Original Article

Anterior Segment Changes and Refractive Outcomes after Cataract Surgery Combined with Gonioscopy-Assisted Transluminal Trabeculotomy in Open-Angle Glaucoma

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Abstract

Objectives: To compare the accuracy of intraocular lens (IOL) calculation formulas in patients undergoing phacoemulsification combined with gonioscopy-assisted transluminal trabeculotomy (phaco-GATT) and to determine the predictive factors for refractive errors.

Materials and Methods: Fifty-three eyes of 53 patients undergoing phaco-GATT were retrospectively reviewed. The preoperative and postoperative 3-month anterior segment (AS) parameters were measured by Scheimpflug camera. The mean prediction error (PE), mean absolute error (MAE) in the Sanders-Retzlaff-Kraft/theoretical (SRK/T), Barrett-Universal II, Hill-radial basis function (Hill-RBF) and Kane formulas were compared. The influence of biometric parameters on PE were analyzed by correlation analysis.

Results: Postoperatively, there was a statistically significant decrease in axial length (AL) and significant enlargement in anterior chamber depth (ACD), anterior chamber angle (ACA), and anterior chamber volume ($p<0.001$). The mean PE using SRK/T (-0.08 diopters [D]) was more myopic than in the Barret (0.01 D) and Hill-RBF (0.01 D). The PE closest to zero was in the Kane formula (0.001 D). The Kane formula provided a lower MAE (0.30±0.28 D) than the SRK/T (0.38±0.32 D) and Barrett (0.36±0.30 D) ($p<0.001$). The MAE in Hill-RBF (0.32±0.28) was comparable with that in Kane ($p=0.02$). Preoperative AL was significantly associated with PE in all formulas except Kane. Barrett was the only formula that did not have a significant correlation between PE and postoperative ACD and ACA.

Conclusion: The Kane formula may provide higher predictability of the IOL power calculation than the SRK/T and Barrett-Universal II formulas in phaco-GATT surgery, which can cause significant changes in the AS and AL.

Keywords: Gonioscopy-assisted transluminal trabeculotomy, intraocular lens formula, phacoemulsification, refractive error

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Introduction

Combining glaucoma surgery with cataract surgery is widely accepted as an appropriate procedure for the management of coexisting cataract and glaucoma.[1,2] Despite advances in surgical techniques, ocular biometry, and intraocular lens (IOL) calculation formulas, calculating IOL power remains a challenge in certain clinical cases such as glaucomatous eyes and combined cataract and glaucoma surgery.[3,4,5,6,7] In these special circumstances, the obstacles to accurate IOL calculation include the intraocular pressure (IOP)-lowering effect of surgery and instability of axial length (AL), keratometry (K), and anterior chamber depth (ACD).[8,9,10]

In eyes with glaucoma, micro-invasive glaucoma surgery (MIGS) has gained popularity as an adjunct procedure during cataract surgery. The reduced risk of a significant refractive surprise compared to traditional filtering surgery is one potential advantage of these less invasive approaches.[11,12,13,14] Gonioscopy-assisted transluminal trabeculotomy (GATT) is a newly described, minimally invasive, sutureless, and blebless procedure for the treatment of glaucoma.[15] The IOP-lowering effect of cataract surgery combined with GATT has been substantiated by several studies.[16,17,18] However, to our knowledge, no studies have investigated the refractive outcomes and predictive factors for refractive error after cataract surgery combined with GATT. Therefore, the present study aimed to evaluate the refractive results of combined phacoemulsification and GATT (phaco-GATT) and determine the factors that can predict unstable refractive outcomes. In this study, we compared the postoperative refractive outcomes in the Sanders-Retzlaff-Kraft/theoretical (SRK/T), Barrett-Universal II, Hill-radial basis function (Hill-RBF), and Kane IOL calculation formulas. We also analyzed the change in IOP and anterior segment (AS) parameters after combined surgery to investigate the influence of these parameters on refractive results.

Materials and Methods

We retrospectively reviewed the medical records of patients with open-angle glaucoma (OAG) who had underwent uncomplicated phaco-GATT at a single center between September 2020 and July 2022. All research and measurements followed the tenets of the Declaration of Helsinki, and the Haydarpaşa Numune Training and Research Hospital Ethics Committee of the same hospital approved the protocol (decision no: HNEAH-KAK-KK-2022-210, date: 07.11.2022). The need for informed consent was waived.

