula) were within 1 D of the predicted refractive error (Table 2).

The SRK/T formula caused nearly the same ME as the Haigis formula, but tend to be higher in myopes (35 eyes with AL >25 mm) (Table 3).

In this study, there was no statistically significant difference between the MAEs of the two formulae used in the overall performance, but is significant in the myopic subcategory (35 eyes with an AL >25 mm) (Table 4).

To verify the biometric variables that could be involved in the discrepancy between the Haigis and SRK/T predictions multivariate linear regression analysis was used to test for the preferential effect of the independent variables (AL and keratometry) on MAE for each equation and the intraindividual

Table 1 Preoperative and postoperative refractive parameters

	Mean±SD	Range
Axial length (mm)	25.795±3.58	20.9–34.05
Keratometry (KV)	44.391±1.95	39.4–48.8
Keratometry (KH)	44.923±2.24	36.8–51.5
Keratometry (D)	44.66±1.94	38.07–50.15
SRK/T-ME (D)	−0.225±0.61	−1.41–1.37
SRK/T-MAE (D)	0.534±0.36	0.03–1.41
Haigis-ME (D)	0.171±0.68	−1.09–2.23
Haigis-MAE (D)	0.533±0.44	0.00–2.23

MAE, mean absolute error; ME, mean error.

Table 2 Percentage of cases predicted to within 0.25, 0.50, 1.00, and 1.50 D for SRK-T and Haigis formulae

	Eyes within [*n* (%)] (D)			
	±0.25	±0.5	±1.0	±1.5
SRK/T formula	20 (28.57)	38 (54.29)	61 (87.14)	70 (100)
Haigis formula	25 (35.71)	39 (55.71)	60 (85.71)	68 (97.14)

Table 3 SRK-T and Haigis formulae

	All eyes	Eyes with AL <25 mm	Eyes with AL >25 mm
SRK/T-MAE (D)	0.534±0.36 (0.03–1.41)	0.59±0.39 (0.03–1.41)	0.48±0.30 (0.03–1.05)
Haigis-MAE (D)	0.533±0.44 (0.00–2.23)	0.69±0.52 (0.01–2.23)	0.38±0.27 (0.00–1.09)

Overall performance and performance in the axial length subcategories. AL, axial length; MAE, mean absolute error.

difference between both formulae predictions (Table 5).

Although the correlation between the mean AL, keratometry, and the Haigis–SRK/T prediction differences is significant (*P*=0.00), it is of weak correlation (r^2=0.273). The linear regression parameter for variable AL=−0.056±0.011 which indicates that a decrease of 1 mm on AL implies an increase of 0.056 D on the difference between formulas prediction, for variable *K*=0.067±0.021 which indicates that an increase of 1 D on *K* implies an increase of 0.067 D on the difference between formulae prediction. Other variables showed nonsignificant correlations, and no significant multivariate linear regression parameters (Table 4).

Discussion

According to the WHO, cataract causes 27–45 million cases of blindness in the world. Cataract surgery is the most common eye surgery in the world [6].

The ability to predict postoperative refraction with accuracy is important to achieve successful result of cataract surgery with IOL implantation. Errors in predicted refraction after IOL implantation are mostly a result of AL measurement error. With the advent of partial coherence interferometry, the AL determination has become more accurate. Therefore, a need has arisen for even more precise IOL formulae [1].

Different studies have evaluated the predictive accuracy of various IOL power calculation formulae; Wang and Chang [7] showed similar performance of the Haigis, Hoffer Q, Holladay 1, and SRK/T in medium eye length. In another study by Wang *et al.* [8], SRK/T and Haigis performed equally well and outperformed the Hoffer Q and Holladay 1 in 34 eyes between 25 and 28 mm. Contrary to Moschos *et al.* [4] and Roh *et al.* [9] who reported that the Haigis formula was more accurate than the other formulae, Kapadia *et al.* [10], Maclaren *et al.* [11], Aristodemou *et al.* [12], and El-Nafees *et al.* [2] reported that the SRK/T formula was more accurate than the other formulae in long eyes.

In this study, we found that similar performance of SRK/T and Haigis (MAE: 0.534 for SRK/T and 0.533 for Haigis), with a little tendency of myopic shift for SRK/T formula (ME=−0.225) and hyperopic shift for the Haigis formula (ME=0.171) (Table 1). Doshi *et al.* [13] in their study also reported that Haigis formula had a little tendency for hyperopic results, in contrarst to Dalto *et al.* [5] who found a significant myopic shift using the Haigis formula and a hyperopic shift with the SRK/T formula.