The diagnostic criteria for OAG included gonioscopically-confirmed open angle, glaucomatous optic nerve head changes, and glaucomatous visual field defects with computerized visual field test (24-2 test, SITA Standard, Humphrey Visual Field Analyzer II; Carl Zeiss Meditec, Jena, Germany). Primary open-angle glaucoma (POAG) was defined as OAG with no secondary cause of glaucoma, and pseudoexfoliation glaucoma (PXG) as OAG with visible exfoliation material in the AS. Phaco-GATT surgery was performed in patients with visually disabling cataract whose IOP could not be controlled despite maximum medical treatment or who could not tolerate medical treatment.

The exclusion criteria included any history of ocular surgery or ocular trauma, coexisting eye diseases that could affect the refractive results (corneal or retinal diseases), intraoperative complications (capsular tear, zonule dialysis), and postoperative complications (prolonged corneal edema, macular edema, retinal detachment, additional glaucoma surgery). In addition, cases who had trabeculotomy of less than 180-degrees were defined as "failed GATT surgery" and were excluded. Eyes with dense cataracts requiring ultrasound biometry were not included in the study. As refractive outcomes could be affected, patients with a postoperative corrected distance visual acuity (CDVA) ≤40/200 and with a postoperative corneal astigmatism ≥2.0 diopters (D) were excluded.

If both eyes of a patient met the study criteria, the first operated eye was included.

All surgical procedures were performed under sub-Tenon anesthesia by one experienced glaucoma surgeon (S.İ.). Corneal incisions were formed in the superior and temporal quadrants with a 20-gauge knife. Ocular viscoelastic substance was injected into the anterior chamber. The patient's head and microscope were tilted to visualize the nasal angle, and a 1- to 1.5-mm goniotomy was made on the nasal iridocorneal angle using a direct gonioscopy lens through a temporal incision. A 6-0 Prolene suture (Kent Medical, Ankara, Türkiye), the end of which was blunted with cautery, was directed to the nasal angle through the superior incision. The suture was inserted into the goniotomy and advanced through the Schlemm canal. The distal edge of the suture protruding from the goniotomy was held, and trabeculotomy was performed by pulling both ends of the suture out of the temporal incision. In 20 cases, 180 to 270-degree trabeculotomy could be achieved. In all patients, a 2.8-mm clear corneal incision in the upper corneal limbus and phacoemulsification with the Infiniti Vision System (Alcon Laboratories, Fort Worth, TX, USA) were performed after GATT. An acrylic hydrophobic, foldable, one-piece IOL (Eyecryl Plus ASHFY600; Biotech Vision Care Pvt. Ltd., Ahmedabad, India) was implanted in the capsular bag. Cefuroxime axetil (1 mg/0.1 mL; Aprokam; Thea Pharma, Clermont-Ferrand, France) was administered into the anterior chamber at the end of surgery. After surgery, patients were treated with 0.5% moxifloxacin eye drops (Vigamox; Alcon Laboratories, Fort Worth, TX, USA) and 1% prednisolone acetate ophthalmic suspension (Pred Forte; AbbVie Biopharma, North Chicago, USA) 4 times per day during the postoperative first month.

Data Collection

The patient's sex, age, glaucoma type, and preoperative data including IOP measured by Goldmann applanation tonometer, CDVA as the logarithm of the minimum angle of resolution, AS parameters measured by Scheimpflug imaging (Sirius topography; Schwind eye-tech-solutions, Kleinostheim, Germany), AL, IOL power (D), and predicted refraction were recorded. AL and IOL power were calculated using partial coherence interferometry (IOL Master 500; Carl Zeiss Meditec, Jena, Germany). The SRK/T formula was used for selecting the IOL power for implantation, with an A-constant of 118.4.

Sirius topography was performed on non-dilated pupils in a standard dimly lit room, with 25 images per scan at the automatic release mode. The patient fixated on a far wall target to prevent accommodation. Scheimpflug camera measurements were exported only when the quality of the measurement showed "OK". ACD was determined as the distance from the central corneal endothelium to the anterior pole of the lens. Anterior chamber volume (ACV), ACD, anterior chamber angle (ACA), and central corneal thickness (CCT) were measured automatically by the Sirius device. Flat and steep K were also measured by the Sirius, and the mean K was calculated. Lens thickness (LT) was measured as the distance between the anterior and posterior surfaces of the crystalline lens. The mean of three values was used for statistical analysis.

Refraction measurements were obtained using an automatic refractor, then the manifest refraction that provided the best-corrected visual acuity from 6 meters was recorded. Manifest refraction was used for statistical analysis after converting to spherical equivalents (SEQ=spherical power+½ cylinder power). The prediction error (PE) was calculated by subtracting the expected refraction from the postoperative SEQ. The mean absolute error (MAE) was defined as the absolute deviation between the postoperative SEQ and predicted refraction. The percentages of eyes with a PE greater than ±1.0 D, greater than ±0.75 D, and greater than ±0.50 D were calculated.

K, ACD, and AL measurements were manually entered into the online Barrett-Universal II calculator (https://calc.apacrs.org/barrett_universal2105/, accessed 28 February 2021), Hill-RBF calculator (Hill-RBF calculator version 3.0. https://rbfcalculator.com/, accessed 4 September 2020), and Kane formula calculator (https://www.iolformula.com/, accessed 16 February 2020) by one investigator (H.T.), and another investigator (S.İ.) checked the results. The lens factor for the Barrett-Universal II was 1.57. A-constants for Hill-RBF and Kane were 118.3 and 118.5, respectively. The predicted refraction in the Hill-RBF, Barrett II, and Kane formulas according to the implanted IOL power were recorded from the online calculation systems.

Postoperative 3-month examination findings, including refractive results, CDVA, IOP, AL, ACD, ACV, ACA, CCT, and K measurements, were recorded as postoperative outcomes. The changes in IOP, AL, mean K, and AS parameters were also calculated by subtracting the postoperative value from the preoperative value.

The primary outcome was to compare refractive results following phaco-GATT in four IOL calculation formulas. The secondary outcome was to determine the effect of preoperative and postoperative factors on the refractive results.

Statistical Analysis

All statistical analyses were performed using SPSS for Windows (v.20.0, IBM Corp., Armonk, NY, USA). Kolmogorov-Smirnov test was used to determine whether the continuous variables were normally distributed. To compare the accuracies of the four formulas, general linear model repeated measures test of the PE (with post-hoc Bonferroni analysis) and nonparametric Friedman test of the MAE (with post-hoc Wilcoxon signed-rank test) were used. Cochran Q test (with post-hoc McNemar test) was performed to compare the percentage of eyes within a certain range of PE between the four formulas. The preoperative and postoperative measurements were analyzed using paired-samples t-test and Wilcoxon test. The independent-samples t-test and Mann-Whitney U test were used for the comparisons of parameters between the 360-degree GATT and 180- to 270-degree GATT subgroups. To determine the association between the pre- and postoperative parameters and PE, Pearson and Spearman correlation analyses were performed. Continuous variables were presented as mean ± standard deviation and categorical variables as percentages (%). A p value <0.05 was considered statistically significant.

Results

Fifty-three eyes of 53 patients with a mean age of 69.26±5.96 years were included in this study. There were 23 (43.4%) men and 30 (56.6%) women, as well as 39 (73.6%) eyes with PXG and 14 (26.4%) eyes with POAG.

Comparisons of the ocular characteristics and AS measurements before and after phaco-GATT are shown in Table 1. Visual acuity improvement and decrease in IOP after surgery were statistically significant ($p<0.001$). There was a statistically significant decrease in AL ($p<0.001$) and significant increases in ACD, ACA, ACV ($p<0.001$), and CCT ($p=0.02$).

The mean IOL power was 20.27±3.53 D. The postoperative mean spherical power, cylinder power, and SEQ were -0.25±0.58 D, -0.90±0.45 D, and -0.68±0.53 D, respectively. There were statistically significant differences in PE, MAE, and percentages of myopic PE lower than -0.50 D among the four IOL formulas ($p<0.05$). Post-hoc analysis for PE showed statistically significant differences between the SRK/T and the Barrett and Hill-RBF formulas ($p<0.05$). There were statistically significant differences

Table 1. Comparison of the ocular characteristics and anterior segment measurements before and after combined cataract surgery and GATT