In this study, we found that about half of cases being within ±0.50 D of predicted refraction (54.29% for SRK/T formula, 55.71% for Haigis formula) and the majority were within ±1.00 D (87.14% for SRK/T formula, 85.71% for Haigis formula) (Table 2). These results were similar to the study done by Sharma *et al.* [1] who achieved a prediction accuracy within 1.00 D of 78% for SRK/T formula, 86% for Haigis formula; El-Nafees *et al.* [2] achieved a prediction accuracy of 83.01% (for both SRK/T, Haigis); Kapadia *et al.* [10] achieved a prediction accuracy 67.85% for SRK/T formula and 68% for Haigis formula. Zhu *et al.* [14] showed a prediction accuracy of 38.8 and 45.6% (SRK/T and Haigis, respectively) for refractive error within 0.50 D.

In this study, by comparing the two studied equations using paired *t*-test, there was no statistically significant difference between the MAEs of the two formulae used in the overall performance, but the difference is significant in the myopic subcategory (35 eyes with an AL >25 mm, *P*=0.012) (Tables 3 and 4). Doshi *et al.* [13] in their study found that in eyes with an AL of more than 24.5 (40 eyes), there was no statistically significant difference between MAE of Haigis,

Table 4 Comparison of SRK-T and Haigis formulae

Comparison of SRK-T and Haigis	Mean±SD	*P* value	Confidence interval
All eyes	0.001±0.49	0.991	−0.117 to 0.118
Eyes with axial length <25 mm	0.097±0.65	0.383	−0.321 to 0.127
Eyes with axial length >25 mm	0.099±0.22	0.012	0.023–0.174

Paired samples test.

Table 5 Correlations between preoperative biometric data and the mean absolute error for each equation and the deviation between Haigis and SRK/T predictions

Linear regression analysis	SRK/T-MAE	Haigis-MAE	The deviation between Haigis and SRK/T predictions
Axial length (mm)	−0.006±0.014*P*=0.64	−0.037±0.016*P*=0.072	−0.056±0.011*P*=0.000
Keratometry (D)	−0.023±0.025*P*=0.360	−0.031±0.030*P*=0.301	0.067±0.021*P*=0.002
r^2	0.013*P*=0.654	0.071*P*=0.085	0.273*P*=0.000

MAE, mean absolute error.

Holladay 1, Hoffer Q, and SRK/T formulae (P>0.05). Dalto *et al.* [5] reported that a difference between SRK/T and Haigis formulae predictability was only found in their study of 108 eyes, when myopia is target for eyes with K less than 43.5.

In this study, the prediction error of SRK/T and Haigis formulae was weakly, nonsignificant, negatively correlated with AL and keratometry (P>0.05), and although the Haigis–SRK/T prediction differences is significantly correlated with both AL and keratometry (P<0.05), it is of weak correlation (r^2=0.273) (Table 5). The linear regression parameter for variable AL=−0.056±0.011 indicates that a decrease of 1 mm on AL implies an increase of 0.056 D on the difference between formulas prediction and for variable K=0.067±0.021 which indicates that an increase of 1 D on K implies an increase of 0.067 D on the difference between formulae prediction (Table 5). This is in contrast to Dalto *et al.* [5] who reported a strong correlation between preoperative keratometry and the difference between SRK/T and Haigis formulas' predictability, when myopia is target for eyes with K less than 43.5. Zhu *et al.* [14] in their study on 103 eyes with an AL of at least 26 mm found that the prediction error of SRK/T formula was positively correlated with AL and corneal astigmatism (P<0.01), while for Holladay and Haigis formulas, in addition to the previous two factors, the errors were also positively correlated with mean corneal curvature (P<0.01).

Kane *et al.* [15] who studied intraocular lens power formula accuracy with comparison of seven formulas on 3241 patients found that MAE of Haigis and SRK/T formulas were 0.420 and 0.413, respectively, compared with 0.533 and 0.534 in our study that may be attributed to a large number of cases compared with the small number of eyes in our study.

The results of our study has shown that the SRK/T formula has a performance similar to Haigis formula, with no statistically significant difference between the MAEs of the two formulae in the overall performance, but the difference is significant in the myopic subcategory where the Haigis formula has a lower MAE. The inclusion of the measured ACD into the Haigis formula has allowed for potentially increased accuracy [16]. In fact, the Haigis formula differs in a very important way. Rather than simply move a fixed, formula-specific outcomes curve up (more IOL power recommended) or down (less IOL power recommended), it uses preoperative ACD and AL to predict the ELP and has three constants [a0+(a1×ACD)+(a2×AL)] for the optimization of results. So in the Haigis formula the IOL power optimization is based on three variables. In contrast, the SRK/T uses two biometric parameters (keratometry, AL) to predict the ELP and one constant for the optimization of the results [17].

Conclusion

The calculation of IOL power using SRK/T and Haigis formulae resulted in an accurate postoperative refraction. The SRK/T formula showed a performance similar to Haigis formula in the overall performance, but a slight lower performance in myopic subgroups.

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Conflicts of interest

There are no conflicts of interest.

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