Parameter mean ± SD (range)	Preoperative	Postoperative	Mean change	p value
CDVA (logMAR)	0.80±0.63 (0.30-3.10)	0.09±0.11 (0.0-0.40)	-0.71±0.60 (-3.10--0.08)	<0.001*
IOP (mmHg)	21.09±5.79 (11.0-40.0)	14.16±3.38 (8.0-21.0)	-6.92±6.18 (-29.0-1.0)	<0.001*
Flat K (D)	43.37±1.50 (40.41-46.53)	43.30±1.60 (40.07-47.25)	-0.07±0.50 (-0.96-1.31)	0.09
Steep K (D)	44.19±1.42 (41.65-47.32)	44.13±1.51 (41.33-48.25)	-0.05±0.48 (-0.89-1.51)	0.42
Mean K (D)	43.78±1.44 (41.11-46.93)	43.72±1.54 (40.75-47.75)	-0.06±0.44 (-0.82-1.41)	0.05
Corneal astigmatism (D)	0.81±0.49 (0.05-1.94)	0.83±0.42 (0.05-1.68)	0.02±0.42 (-1.22-1.10)	0.71
AL (mm)	23.80±1.32 (22.02-28.07)	23.60±1.32 (21.70-27.85)	-0.19±0.12 (-0.43-0.37)	<0.001*
ACD (mm)	2.70±0.37 (1.92-3.44)	3.54±0.37 (2.15-4.51)	0.83±0.39 (0.13-1.89)	<0.001*
ACV (mm^3)	136.1±26.41 (86.0-210.0)	176.5±23.35 (121.0-221.0)	40.35±19.43 (9.0-88.0)	<0.001*
ACA (°)	40.79±6.91 (29.0-53.0)	53.52±5.45 (38.0-65.0)	12.73±5.69 (4.0-28.0)	<0.001*
CCT (μm)	531.4±34.15 (450.0-590.0)	536.3±39.88 (455.0-624.0)	4.94±15.10 (-18.0-68.0)	0.02*
LT (mm)	1.48±0.46 (0.50-2.22)			

*p<0.05. GATT: Gonioscopy-assisted transluminal trabeculotomy, SD: Standard deviation, logMAR: Logarithm of the minimum angle of resolution, CDVA: Corrected distance visual acuity, IOP: Intaocular pressure, K: Keratometry D: Diopters, AL: Axial length, ACD: Anterior chamber depth, ACV: Anterior chamber volume, ACA: Anterior chamber angle, CCT: Central corneal thickness, LT: Lens thickness between Kane and SRK/T, Kane and Barrett, and also Hill-RBF and Barrett in pairwise comparisons for MAE (p<0.008). The only statistically significant difference in myopic surprise frequency was between SRK/T and Kane (p<0.008) (Table 2).

Comparisons of preoperative and postoperative CDVA, IOP, AL, and AS between eyes with 360-degree GATT and those with 180- to 270-degree GATT are presented in Table 3. The only statistically significant difference between groups was in preoperative CDVA (p=0.01), and this difference became insignificant after surgery (p=0.80). There were no statistically significant differences between the two subgroups in MAE or PE with any of the investigated formulas (p>0.05) (Table 4).

Correlation analysis for PE in SRK/T revealed that there was a statistically significant negative correlation with preoperative AL (p=0.04) and significant positive correlation with postoperative ACD (p=0.04) and postoperative ACA (p=0.008) (Figure 1). The only statistically significant association for PE was with preoperative AL in the Barrett-Universal II (p=0.03) (Figure 2). For PE in Hill-RBF, there was a statistically significant negative correlation with preoperative AL (p=0.04) and a significant positive correlation with postoperative ACA (p=0.01) (Figure 3). In the results with the Kane formula, PE was significantly positively associated with postoperative ACD (p=0.02) and postoperative ACA (p=0.005) (Figure 4). The PE did not show any significant association with age, CDVA, LT, ACV, CCT, or keratometric values in all four IOL formulas. There was also no statistically significant correlation between PE in any formula and preoperative IOP, postoperative IOP, or reduction in IOP (p>0.05).

Discussion

Combined cataract surgery and trabeculectomy was recently shown to cause changes in AS configuration and AL.[19,20] Even if newer angle-based procedures provide less dramatic IOP-lowering than trabeculectomy, significant changes in AS following combined cataract surgery and MIGS have been reported.[21,22,23,24] Changes in IOP and AS may cause unexpected results in refractive findings following combined surgery, so the chosen IOL calculation formula may become more critical in these cases. To our knowledge, our study is the first analysis of refractive outcomes in different IOL formulas and changes in AS parameters after phaco-GATT.

In our study, there was a significant decrease in AL and significant increases in ACD, ACA, ACV, and CCT after combined surgery. The Kane formula produced a higher predictability of IOL power calculation compared to SRK/T and Barrett-Universal II. The refractive outcomes in Hill-RBF were comparable with those in the Kane formula. The AS parameters and refractive outcomes did not differ between 360-degree GATT and 180- to 270-degree GATT.

In the published literature discussing the PE results in MIGS combined with cataract surgery, traditional IOL formulas have been used in all studies.[11,12,13,14,25] Luebke et al.[11] reported a mean PE of 0.53 D in patients who had combined cataract and trabectome surgery. In a study by Sieck et al.,[13] refractive error occurred in 20 (26.3%) of 76 eyes that underwent Kahook Dual Blade-goniotomy with phacoemulsification. Fifteen cases with refractive surprise in this group were between ±0.50 and ±1.00 D of the intended target. Scott et al.[14] reported 95% and 80% of 76 eyes were within ±1.0 D and ±0.50 D, respectively, in the combined trabecular micro-bypass stent and cataract surgery group. Ioannidis et al.[25] determined the MAE was 0.36±0.25 D, with 73.9% of 89 eyes within 0.50 D and with 98.9% within 1.00 D of the predicted refractive target after trabecular micro-bypass stent combined with cataract surgery. In the present

Table 2. Refractive outcomes after combined cataract surgery and GATT in four intraocular lens calculation formulas

Parameter mean ± SD	SRK/T	Barrett Universal II	Hill-RBF	Kane	p value
PE (D)	-0.076±0.45	0.011±0.43	0.010±0.41	0.001±0.39	0.004*
MAE (D)	0.38±0.32	0.36±0.30	0.32±0.28	0.30±0.28	<0.001*
PE > ±0.50 D (n, %) Myopic PE <-0.50 D Hyperopic PE >0.50 D	18 (34) 13 (24.5) 5 (9.4)	16 (30.2) 8 (15.1) 8 (15.1)	14 (26.4) 6 (11.3) 8 (15.1)	11 (20.8) 4 (7.5) 7 (13.2)	0.07 <0.001* 0.26
PE > ±0.75 (n, %)	5 (9.4)	4 (7.5)	3 (5.7)	3 (5.7)	0.46
PE > ±1.00 (n, %)	0	0	0	0	-
Pairwise comparisons		PE[a]	MAE[b]	Myopic PE <-0.50 D[c]	
SRK/T vs. Barrett Universal II		0.01*	0.58	0.06	
SRK/T vs. Hill-RBF		0.03*	0.01	0.01	
SRK/T vs. Kane		0.08	<0.001*	0.004*	
Barrett Universal II vs. Hill-RBF		>0.99	0.004*	0.50	
Barrett Universal II vs. Kane		>0.99	<0.001*	0.12	
Hill-RBF vs. Kane		>0.99	0.02	0.50	

*p<0.05, [a]Post-hoc analysis with Bonferroni correction (*p<0.05), [b]Post-hoc analysis with Wilcoxon signed rank test (*p<0.008), [c]Post-hoc analysis with McNemar test (*p<0.008). GATT: Gonioscopy-assisted transluminal trabeculotomy, SD: Standard deviation, SRK/T: Sanders-Retzlaff-Kraft/theoretical, Hill-RBF: Hill-radial basis function, MAE: Mean absolute error, PE: Prediction error, D: Diopters

Table 3. Comparisons between 360-degree GATT and 180- to 270-degree GATT

Parameter mean ± SD	360-degree GATT (n=33)	180- to 270-degree GATT (n=20)	p value
CDVA (logMAR)			
Preoperative	0.69±0.57	0.99±0.68	0.01*
Postoperative	0.10±0.13	0.08±0.10	0.80
Mean change	-0.58±0.54	-0.91±0.65	0.008*
IOP (mmHg)			
Preoperative	21.15±6.22	21.00±5.17	0.93
Postoperative	14.06±3.40	14.35±3.42	0.76
Mean change	-7.09±6.57	-6.65±5.65	>0.99
Mean K (D)			
Preoperative	43.89±1.56	43.60±1.25	0.48
Postoperative	43.75±1.64	43.65±1.41	0.91
Mean change	-0.13±0.41	0.05±0.49	0.34
Corneal astigmatism (D)			
Preoperative	0.78±0.44	0.86±0.56	0.59
Postoperative	0.85±0.41	0.80±0.44	0.67
Mean change	0.06±0.33	-0.05±0.54	0.29
AL (mm)			
Preoperative	23.88±1.46	23.66±1.08	0.77
Postoperative	23.69±1.46	23.45±1.05	0.65
Mean change	-0.19±0.12	-0.20±0.12	0.89
ACD (mm)			
Preoperative	2.74±0.40	2.64±0.32	0.25
Postoperative	3.54±0.37	3.53±0.37	0.93
Mean change	0.80±0.39	0.89±0.39	0.46
ACV (mm^3)			
Preoperative	138.54±29.17	132.15±21.21	0.39
Postoperative	177.78±23.87	174.35±22.91	0.60
Mean change	39.24±21.25	42.20±16.32	0.59
ACA (°)			
Preoperative	40.93±6.76	40.55±7.31	0.84
Postoperative	53.33±5.39	53.85±5.66	0.74
Mean change	12.39±6.20	13.30±4.82	0.39
CCT (μm)			
Preoperative	533.21±32.13	528.40±37.92	0.62
Postoperative	537.12±34.93	529.70±40.13	0.48
Mean change	3.90±10.38	1.30±8.64	0.60
LT (mm)	1.49±0.50	1.47±0.39	0.85

*p<0.05. GATT: Gonioscopy-assisted transluminal trabeculotomy, SD: Standard deviation, logMAR: Logarithm of the minimum angle of resolution, CDVA: Corrected distance visual acuity, IOP: Intraocular pressure, K: Keratometry, D: Diopters, AL: Axial length, ACD: Anterior chamber depth, ACV: Anterior chamber volume, ACA: Anterior chamber angle, CCT: Central corneal thickness, LT: Lens thickness

study, PE greater than ±0.50 D was demonstrated in 34%, 30%, 26%, and 21% of cases, respectively, in the SRK/T, Barrett II, Hill-RBF, and Kane formulas. There was no refractive error greater than ±1.0 D in any of the investigated IOL formulas.

A few studies have evaluated refractive results with different IOL formulas in combined cataract and glaucoma surgery.[26,27,28] Iijima et al.[26] compared the accuracy of IOL power calculation using the SRK/T and Barrett-Universal II formulas in 56 eyes

Table 4. Refractive outcomes of 360-degree GATT and 180- to 270-degree GATT

Parameter (mean ± SD)	360-degree GATT (n=33)	180- to 270-degree GATT (n=20)	p value
PE (D)			
SRK/T	-0.06±0.45	-0.09±0.47	0.84
Barrett Universal II	0.03±0.43	-0.02±0.45	0.67
Hill-RBF	0.01±0.38	0.00±0.47	0.96
Kane	0.01±0.34	-0.01±0.48	0.83
MAE (D)			
SRK/T	0.38±0.24	0.38±0.42	0.23
Barrett Universal II	0.35±0.23	0.36±0.39	0.39
Hill-RBF	0.31±0.20	0.34±0.39	0.37
Kane	0.27±0.19	0.34±0.38	0.70

GATT: Gonioscopy-assisted transluminal trabeculotomy, SD: Standard deviation, PE: Prediction error, D: Diopters, SRK/T: Sanders-Retzlaff-Kraft/theoretical, Hill-RBF: Hill-radial basis function, MAE: Mean absolute error

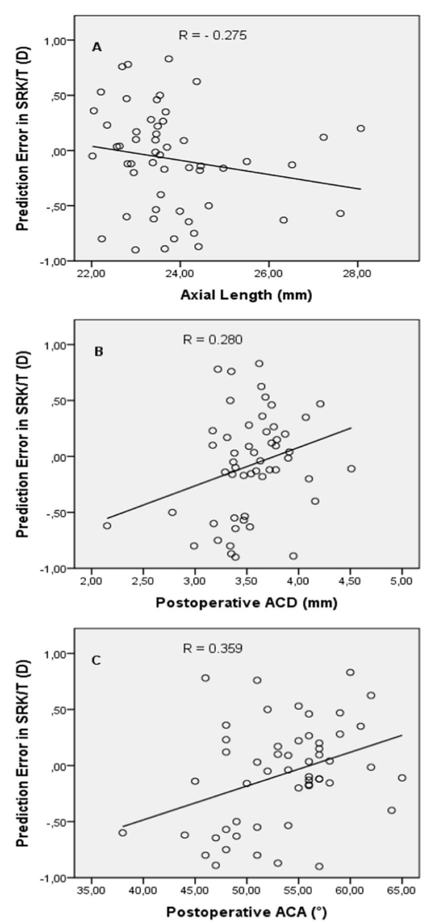

Figure 1. Scatterplot of mean prediction error in the SRK/T formula versus preoperative axial length (A), postoperative anterior chamber depth (ACD) (B), and postoperative anterior chamber angle (ACA) (C)
SRK/T: Sanders-Retzlaff-Kraft/theoretical, D: Diopters

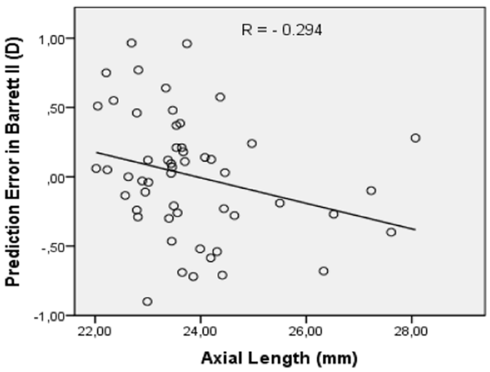

Figure 2. Scatterplot of mean prediction error in the Barrett Universal II formula versus preoperative axial length
D: Diopters

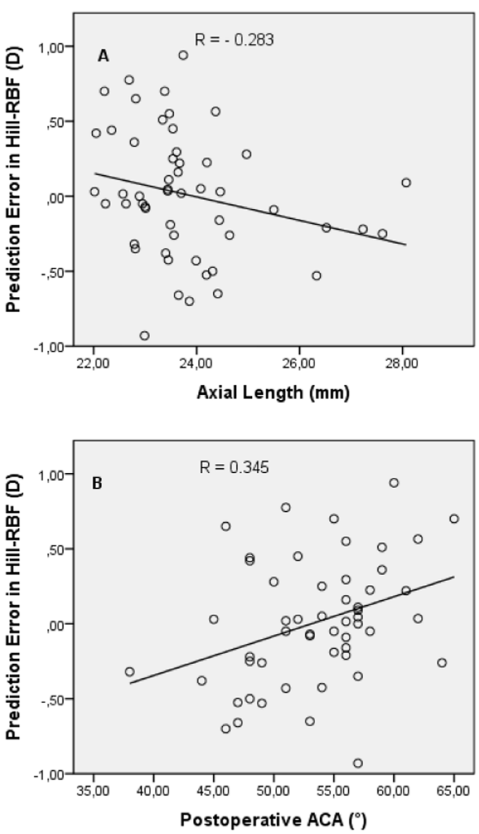

Figure 3. Scatterplot of mean prediction error in the Hill-RBF formula versus preoperative axial length (A) and postoperative anterior chamber angle (ACA) (B)
Hill-RBF: Hill-radial basis function, D: Diopters

after combined trabeculectomy and cataract extraction and found that the Barrett provided a smaller absolute error. Marta et al.[27] analyzed refractive errors in the Haigis, SRK/T, Holladay 1, Hoffer Q, Barrett-Universal II, Hill-RBF, and Kane formulas in combined cataract surgery and Ahmed glaucoma valve implantation. They reported that in the eyes with anterior chamber implant, the formula with the best PE was Barrett

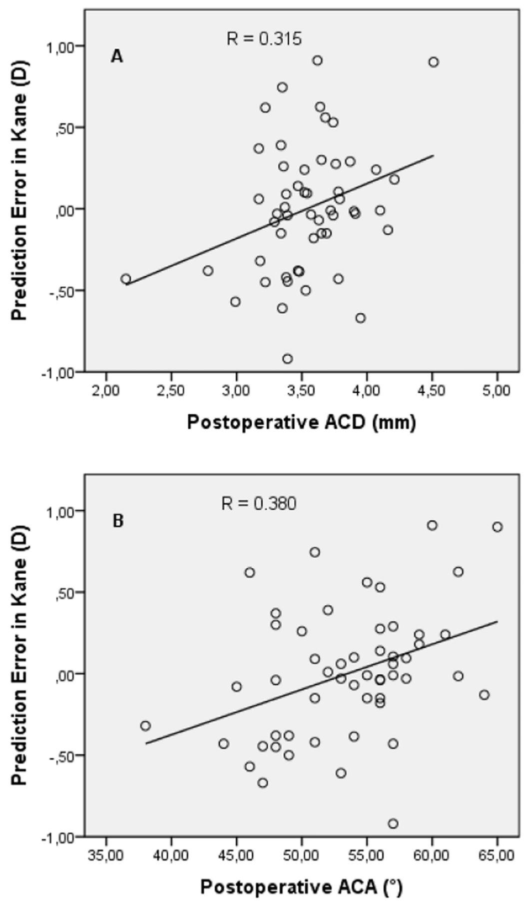

Figure 4. Scatterplot of mean prediction error in the Kane formula versus postoperative anterior chamber depth (ACD) (A) and postoperative anterior chamber angle (ACA) (B)
D: Diopters

II. Li et al.[28] evaluated the accuracy of SRK/T, Hoffer Q, Barrett II and Kane formulas in 111 eyes with primary angle-closure glaucoma (PACG) that underwent goniosynechialysis with phacoemulsification. The Kane (-0.06 D) and Barrett II (-0.07 D) formulas had a mean PE close to zero, while the Hoffer Q (-0.26 D) and SRK/T (-0.21 D) produced significantly myopic outcomes.[28] Although SRK/T showed significantly more myopic outcomes among the four formulas in our study, the mean PE (-0.08 D) was closer to zero than in the study by Li et al.[28] This difference may be due to the inclusion of eyes with PACG in the previous study.

In two previous studies that have reported the refractive outcomes of the latest formulas using the largest database in the literature, the Kane formula was found to be the most accurate compared to other traditional and newer formulas.[29,30] The Kane formula is a new formula that combines theoretical optics with artificial intelligence to calculate IOL power.[31] Similar to these studies, we obtained results closest to zero in mean PE and MAE with the Kane formula. The second-best outcomes were in the Hill-RBF formula, which uses artificial intelligence and regression analysis of a large database of actual postsurgical refractive results for IOL power calculation.[32]

There are only three studies evaluating the AS changes in combined cataract surgery and MIGS.[22,23,24] In a study by Shao et al.,[22] ACA widened significantly after phaco-goniosynechialysis in 20 eyes with PACG. Moghimi et al.[23] indicated an improvement in gonioscopic measurements with AS-optical coherence tomography (AS-OCT) after phaco-viscogonioplasty in 45 eyes with PACG. Akil et al.[24] investigated AS parameters with AS-OCT following combined trabectome and cataract surgery in 20 OAG eyes and reported mean increases of 0.5±0.11 mm in ACD, 26.65±8.8 mm^3 in ACV, and 7.8±1.58° in trabecular iris angle. In our study, there was a mean increase of 0.83±0.39 mm, 40.35±19.43 mm^3, and 12.73±5.69° in ACD, ACV and ACA, respectively.

Postoperative ACD was shown to be a potential factor in postoperative refractive surprise.[33] IOP change, shallow ACD, worse preoperative visual acuity, and higher preoperative IOP were found to be risk factors for refractive error after combined cataract and glaucoma surgery.[8,10,13] In the present study, postoperative ACD and ACA correlated significantly with mean PE in the SRK/T and Kane formulas. In Hill-RBF, postoperative ACA was the only AS parameter significantly associated with PE. Preoperative AL correlated with the errors in all formulas except Kane. It is suggested that the Kane formula was not susceptible to AL, even in eyes undergoing phaco-GATT. This is consistent with previous studies reporting that the Kane formula was the most accurate IOL calculation formula for all ranges of ALs in cataract surgery alone when compared to the traditional and new-generation IOL formulas.[34,35]

Strengths of our study are the use of a single IOL model implanted by a single experienced surgeon and the exclusion of eyes with postoperative CDVA ≤20/400 and corneal astigmatism ≥2.0 D to ensure reliable refraction could be achieved. The results of both the traditional IOL calculation formula (SRK/T) and the newer IOL formulas (Barrett-Universal II, Hill-RBF, and Kane) were reported. Finally, this is a novel study reporting changes in AS parameters after phaco-GATT surgery and their effect on refractive outcomes.

Study Limitations

The study was performed retrospectively. We did not have a cataract surgery only control group, so the effect of GATT itself on refractive accuracy and AS configuration remains unclear. We could not analyze the effect of cataract density on refractive results, but LT was recorded and no significant relationship was found with the refractive results. Postoperative mean CCT was significantly greater than baseline. This may be due to the surgical parameters such as surgical time and cumulative dissipated energy. However, we could not record these parameters because of the retrospective nature of the study. As postoperative K values and corneal astigmatism did not differ from preoperative values, we think that the change in CCT did not affect our refractive outcomes. A Scheimpflug camera was used for the analysis of AS parameters in our study. Different associations may be found with different devices such as AS-OCT. Glaucoma subtype could have some effect on AS configuration and refraction, but our sample size was insufficient for subgroup analysis. A prospective study with a large number of patients would be helpful for determining the difference between POAG and PXG.

Conclusion

Our results support the view that the Kane formula may provide higher predictability of the IOL power calculation than the SRK/T and Barrett-Universal II in eyes undergoing phaco-GATT. The accuracy of Hill-RBF 3.0 was comparable to that of the Kane formula. The only PE that did not have a significant correlation with AL was in the Kane formula. Postoperative enlarged ACD and ACA were associated with more hyperopic PE. This information may be clinically helpful for choosing the most accurate IOL formula when planning combined cataract and GATT surgery, which may cause unexpected changes in AS and AL.

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Ethics

Ethics Committee Approval: Haydarpaşa Numune Training and Research Hospital Ethics Committee of the same hospital approved the protocol (decision no: HNEAH-KAK-KK-2022-210, date: 07.11.2022).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.İ., H.T., Concept: H.T., S.İ., Design: H.T., M.S.M., Data Collection or Processing: H.T., S.İ., M.S.M., Analysis or Interpretation: H.T., M.S.M., Literature Search: H.T., S.İ., Writing: H.T.

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